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Evaluation of PAZA Ambient Air Quality Monitoring Network

Prepared for:
Peace Airshed Zone Association
Technical Working Committee

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"PAZA policy and monitoring are informed by PAZA's Network Assessments. This document is not to be interpreted as requirements or plans. Reports and recommendations are for information only."

Table of Contents

List of Tables

Page

List of Figures

Page

1.0 INTRODUCTION

The Peace Airshed Zone Association (PAZA) operates a network of continuous and semi-permanent continuous ambient air monitoring stations and one portable continuous monitoring station.

In 2017, the PAZA continuous network consisted of seven air monitoring stations as listed below and shown in Figure 1.1. In addition, continuous monitoring is currently undertaken by industry south of the PAZA airshed at several locations (Figure 1.2).

1. **Beaverlodge** – The Beaverlodge station is in a field used for research; it is designated as a regional/background monitor serving the town of Beaverlodge. There is a highway 2 km south with a traffic volume of 6,590 vehicles per day. A smaller, unpaved road is approximately 500 metres north of the site. The station is part of the National Air Pollution Surveillance (NAPS) network.
2. **Evergreen Park** – The Evergreen Park station is located on a cell tower in an industrial/municipal park, just south of the Grande Prairie city limits. It is designated as a regional site that is near (100 m) a paved highway and an asphalt plant (0.35 km).
3. **Donnelly** – The original Falher site was relocated to Donnelly in August 2016.
4. **Henry Pirker** – The Henry Pirker site is located at the north end of Muskoseepi Park in Central Grande Prairie. It is designated as an urban/regional location and is impacted by localized automobile and home heating emissions from the areas near the park.
5. **Smoky Heights School** – The Smoky Heights School site is in a farmer's field approximately 10 km northeast of the town of Teepee Creek. It is designated as a regional site. The site is immediately adjacent to a field where cows are often kept, is 250 m from a gravel roadway, and 2 km from an oilfield material construction site.
6. **Valleyview** – The Valleyview station is located due south of the town of Valleyview and approximately 1.5 km east of the Derek Energy Sturgeon Lake South plant. This site was originally a compliance site, but now serves as a regional site as well. There are also several gravel roads located 20 m of the site.
7. **Portable** – The portable site is currently located at Wembley, approximately 7.5 km south of the Town of Wembley. The portable monitor is relocated as needed to investigate air quality in different areas. In previous years, portable monitors have been deployed at Reno, Sunset House, Kinuso, Spirit River, Bonanza, Girouxville, Falher, and Clairmont.

Historically, the PAZA passive air monitoring network consisted of 47 sampling locations. The parameters measured at 44 sites were SO2, NO2, and O3. Three additional sites measured H2S. The passive monitoring network was restructured in February 2017 to consist of twenty-six (26) sampling locations. The parameters measured at each site are sulphur dioxide (SO_2 at 50 sites), nitrogen dioxide (NO_2 at 50 sites), ozone (O_3 at 3 sites) and/or hydrogen sulphide (H_2S at 3 sites) (Figure 1.3).

PAZA contracted Millennium EMS Solutions (MEMS) to evaluate the performance of the network to enable it to achieve its monitoring objectives, consistent with its vision. Specifically, to:

- identify and review monitoring needs in the expanded boundary region;
- recommend changes to the monitoring network to more effectively meet the monitoring objectives; and
- present the key findings and recommendations to PAZA stakeholders.

The remainder of this report documents the approach adopted by MEMS to undertake the work.

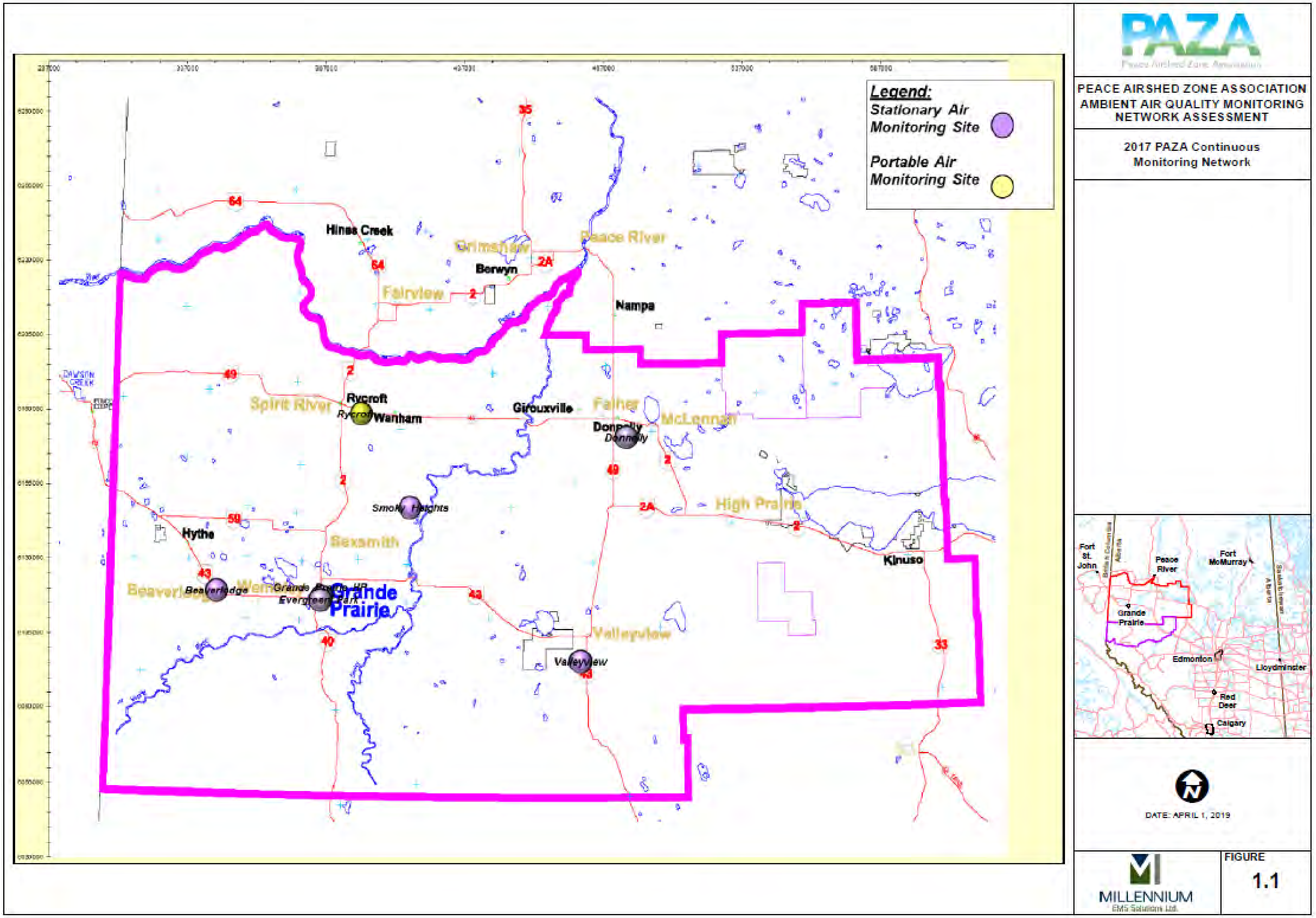

Figure 1.1 2017 PAZA Continuous Monitoring Network

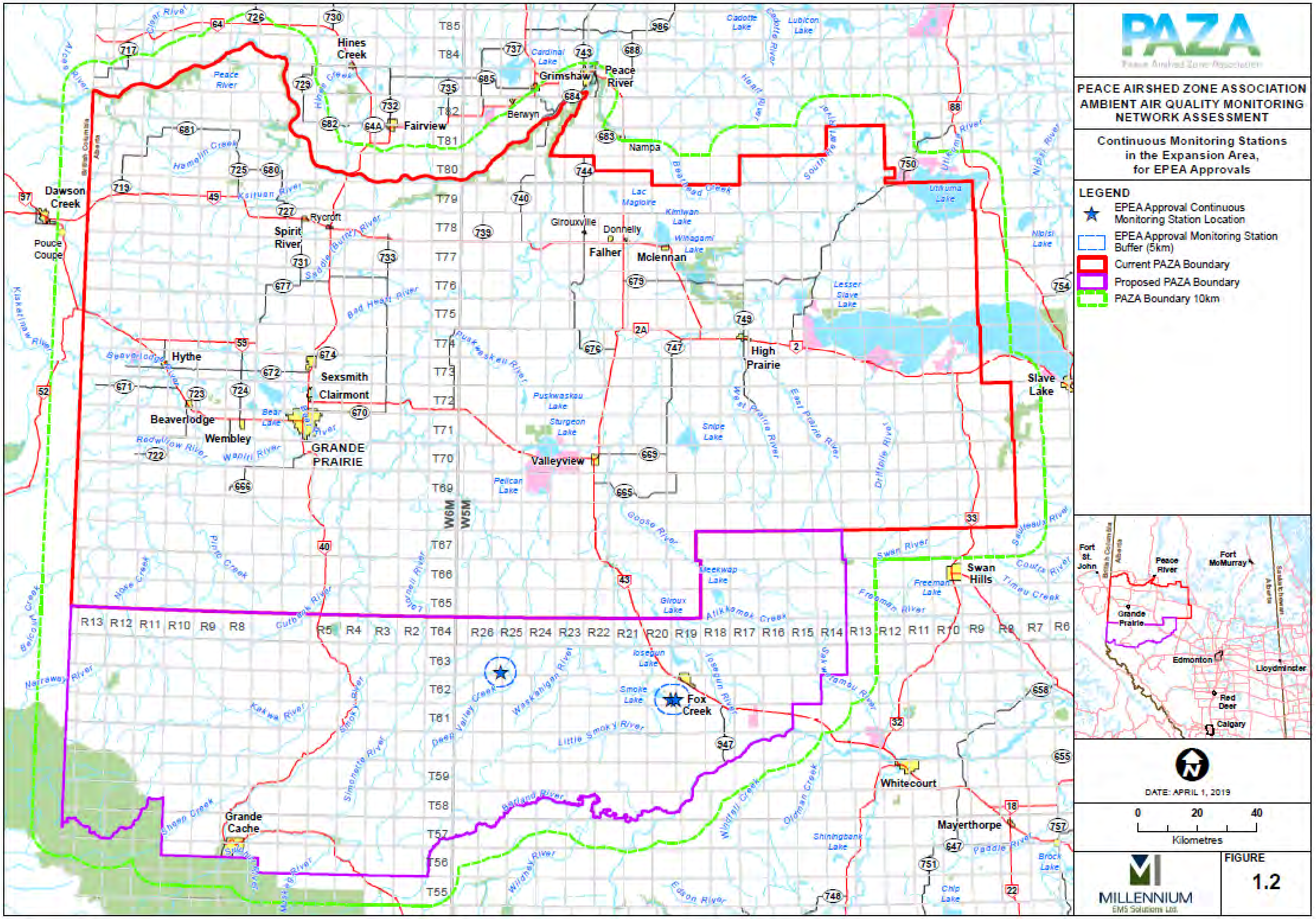

Figure 1.2 Continuous Monitoring Stations in the Expansion Area, for EPEA Approvals

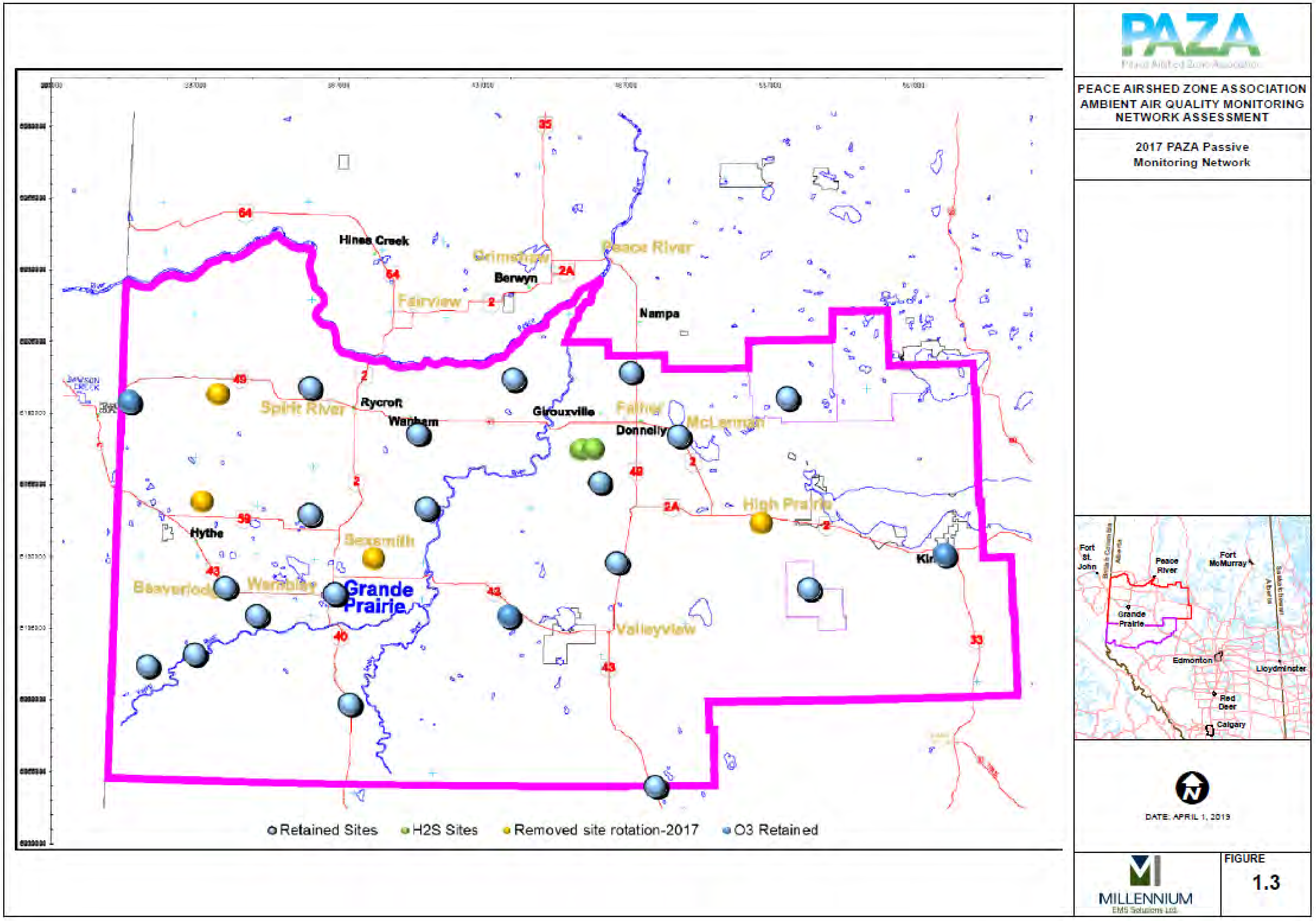

Figure 1.3 2017 PAZA Passive Monitoring Network

2.0 PROJECT EXPECTATIONS

PAZA required the evaluation to maximize the information of the monitoring network in a cost effective and sustainable way to achieve the following objectives:

1. Monitor to ensure compliance to EPEA Approvals.
2. Measure and assess air quality relevant to AAAQOs and CAAQS.
3. Understand the spatial distribution of monitored pollutants in the region.
4. Identify regional air quality trends and emerging issues.
5. Characterize specific geographic locations or sources.
6. Provide information required to understand potential population impacts to ambient air quality.
7. Provide information required to understand potential air quality impacts on the environment and population.
8. Improve the ability to identify and apportion pollutant sources for purposes of air quality management.
9. Provide adequate input and validation information for dispersion modeling.
10. Monitoring will be conducted using best available technology economically achievable.

In addition, PAZA wished the evaluation to address several specific key issues for the network. These are:

- understand the spatial distribution of monitored pollutants in the region;
- address emerging issues;
- provide data to stakeholders to evaluate potential population exposure to air pollutants, including representative Air Quality Health Index (AQHI) reporting for population centers within the Airshed;
- suitability and completeness for the data set to provide adequate input (background, meteorological information) and validation information for dispersion modeling;
- recommendations that serve multiple monitoring purposes;
- benefits, if any, of monitoring outside of current boundaries; and
- other aspects and observations of the PAZA network based on previous monitoring network experience.

These objectives were met through quantitative and qualitative approaches, and MEMS proposed a combination of approaches for some.

3.0 APPROACH AND METHOD

3.1 Overview of Suitability Analysis Approach

Site selection or suitability analysis is a type of analysis used in GIS to optimize siting. The result is a suitability surface which ranks potential sites from least to most suitable.

In GIS, the broadest classification of data is whether the data is of vector or raster type. The most common vector type data is the points, lines, and polygons you see on maps. With raster data, the surface of the earth is conceptually gridded into cells (of whatever size is appropriate for the exercise), with each cell having a value. Raster data forms a continuous surface; the most familiar of this data format would be digital elevation data and satellite imagery.

Vector features, or zones of influence (buffers) around a feature, can be assigned a value based on decisions around the appropriate weighting factors. For example, proximity to access may be a factor being considered. A zone of up to 500 m may have a high value, beyond that to 2 km of moderate value, and anything beyond 2 km of low value. The low value buffer zones would be assigned a numeric value of 1, the moderate value buffer zones assigned a numeric value of 2, and the high value buffer zones (closest to the access route) assigned a numeric value of 3.

Assigned values may change with scenario. For example, to address population exposure, high values might be assigned to zones nearest the highest population centres and low values assigned to the lowest population density areas. Conversely, if broad geographic coverage is desired in another scenario, low to moderate values might be assigned to zones near population centres and in low population density areas.

These sorts of factors are determined for the various data layers that are being used as input to any particular model. For the preceding example on access zones of influence, a different model may use different size zones, or only have two classes of rating – essentially a yes/no.

After each vector data layer is prepared according to the rules and weighting factors, it is converted to a raster format, using a cell size appropriate to all models. A consistent cell size is necessary so that comparisons can be made between all final models.

When all the vector data has been converted to raster, there will be a collection of raster datasets (surfaces) with every location (cell) on each grid having a numeric value. All the surfaces are combined with an addition process. If there are, for example, six surfaces, each of which has cell values of 1, 2, or 3, then the surface resulting from the addition will have values ranging from 6 (all 6 surfaces have a cell value of 1 at the same location) to 18 (all 6 surfaces have a cell value of 3 at the same location).

The final surface pattern is composed of grid points or cells that contain suitability ratings. Cells of equal rating can be combined into polygons. The locations of the highest rated polygons would identify where monitoring ought to occur.

This approach provides an objective means of providing the highest value network to PAZA. This recommended network would need to be adjusted because the evaluation is made at a high level and without knowledge gained by direct access to potential sites.

3.2 GIS Data

3.2.1 General

MEMS built the suitability model on its ArcGIS platform. MEMS used the following data layers to reflect current monitoring:

- Continuous and passive monitoring sites. Given that stations are already established in the existing PAZA area, new sites close to these is less desirable. Nonetheless, one model scenario was a complete re-evaluation of the network (*e.g.,* starting from scratch based on information in other layers). In the expansion area, we included existing EPEA approval sites or assume they could be moved eventually to provide optimum coverage. The latter assumption was made.

Other layers reflect the most recently available emissions or emission locations:

- NPRI emissions for reporting facilities, from the NPRI website (NPRI 2017);
- CMAQ emissions from a recent province-wide study (provided by PAZA);
- oil and gas emitter locations from the AER (Source: AbaData, 2019);
- communities based on location and population from Statistics Canada census (Populated Places data source: AltaLIS, 2015; Population source: Statistics Canada, 2016);
- major and minor roads from current Alberta Transportation databases (AltaLIS Base Features 1:20,000 Roads and Trails, 2018; National Road Network, 2018); and
- Correlation Analysis, 2019 MEMS from CMAQ data.

Observed air quality was another layer, specifically spatial contours of passive concentration data or trends in concentration data. High concentration areas and/or areas in which concentrations are trending up are desirable. Areas where measurements are highly correlated with other measurements have lower suitability.

Emerging issues were incorporated into the suitability analysis as follows:

- For example, the RFP noted "increasing industrial development in the County of Grande Prairie No.1 along Highway No.43 near Wembley, in and around the Fox Creek area".
  - The Wembley development was modelled as an exclusion zone extending 1 km from the highway and 2 km in either direction from the community of Wembley along the highway. Monitoring outside this new development zone was considered desirable.
  - The latter area is occurring within the already-active Fox Creek area. No further weighting was considered necessary.
- Locations of known sources outside but within 10 km of the PAZA boundary. Sources within 10 km of the PAZA boundary were identified (*e.g.*, near Dawson Creek) and could have resulted in locations outside the boundary being considered as suitable areas. This was judged to be inappropriate.
- Transboundary sources. It was not attempted to use a suitability model approach to establish background monitoring, for distance sources whose plumes might affect the PAZA airshed (*e.g.*, forest fires).
- Population Growth, leading to increased populations in communities, additional traffic, *etc.* Population growth was assumed to occur in current population centres, which are already identified as suitable for continuous stations (based on population).

Receptor Locations

- communities were suitable locations for continuous monitoring given population density and site accessibility;
- terrain (Terrain – Alberta Provincial Digital Elevation Model (1:20,000) from AltaLIS, 2015); and
- major and minor roads from current Alberta Transportation databases and other transportation sources (either Base Features from AltaLIS or National Road Network from Natural Resources Canada.). Proximity to all weather roads and power is desirable, especially for the continuous network which must be accessed monthly for calibration.

3.2.2 Passive Network Layers Detail

3.2.2.1 Exclusions

Exclusion zones (areas where monitoring is unsuitable) were established based on several factors:

- Areas outside the 10-km buffer around the current and expanded PAZA boundaries were excluded based on location.

- Areas within specific distances of NO_2 emission sources were excluded based on the magnitude of emissions in the CMAQ database as identified in Table 3.1. The distances are approximately those in which plume influences would be expected. Passive stations are not meant to be in the immediate zone of these sources, as they are meant to offer a broad indication of the airshed. NO_2 was chosen, rather than SO_2 or H_2S, because NO_2 emissions are more widespread in the airshed. Figure 3.1 illustrates exclusion zones around NO_2 sources.
- Exclusion distances around all AER facilities, regardless of emissions, was 500 m. Larger sources would already be included in the CMAQ NO_2 emission database and may be associated with a larger exclusion zone. AER facility exclusion zones are also shown in Figure 3.1.

Table 3.1 Passive Network Exclusion zone around NO_2 sources (CMAQ Emissions)

NO_2 Emission Source Strength (Percentile)	Exclusion Zone (m)
99	1000
95	1000
90	500
75	500
< 75	500

Because of emissions associated with communities, exclusion zones were also established around them, based approximately on the expected area of influence of urban plumes. An exclusion zone of 5 km was established around Grande Prairie. A 1-km zone was established around other population centres.

Roadways are emission sources with an associated exclusion zone and required access. For simplicity, distances within 750 m of all roadways were excluded. Figure 3.1 also includes roadways in the airshed.

Terrain exclusion zones were also established. These were meant to indicate areas where access was expected to be challenging. Areas with slope >40% and elevations above 1500 m were excluded. Exclusion zones based on slope and elevation are shown in Figure 3.1.

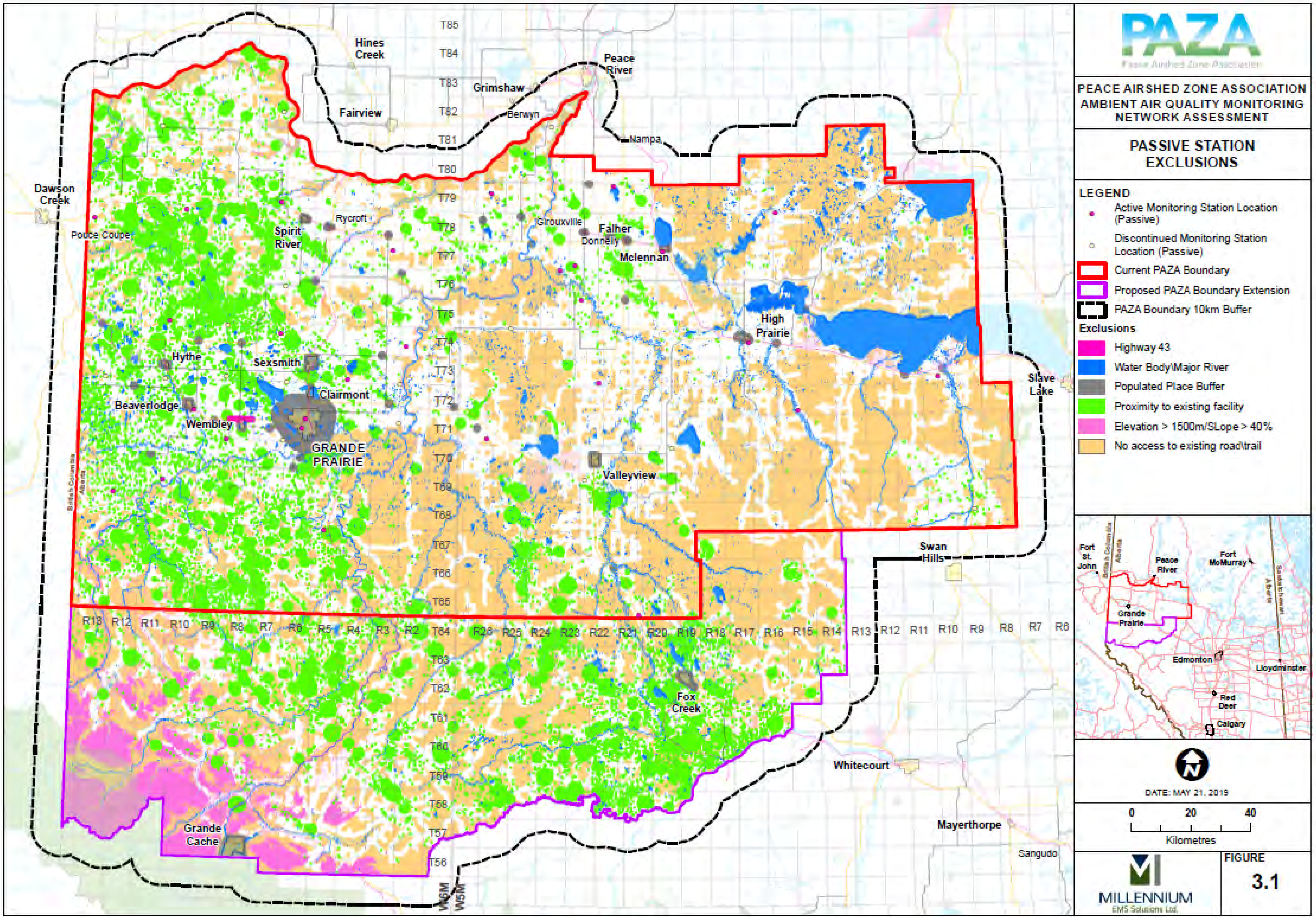

Figure 3.1 Passive Network Exclusion Zones

3.2.2.2 Suitability

Suitable areas for passive monitoring were based on several considerations. It is observed in the current network that substantially more development (oil and gas activity) occurs in the western half of the current PAZA airshed while the density of monitoring stations is approximately equal in the two halves of the airshed. Thus, while exclusion zones are established around (NO2) sources, it appeared reasonable to monitor more in general areas – say, townships – where more activity occurs. Table 3.2 shows how this was accomplished, by noting that monitoring near but not immediately near sources. This approach discourages monitoring in areas with large numbers of overlapping facilities but would encourage monitoring in larger areas (*e.g.*, townships) with higher emissions. Figure 3.2 shows the effect.

Table 3.2 Passive Network Suitability near NO_2 Sources

NO_2 Emission Source Strength Percentile	Suitable Zone (m)
99	1000-6000
95	1000-4000
90	500-2000
75	500-1000
< 75	500-1000
0	0
Null	0

0 = Not in proximity to a facility (Unsuitable)

1-75 = Within proximity of a facility. 1 = only one facility (low suitability), 75 = 75 overlapping facility buffers (high suitability)

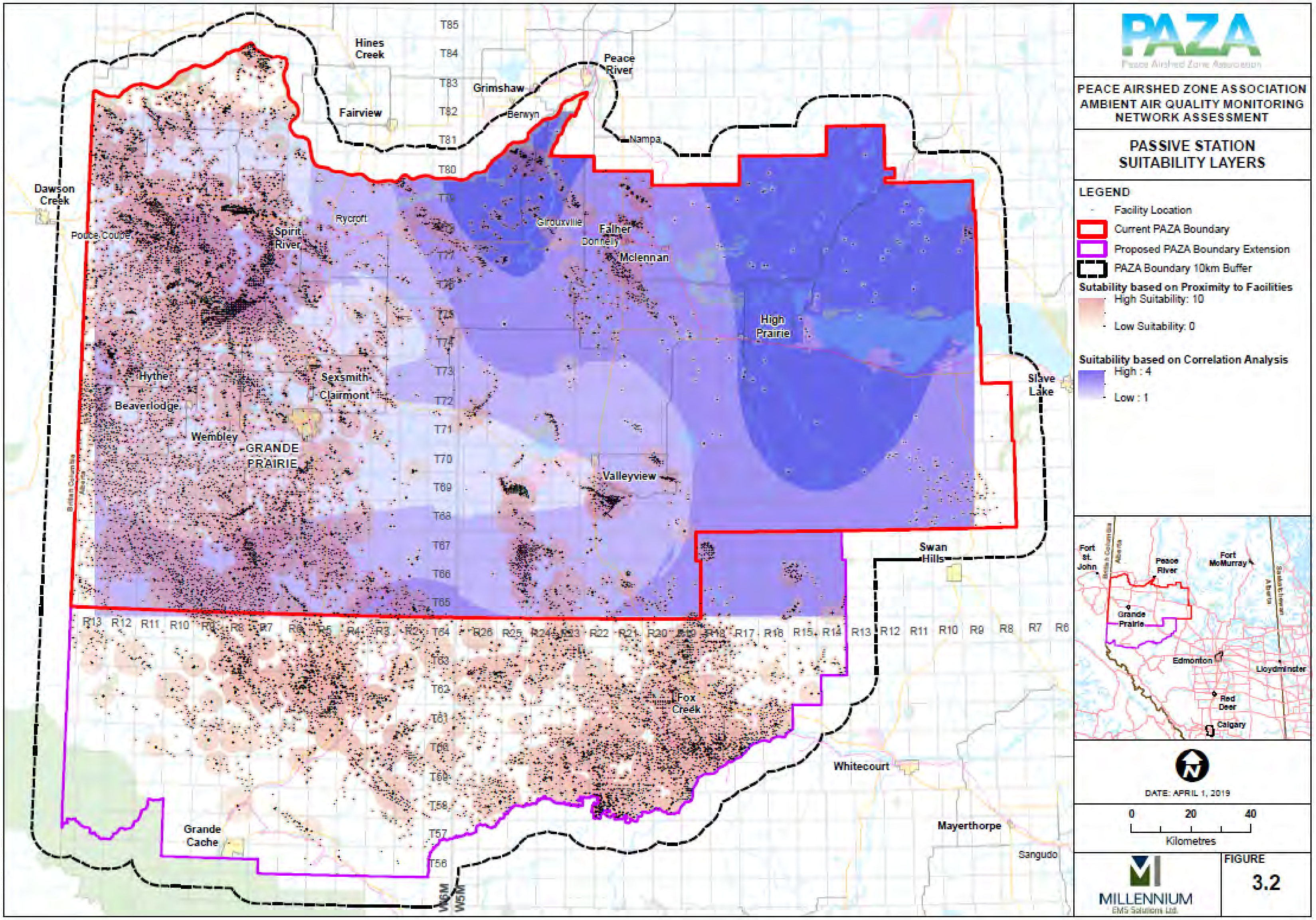

Figure 3.2 Passive Network Suitability

A correlation analysis was completed as part of this work. For the suitability analysis, highs of high correlation are unsuitable for additional monitoring, based on a reclassification of raw correlation values as outlined in Table 3.3 (using the Natural Breaks Jenks function in ArcGIS). It is expected the correlation layer would counter the NO_2 source layer in Table 3.2 as measurements in more active areas of the airshed are likely to be more highly correlated. The correlation evaluation for the existing network is discussed in Section 5.1; isopleths from that analysis underly Figure 3.2.

Table 3.3 Correlation layer

Original Correlation	Reclassification	Comment
0.420017-0.516259	4	low correlation, high suitability
0.516259-0.614005	3	moderate suitability
0.614005-0.698216	2	low-moderate suitability
0.698216-0.804985	1	highly correlate, low suitability
	0	No data
	-1	Outside 10-km PAZA buffer

3.2.3 Continuous Network Layers Detail

3.2.3.1 Exclusions

Exclusion zones (areas where monitoring is unsuitable) were established based on several factors:

- Areas outside the 10-km buffer around the current and expanded PAZA boundaries were excluded based on location.
- Only the largest CMAQ sources were considered for continuous monitoring and areas within 1 km of the largest NO_2 sources were excluded. NO_2 was chosen, rather than SO_2 or H_2S, because NO_2 emissions are more widespread in the airshed. Figure 3.4 illustrates exclusion zones around NO_2 sources.

Communities were not exclusion zones, as monitoring within (the larges of) them is preferred in this scenario. Distances within 250 m of all roadways were excluded. Figure 3.3 also includes roadways in the airshed.

Terrain exclusion zones were also established. These were meant to indicate areas where access was expected to be challenging. Areas with slope >40% and elevations above 1500 m were excluded. Exclusion zones based on slope and elevation are shown in Figure 3.3.

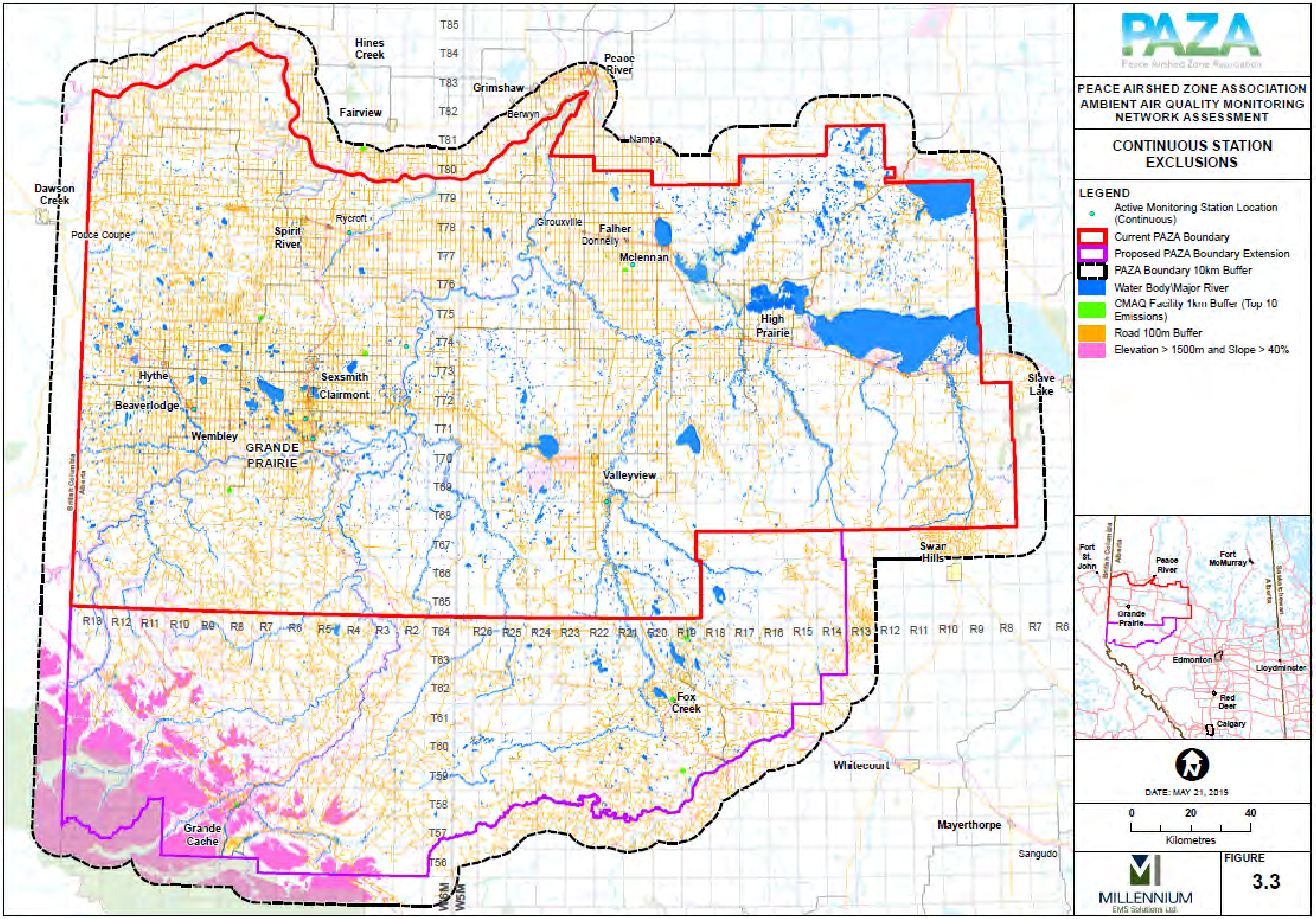

Figure 3.3 Continuous Monitoring Exclusion Zones

3.2.3.2 Suitability

Suitable areas for continuous monitoring were based on several considerations:

- The top 10 CMAQ sources were included, to provide an indication of the location of the largest sources in the airshed. Beyond the 1-km exclusion zone, the most suitable zones ranged to 4 km from the facility.
- Monitoring within the boundaries of communities was highly suitable, with higher ranking for more populous communities.
- Industrial emissions within 3 km of community boundaries also contributed to higher suitability, as industrial and urban plumes were assumed to overlap.

Figure 3.4 shows the location of the communities and the highest emitters in the airshed. These are recommended to be the most suitable locations for monitoring of the continuous network (Section 6.2). Figure 3.5 shows the suitability in higher definition near Fox Creek as an example.

3.3 Suitability Scenario Definition

Based on discussions with PAZA, two suitability scenarios were established.

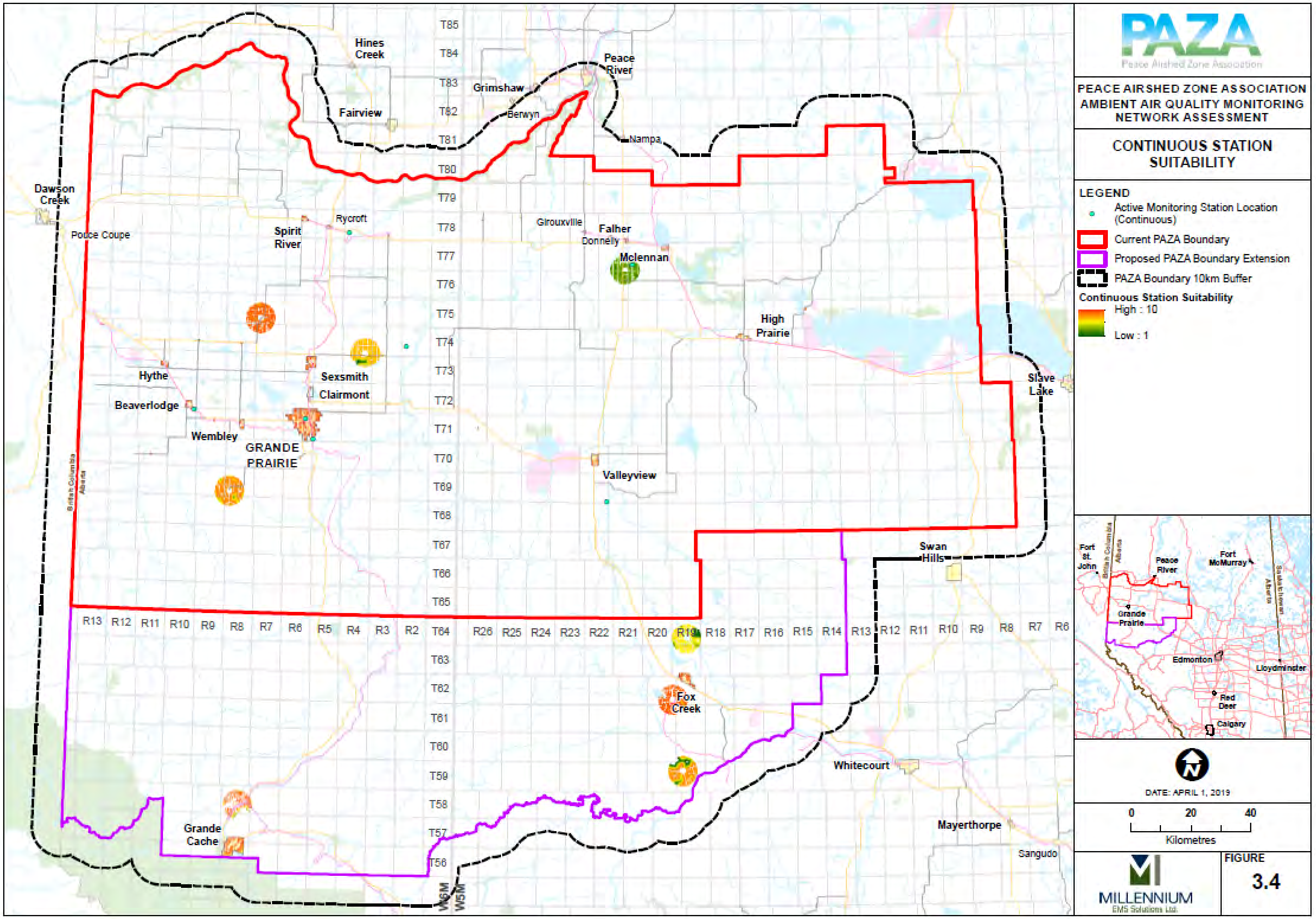

Figure 3.4 Regional Suitability for Continuous Monitoring

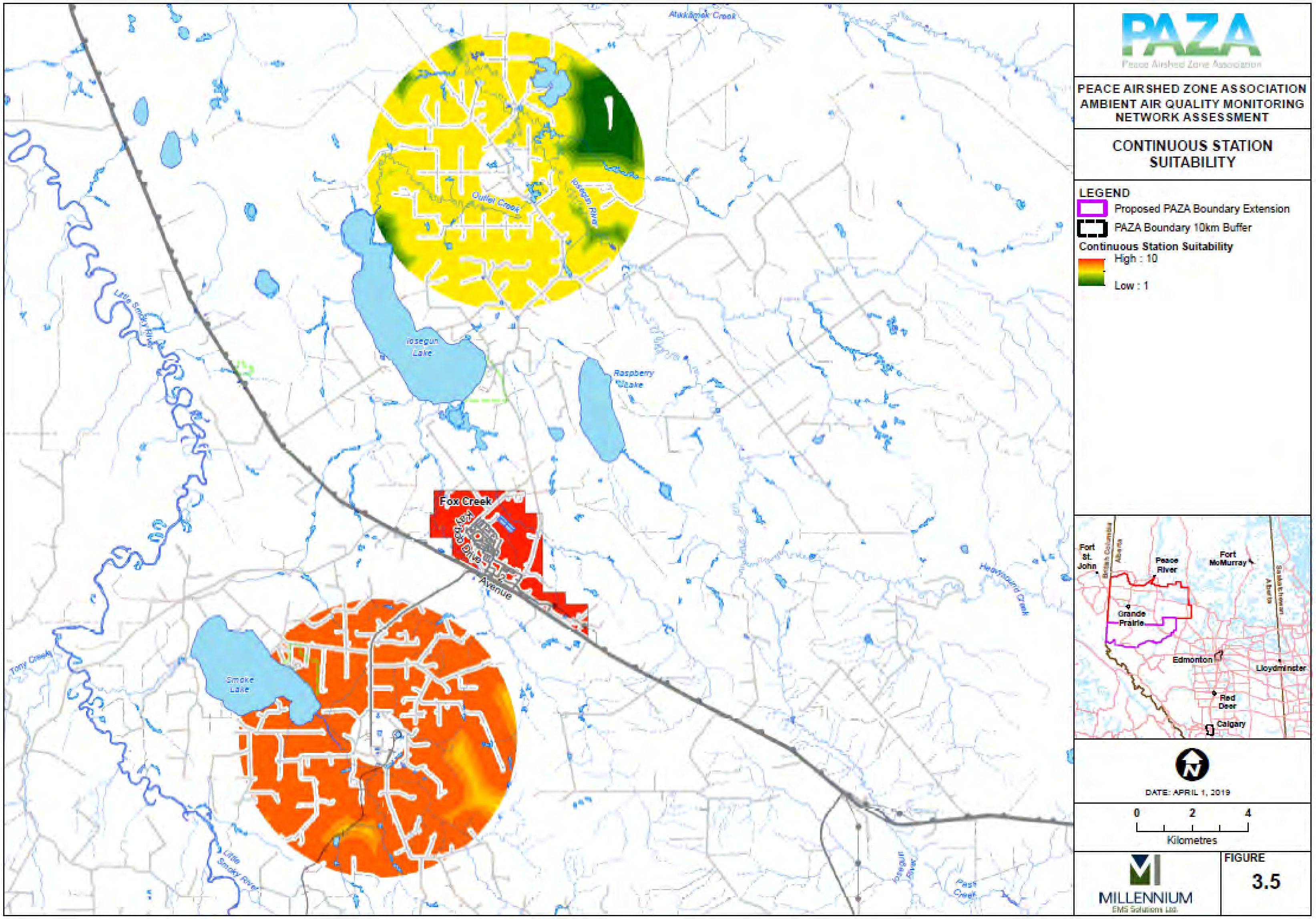

Figure 3.5 Local Suitability for Continuous Monitoring

3.3.1 Passive Network

The basis of the network is a broad uniform view of the airshed, away from the influence of specific (large) sources. For an evaluation of the basic network, assume the number of stations in the network (in 2018) is a reasonable starting point for the number of points in the grid.

1. If the EPEA approvals require any passive stations, hardwire these into the network, in an efficient manner. There were no EPEA sites in the current PAZA area. There were several sites with monitoring under EPEA approvals in the expansion area.
2. Use correlation analysis of measured concentrations to establish which sites are most independent of each other, based on an analysis of all measurements to date, including the previous (denser) network. This analysis is independent of the suitability model.
3. Key emission layer for suitability model. Use the CMAQ emission file rather than the NPRI file to identify source location and emissions. Base the "exclusion zone" for monitoring only on NOx emissions (to keep the model manageable). The exclusion zone is highly unsuitable for monitoring. Establish variably-sized exclusion zones based on emission strength from each source, with the following starting point:
4. Secondary emission layer. Use the AER facility location file which may have overlap with the CMAQ file. Avoid all sources in this file by 500 m that aren't already in the CMAQ file.
5. No passives in communities. Avoid Grande Prairie by 5 km and all others by 1 km. Passives can be used in communities; however, they don't provide information on human health.
6. Do not monitor near existing roads. The assessment was based on a setback of 750 m. However, this setback is impractical, and a more manageable distance will be required in practice. The general guidance is that this distance should be as large as reasonably possible given access constraints in winter. A reduction in the setback would not change the suitable map at the macro level.
7. Identify new development areas. One area (Wembley) was identified, an exclusion zone established around it, and a high suitability area established outside it (a higher suitability buffer around the section of Highway 43 was included in the analysis). Other areas of increasing development appeared to be within other development areas and were not altered.
8. Avoid areas of high or steep terrain, open water (> 1500m in elevation > 40% slope). All perennial lakes and major rivers.
9. There is a higher density of sources in the western part of the current airshed zone. It is possible that use of a correlation approach would reduce the density of the passive

network even more in that location. Further, the use of exclusion zones would "sterilize" more of the area for high suitability sites than the eastern side of the airshed.

Therefore, an approach based on emission "density" will objectively weight suitability higher in areas of higher emissions. The a priori establishment of grids (*e.g.*, 20 x 20 km) within which to determine emission density and to provide a higher weighting for grids with higher emissions was used.

3.3.2 Continuous Network

The basis is monitoring where people are most affected for health effects or near the highest emitting sources, but not in their immediate proximity.

1. AEP does not specify what monitoring is required for PAZA members. The responsibility is left with PAZA to ensure that monitoring adequately addresses the potential air quality concerns from facilities required by their EPEA Approval to be a PAZA member. There are stations required in the expansion area. These could be hardwired into the expansion area suitability model, or approvals could be amended to offer flexibility to PAZA to resite the stations. This latter approach is expected and built into recommendations in Section 6.
2. The basis of the continuous network is populations including those that may be affected by large emission sources. Populated places will be ranked based on proximity to known emission sources. Use a combination of highest population and proximity to emission sources to generate a final suitability rank. Hardwire two sources inside Grande Prairie as the highest population within the PAZA Zone. No monitoring is planned near or downwind of Dawson Creek even though it is about 10 km from the AB border, because monitoring in B.C. is not planned.
3. Primary emission layer for non-urban siting. Use the CMAQ emission file. Look to place a monitor near the highest NO_x, $PM_{2.5}$ and SO_2 sources, but maintaining an exclusion zone of about 2 km (*i.e.,* areas within 2 km of these sources are highly unsuitable based on dispersion model considerations). Also apply exclusion zones to all smaller sources.
4. Access consideration. All continuous monitors must be within say 2 km of a roadway (for access) but not closer than 250 m.
5. Avoid areas of high or steep terrain, open water.

4.0 ANALYSIS

4.1 Historical Air Quality

4.1.1 Continuous Monitoring – Temporal Changes

Based on information obtained from the AEP Data Warehouse (AEP 2019), hourly measurements from five continuous stations for January 2013 to December 2018, one continuous and one portable station for 2016 to 2018 were summarized. The parameters measured at each station are listed in Table 4.1.

Table 4.1 Continuous Ambient Air Quality Stations in the PAZA Area, 2013 - 2018

Parameter		Beaverlodge	Evergreen Park	Grande Prairie (Henry Pirker)	Smoky Heights	Valleyview	Donnelly	Rycroft - Portable
Location	Latitude	55.1963	55.1175	55.17667	55.40278	54.94049	55.65611	55.74194
	Longitude	-119.397	-118.765	-118.808	-118.281	-117.215	-117.082	-118.598
Data Period		2013-2018	2013-2018	2013-2018	2013-2018	2013-2018	2016-2018	2016-2018
Nitrogen dioxide (NO_2)		✓	–	✓	–	–	–	✓
Sulphur dioxide (SO_2)		✓	✓	✓	✓	✓	✓	✓
Particulates ($PM_{2.5}$)		✓	✓	✓	✓	–	–	✓

Source: AEP 2019
✓ parameter measured at Station
– parameter not measured at station

Monthly average concentrations for NO_2, SO_2 and $PM_{2.5}$ for 2013 to 2018 at PAZA continuous monitoring stations are presented in Figures 4.1 to 4.3, respectively. Key observations are:

- There were no 1-hour, 24-hour or annual average measurements of sulphur dioxide and nitrogen dioxide above the Alberta Ambient Air Quality Objectives (AAAQO) during the 6-year period at any of the stations.
- The highest month-average NO_2 concentrations were measured in Grande Prairie. All stations showed seasonal variability with the highest values in the coldest months, because of poorer dispersion conditions and possibly increased heating emissions and vehicle idling.

- There is no trend in monthly average SO_2, Higher concentrations were measured in 2015 at Valleyview and in 2016-2017 at the Rycroft portable.
- There is no seasonal trend evident in the $PM_{2.5}$ data at any stations. All stations measured elevated concentrations in summer 2018.

Rycroft SO_2 measurements were relatively high in 2016 and 2017 and lowered substantially in early 2018. The reason is not known.

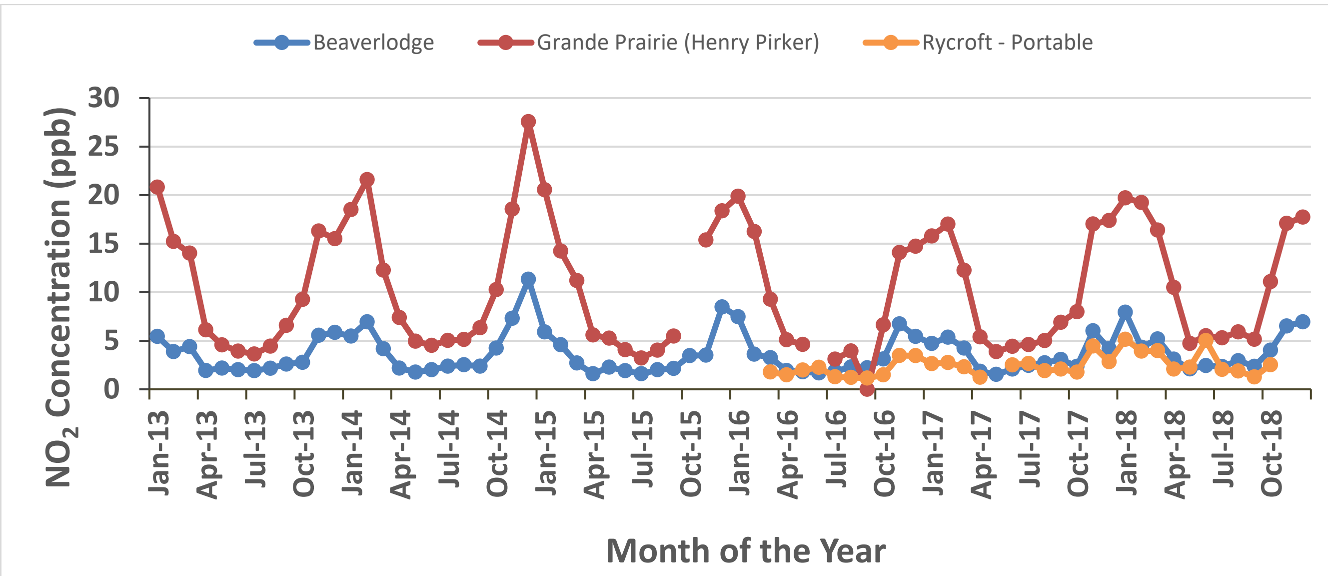

Figure 4.1 Monthly Average NO_2 Measurements at PAZA Continuous Stations, 2013 - 2018

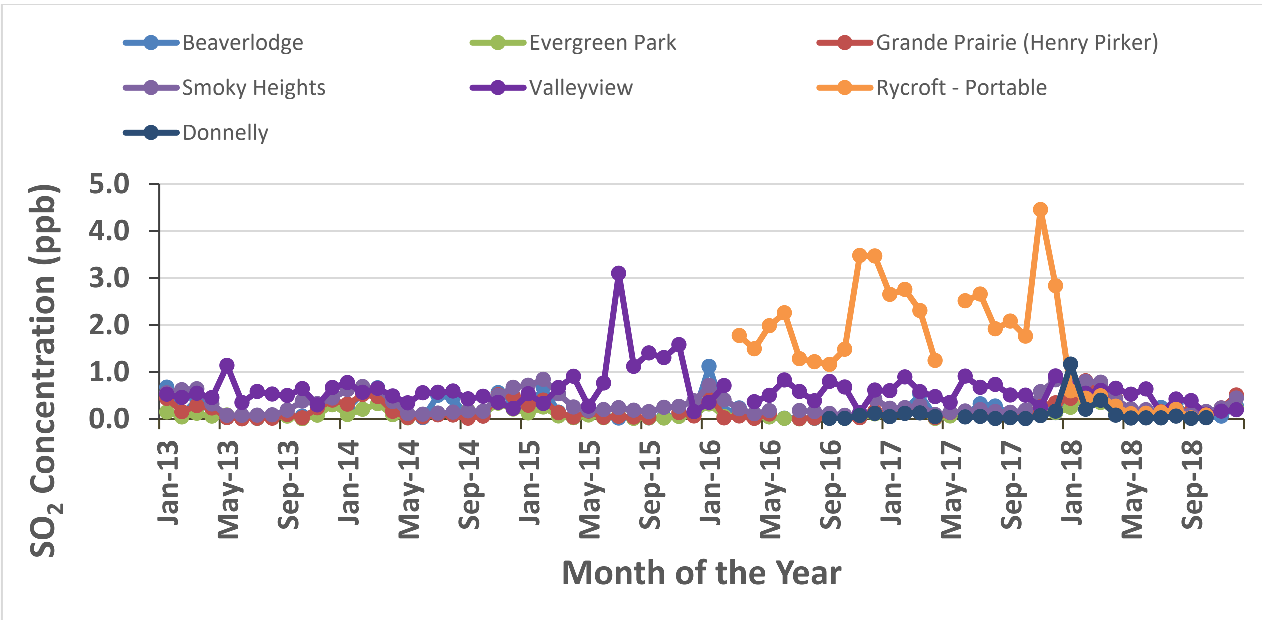

Figure 4.2 Monthly Average SO_2 Measurements at PAZA Continuous Stations, 2013 – 2018

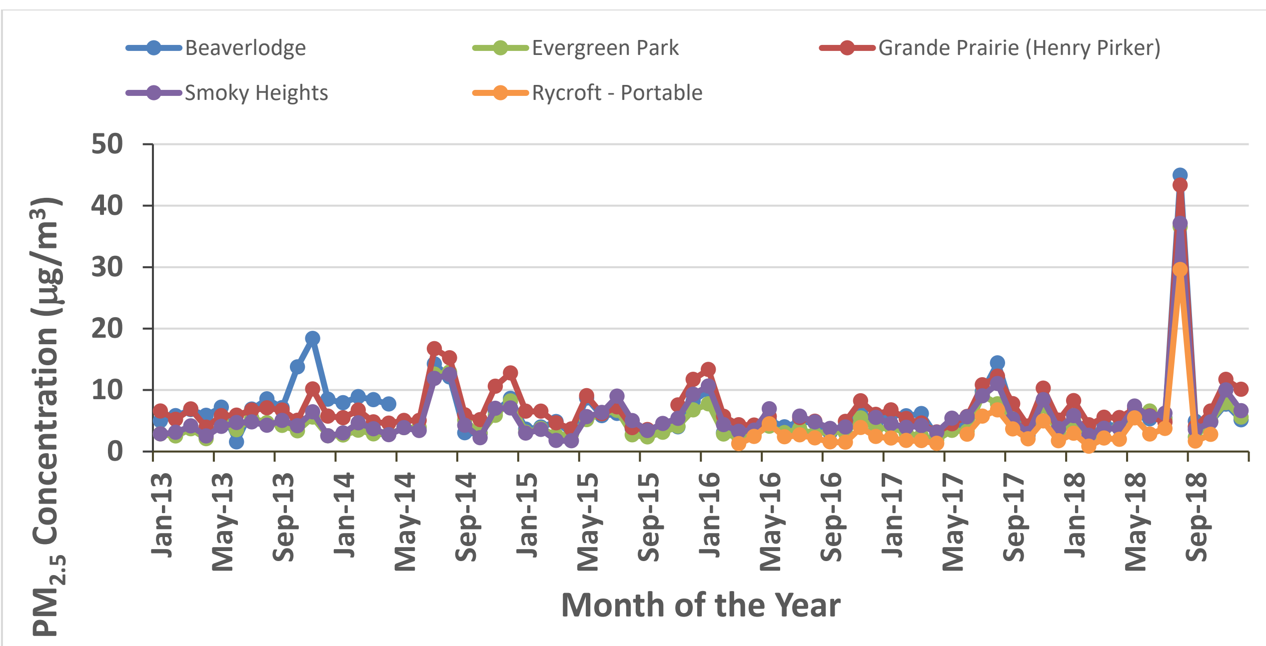

Figure 4.3 Monthly Average $PM_{2.5}$ Measurements at PAZA Continuous Stations, 2013 – 2018

Table 4.2 and Figure 4.4 summarize annual exceedances of $PM_{2.5}$ measurements above the 1-hour AAAQG of 80 µg/m³ and 24-hour AAAQO of 29 µg/m³. The highest measured values occurred in

2014, 2017 and 2018. In 2018, 97% of the exceedances occurred in August, due mostly to widespread forest fires in B.C.

Usually, the Beaverlodge and Henry Pirker stations had more exceedances than other stations. However, for the most part exceedances were distributed among all or most stations indicating either the influence of wide-spread local sources or large upwind sources (B.C. fires in 2018).

Wind directions have value for the placement of monitoring stations. Locations downwind of the prevailing wind from a source provide a good indication of long-term effects. The location of the maximum short-term concentrations may occur in any direction from the facility - where available dispersion modelling can provide guidance on location with respect to industrial facilities. Windroses at PAZA continuous measurement sites for 2017 are shown in Figure 4.5. At most locations, prevailing winds are from the WSW or SW. At Rycroft and Valleyview, winds contain a stronger southerly component. The strongest winds generally blow from the SW.

Table 4.2 $PM_{2.5}$ Measurements above AAAQOs, 2013 - 2018

Year	Beaverlodge	Grande Prairie (Henry Pirker)	Evergreen Park	Smoky Heights	Rycroft - Portable
	Reading above 1-hour AAAQG of 80 μg/m³				
2013	4	0	1	6	0
2014	24	25	17	19	0
2015	3	3	3	2	0
2016	1	1	0	4	4
2017	25	22	14	20	12
2018	128	123	112	93	69
	Reading above 24-hour AAAQO of 29 μg/m³				
2013	1	0	0	0	0
2014	9	14	8	8	0
2015	0	1	0	1	0
2016	1	1	0	0	0
2017	6	6	3	4	2
2018	14	13	11	13	10

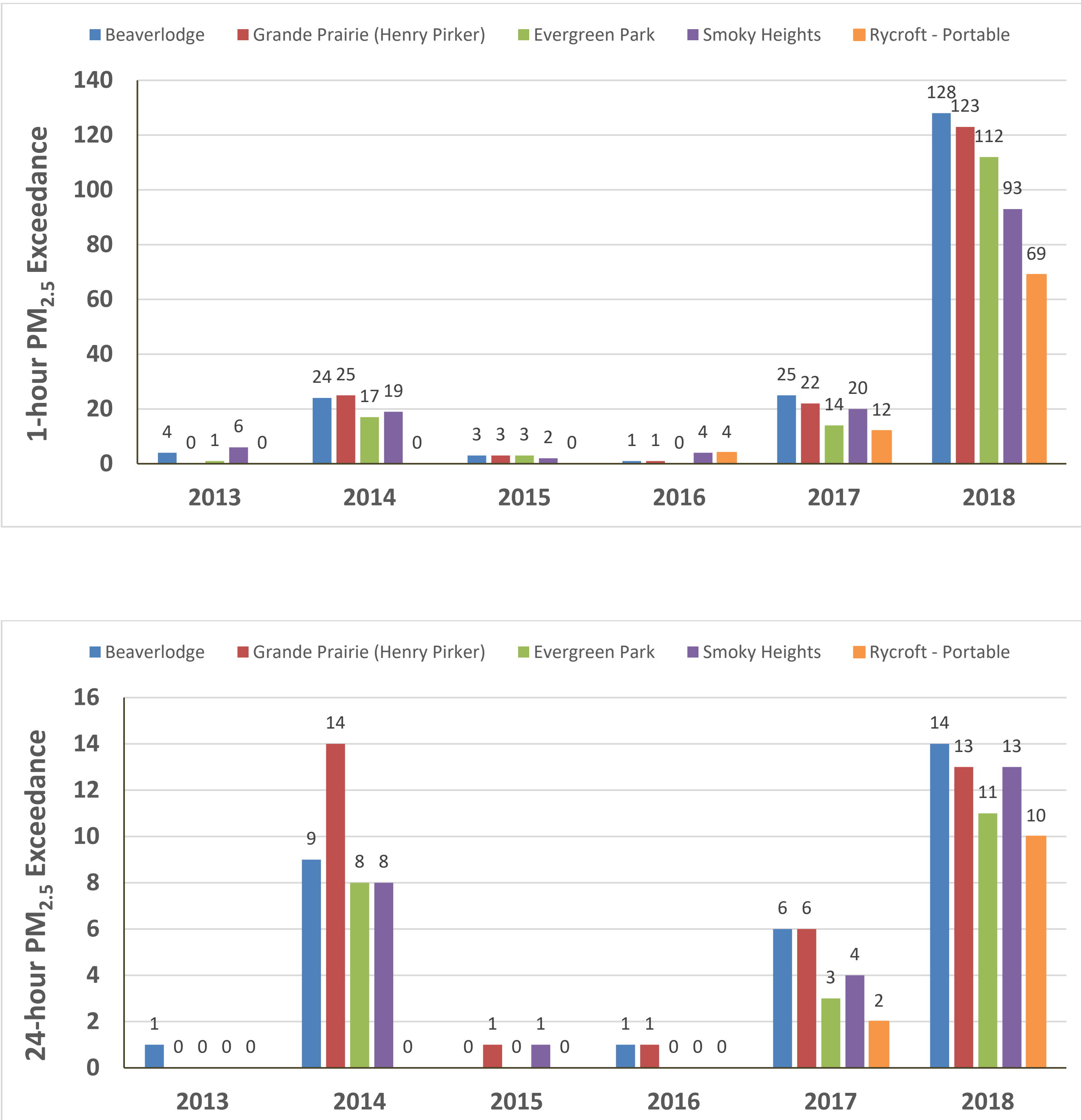

Figure 4.4 Hourly (top) and Daily (bottom) $PM_{2.5}$ Exceedances at PAZA Continuous Stations, 2013 – 2018

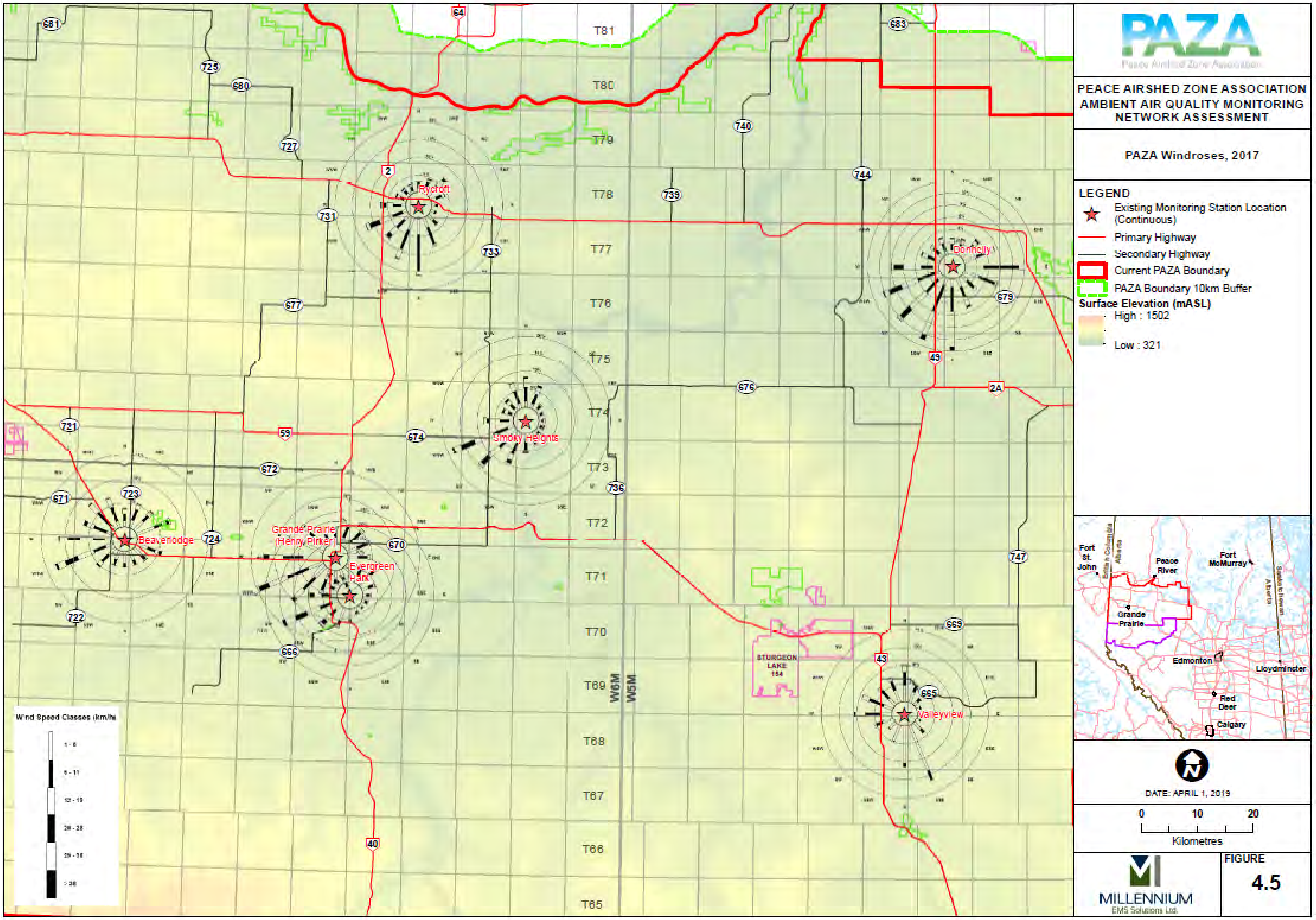

Figure 4.5 PAZA Windroses, 2017

4.1.2 Passive Monitoring – Temporal Changes

Table 4.3 lists all passive stations within the airshed, based on historical passive monitoring data provided by PAZA. To establish long term trends, monthly passive concentrations were averaged in the airshed for January 2010 to November 2018 and illustrated in Figures 4.6 and 4.7 for NO_2 and SO_2, respectively. Monthly passive concentrations from February 2017 to November 2018 were averaged based on reduced sampling locations. Observations are:

- The black line represents a linear trend line and shows that average NO_2 values increased slightly, by about 14% over the period.
- Average SO_2 values measured at the stations decreased from 2010 to 2018, by about 30%. Peak SO_2 concentrations also decreased.
- Both NO_2 and SO_2 show seasonal variations, with higher concentrations in colder months because of poorer dispersion conditions.

Annual average concentrations for NO_2 and SO_2 from 2010 to 2017 at 26 passive stations are presented in Figures 4.8 and 4.9, respectively, and offer a means of examining the contribution of individual stations with time. High NO_2 values are measured in Grande Prairie. The trends with time to increasing NO_2 and decreasing SO_2 are also evident in this representation.

Figure 4.10 shows H_2S annual concentrations measured at three stations. The trend is generally to increasing concentrations of H_2S, although measurements at three stations does not necessarily justify a regional trend.

4.2 Passive Monitoring - Spatial Distribution

The spatial distributions of NO_2 and SO_2 are illustrated in Figures 4.11 and 4.12, based on 2017 passive measurements at 26 stations. Dots are scaled for size and colour coded by measurement values. Spatial contours of passive concentration data show the highest NO_2 concentrations are in Grande Prairie and the surrounding area, from urban and industrial activity.

The highest SO_2 concentrations are in the northwestern portion of the airshed associated with oil and gas activity.

Table 4.3 Passive Stations Within PAZA

Number	Station Name	Longitude	Latitude	Northing	Easting	Site Legal Location	Elevation of Passive Head (m)	Monitored Pollutants			
								SO_2	NO_2	O_3	H_2S
1	Silver Valley*	119°37'07.5"	56°02'52.6"	6,214,509	336,898	08-27-081-11 W6M	651	✓	✓	✓	
2	Bay Tree	119°57'54.8"	55°45'58.7"	6,184,052	313,982	13-16-078-13 W6M	700	✓	✓	✓	
3	Forth Creek*	118°57'54.7"	56°06'08.8"	6,219,222	377,769	04-13-082-07 W6M	695	✓	✓	✓	
4	Gordondale	119°28'26.0"	55°47'56.5"	6,186,483	344,928	04-34-078-10 W6M	788	✓	✓	✓	
5	Boone Creek	119°32'24.7"	55°27'40.7"	6,149,061	339,396	16-36-074-11 W6M	800	✓	✓	✓	
7	Steeprock Creek*	119°52'19.4"	55°17'16.1"	6,130,578	317,623	01-02-073-13 W6M	832	✓	✓	✓	
9	Spirit River	118°57'57.5"	55°49'49.6"	6,188,958	376,859	08-12-079-07 W6M	630	✓	✓	✓	
10	Woking*	118°55'53.4"	55°34'43.2"	6,160,880	378,239	01-13-076-07 W6M	722	✓	✓	✓	
11	Webber Creek*	119°14'01.9"	55°27'14.9"	6,147,598	358,736	09-36-074-09 W6M	769	✓	✓	✓	
12	Hythe*	119°33'19.3"	55°17'12.0"	6,129,668	337,724	14-36-072-11 W6M	745	✓	✓	✓	
14	Sylvester	119°48'22.6"	54°56'30.3"	6,091,914	320,251	08-06-069-12 W6M	797	✓	✓	✓	
16	Beaverlodge	119°23'50.6"	55°11'46.4"	6,119,249	347,407	15-36-071-10 W6M	749	✓	✓	✓	
17	Poplar*	119°13'50.5"	55°17'59.3"	6,130,422	358,384	13-06-073-08 W6M	730	✓	✓	✓	
18	Saddle Hills	118°56'55.6"	55°26'01.1"	6,144,774	376,696	04-25-074-07 W6M	785	✓	✓	✓	
19	Wanham	118°21'46.4"	55°41'37.0"	6,172,821	414,332	16-22-077-03 W6M	656	✓	✓	✓	
20	Shaftesbury*	117°31'12.9"	56°04'21.6"	6,214,288	467,614	04-03-082-23 W5M	513	✓	✓	✓	
21	Eaglesham	117°50'16.8"	55°52'07.7"	6,191,797	447,560	16-21-079-25 W5M	564	✓	✓	✓	
23	Bear Lake*	118°54'37.4"	55°17'11.4"	6,128,336	378,676	15-31-072-06 W6M	686	✓	✓	✓	
24	Wembley	119°13'15.3"	55°06'43.2"	6,109,507	358,340	12-31-070-08 W6M	686	✓	✓	✓	
25	Pinto Creek	119°33'04.4"	54°58'53.8"	6,095,723	336,746	04-24-069-11 W6M	721	✓	✓	✓	

Table 4.3 Passive Stations Within PAZA

Number	Station Name	Longitude	Latitude	Northing	Easting	Site Legal Location	Elevation of Passive Head (m)	Monitored Pollutants			
								SO_2	NO_2	O_3	H_2S
26	Flyingshot*	118°55'25.8"	55°06'42.5"	6,108,923	377,286	15-36-070-07 W6M	665	✓	✓	✓	
27	Grande Prairie I	118°49'26.7"	55°08'55.4"	6,112,860	383,755	08-15-071-06 W6M	667	✓	✓	✓	
28	Clairmont Lake	118°35'24.3"	55°17'53.5"	6,129,128	399,046	09-06-073-04 W6M	686	✓	✓	✓	
29	Smoky Heights	118°16'52.7"	55°24'09.9"	6,140,357	418,862	13-08-074-02 W6M	641	✓	✓	✓	
30	Fitzsimmons*	118°18'47.5"	55°17'13.6"	6,125,270	416,600	01-01-073-03 W6M	632	✓	✓	✓	
32	Gold Creek	118°41'45.6"	54°50'29.24"	6,078,467	391,088	07-33-067-05 W6M	689	✓	✓	✓	
33	Wapiti*	118°18'56.0"	55°10'14.6"	6,114,580	416,206	02-25-071-03 W6M	621	✓	✓	✓	
34	Puskwaskau*	117°43'46.3"	55°27'40.7"	6,146,370	453,870	15-35-074-25 W5M	653	✓	✓	✓	
35	Jean Cote	117°11'06.2"	55°53'37.8"	6,194,281	488,426	12-35-079-21 W5M	607	✓	✓	✓	
36	Guy	117°21'10.8"	55°32'55.4"	6,155,912	477,730	03-04-076-22 W5M	562	✓	✓	✓	✓
37	Crooked Creek	117°50'52.1"	55°07'37.0"	6,109,246	445,939	19-01-071-26 W5M	675	✓	✓	✓	
38	Karr Creek*	118°14'23.7"	54°37'33.4"	6,053,873	419,950	10-16-065-02 W6M	811	✓	✓	✓	
39	Clouston Creek	117°15'27.3"	55°17'48.3"	6,127,845	483,645	12-01-073-22 W5M	647	✓	✓	✓	
40	McLennan	116°55'08.5"	55°41'39.3"	6,172,054	505,089	03-29-077-19 W5M	622	✓	✓	✓	
41	Valleyview*	117°19'54.8"	55°00'11.7"	6,095,204	478,771	09-30-069-22 W5M	753	✓	✓	✓	
42	Sunset House*	116°52'25.8"	55°06'05.8"	6,106,104	508,051	05-32-070-19 W5M	776	✓	✓	✓	
43	High Prairie	116°27'47.4"	55°25'05.9"	6,141,469	533,933	16-13-074-17 W5M	595	✓	✓	✓	
44	Peavine	116°18'52.6"	55°48'42.7"	6,185,353	542,954	03-05-079-15 W5M	650	✓	✓	✓	
45	Gift Lake*	115°51'42.9"	55°50'04.0"	6,188,239	571,282	10-07-079-12 W5M	679	✓	✓	✓	✓
46	Little Smoky	117°02'45.2"	54°35'48.4"	6,049,923	497,036	12-01-065-21 W5M	772	✓	✓	✓	

Table 4.3 Passive Stations Within PAZA

Number	Station Name	Longitude	Latitude	Northing	Easting	Site Legal Location	Elevation of Passive Head (m)	Monitored Pollutants			
								SO_2	NO_2	O_3	H_2S
47	Kinuso	115°27'46.1"	55°18'44.1"	6,130,615	597,562	12-10-073-10 W5M	592	✓	✓	✓	
48	Deer Mountain*	115°17'07.9"	54°54'28.5"	6,085,891	609,918	15-22-068-09 W5M	842	✓	✓	✓	
49	Grande Prairie HP	118°48'27.67"	55°10'35.90"	6,115,939	384,880	07-26-071-06 W6M	654	✓	✓	✓	
50	East Prairie	116°12'23.39"	55°12'23.39"	6,118,741	550,490	13-02-072-15 W5M	631	✓	✓	✓	
G3	Girouxville 3	117°27'58.5"	55°38'13.380"	6,165,784	470,648	04-02-077-23 W5M	562				✓
G4	Girouxville 4	117°23'19.1"	55°39'1.860"	6,167,253	475,544	13-05-077-22 W5M	565				✓

* Monitoring at these sites discontinued January 2017

✓ parameter measured at Station

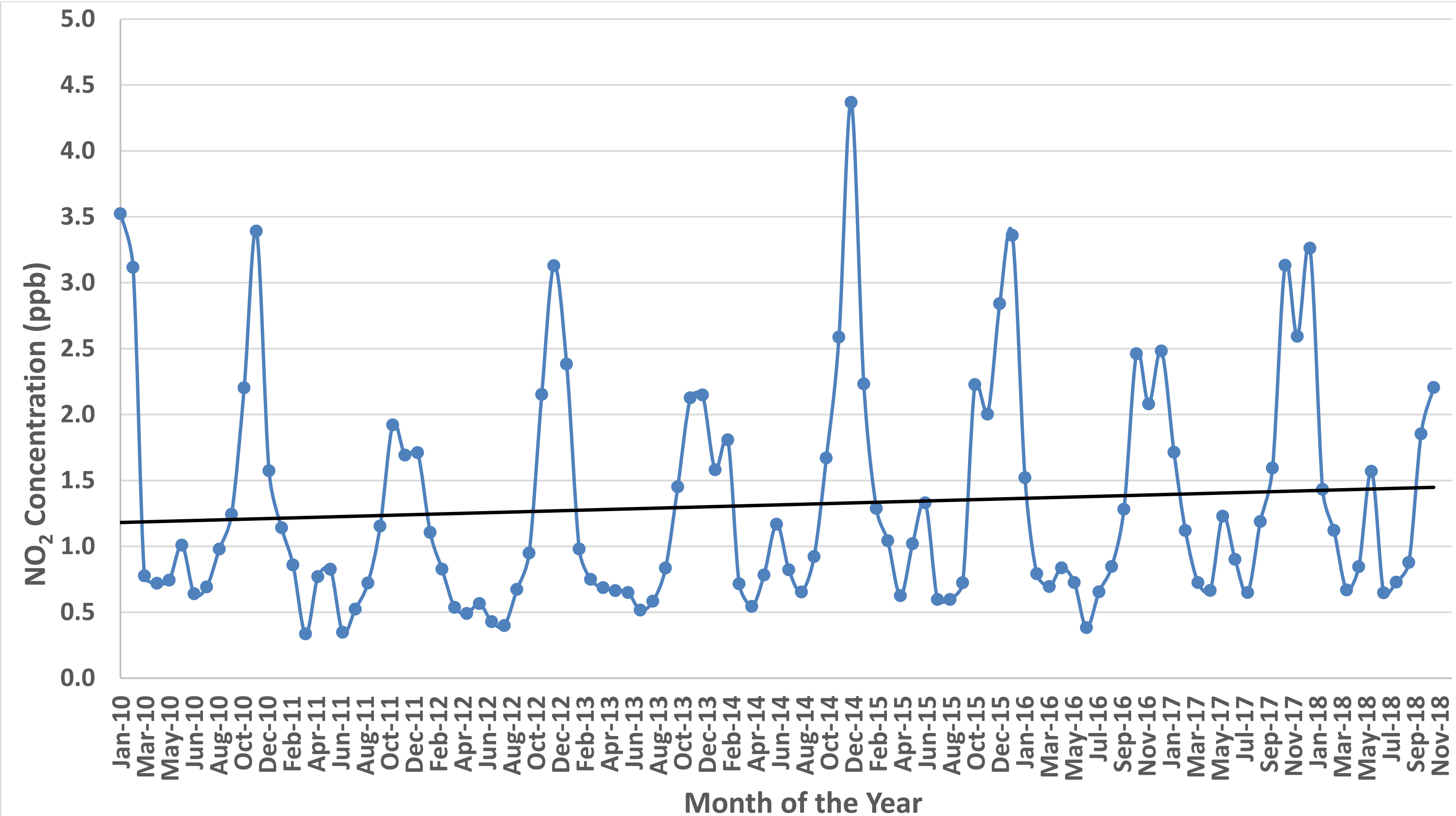

Figure 4.6 Average Monthly NO_2 Concentrations in PAZA, January 2010 - November 2018

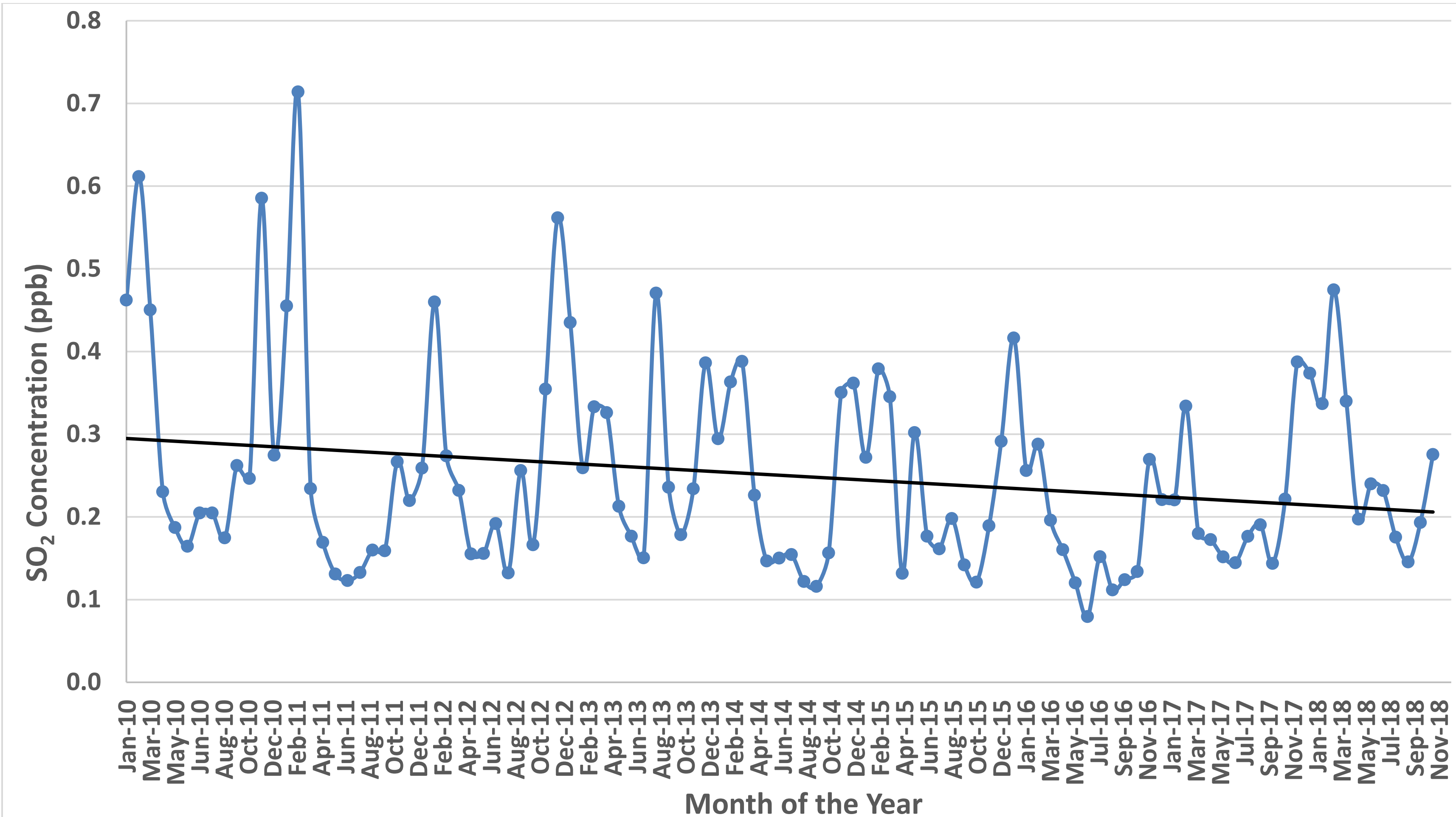

Figure 4.7 Average Monthly SO_2 Concentrations in PAZA, January 2010 – November 2018

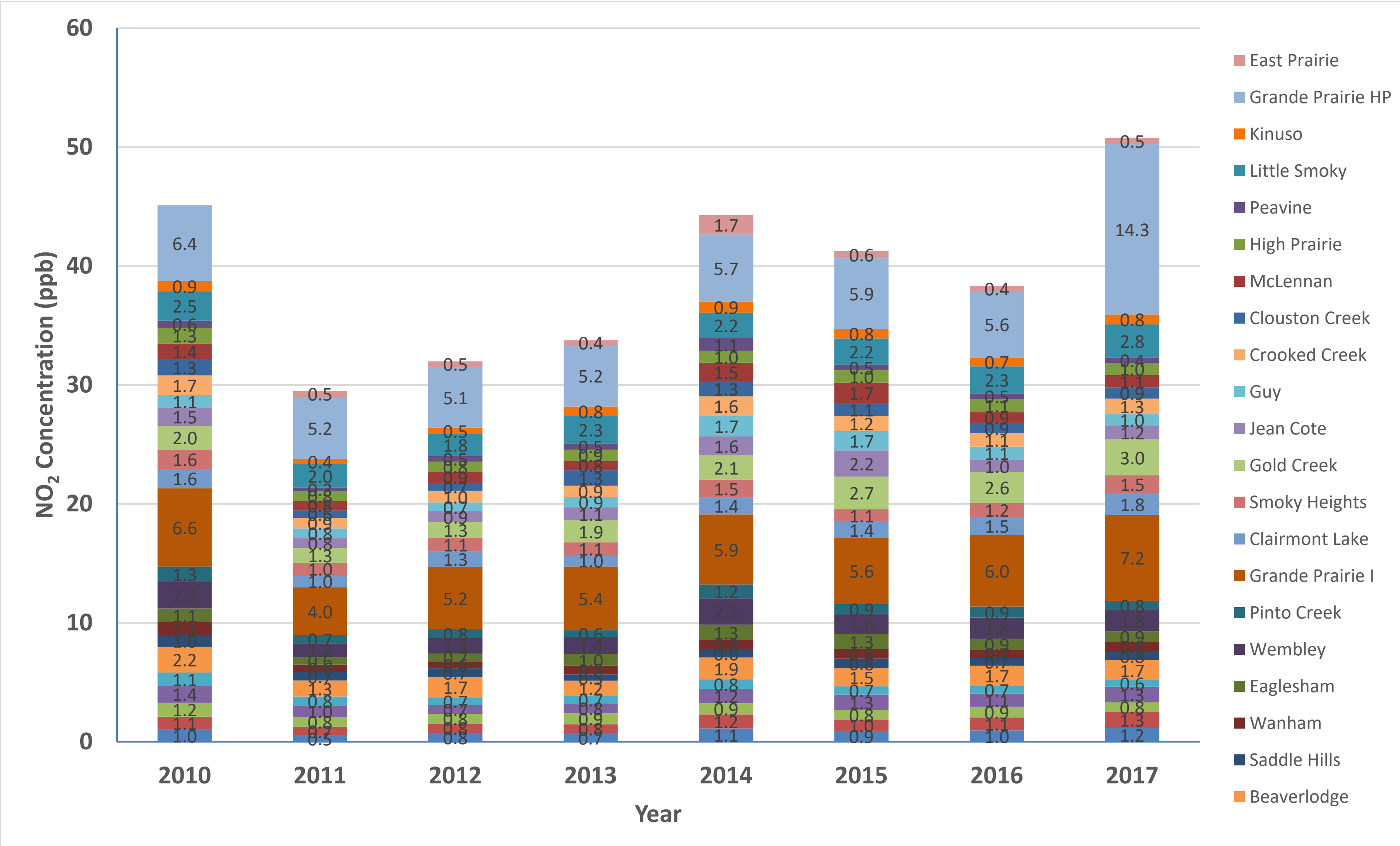

Figure 4.8 **Annual NO_2 Measurements at 26 PAZA Passive Stations, 2010 - 2017**

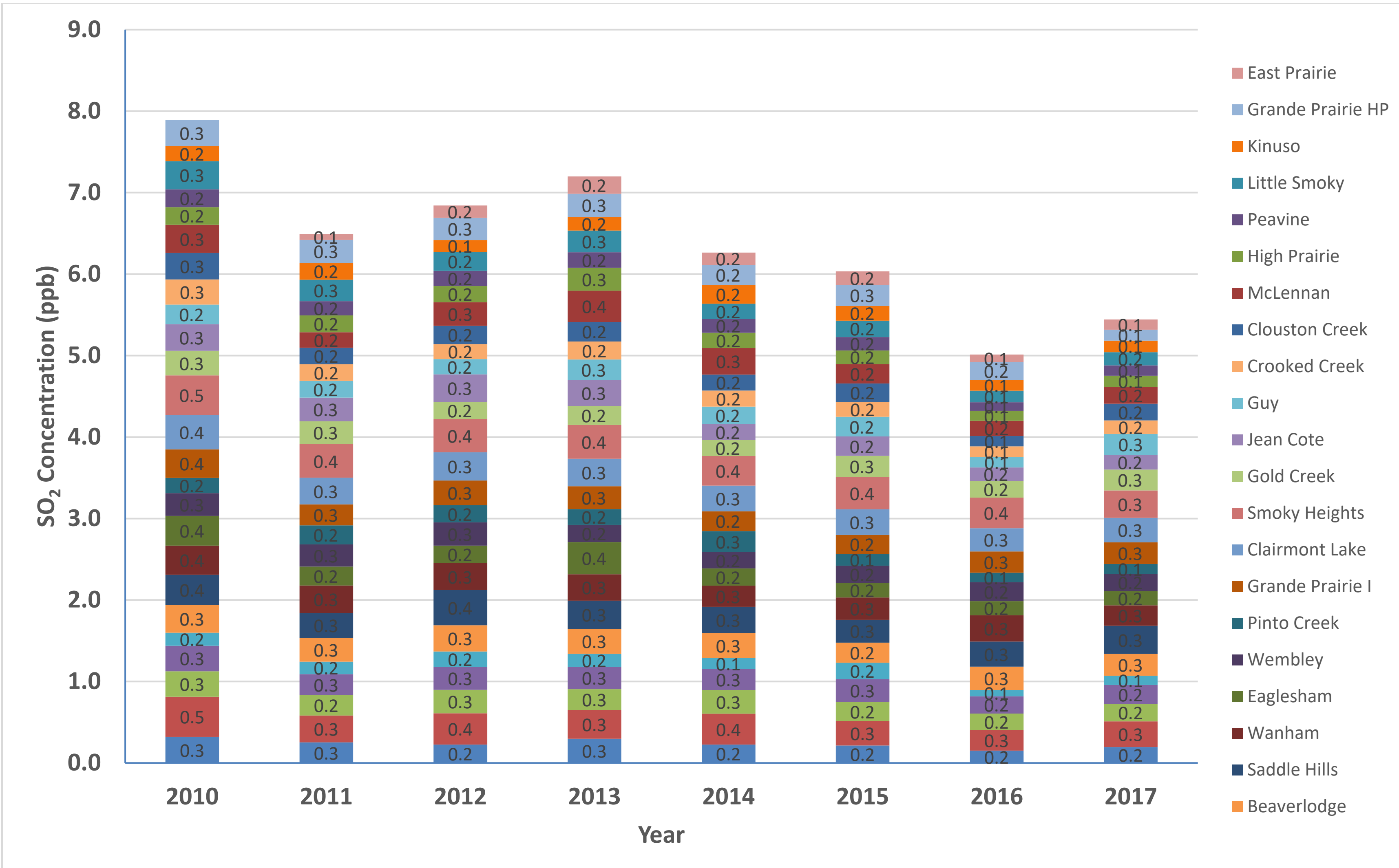

Figure 4.9 Annual SO_2 Measurements at 26 PAZA Passive Stations, 2010 - 2017

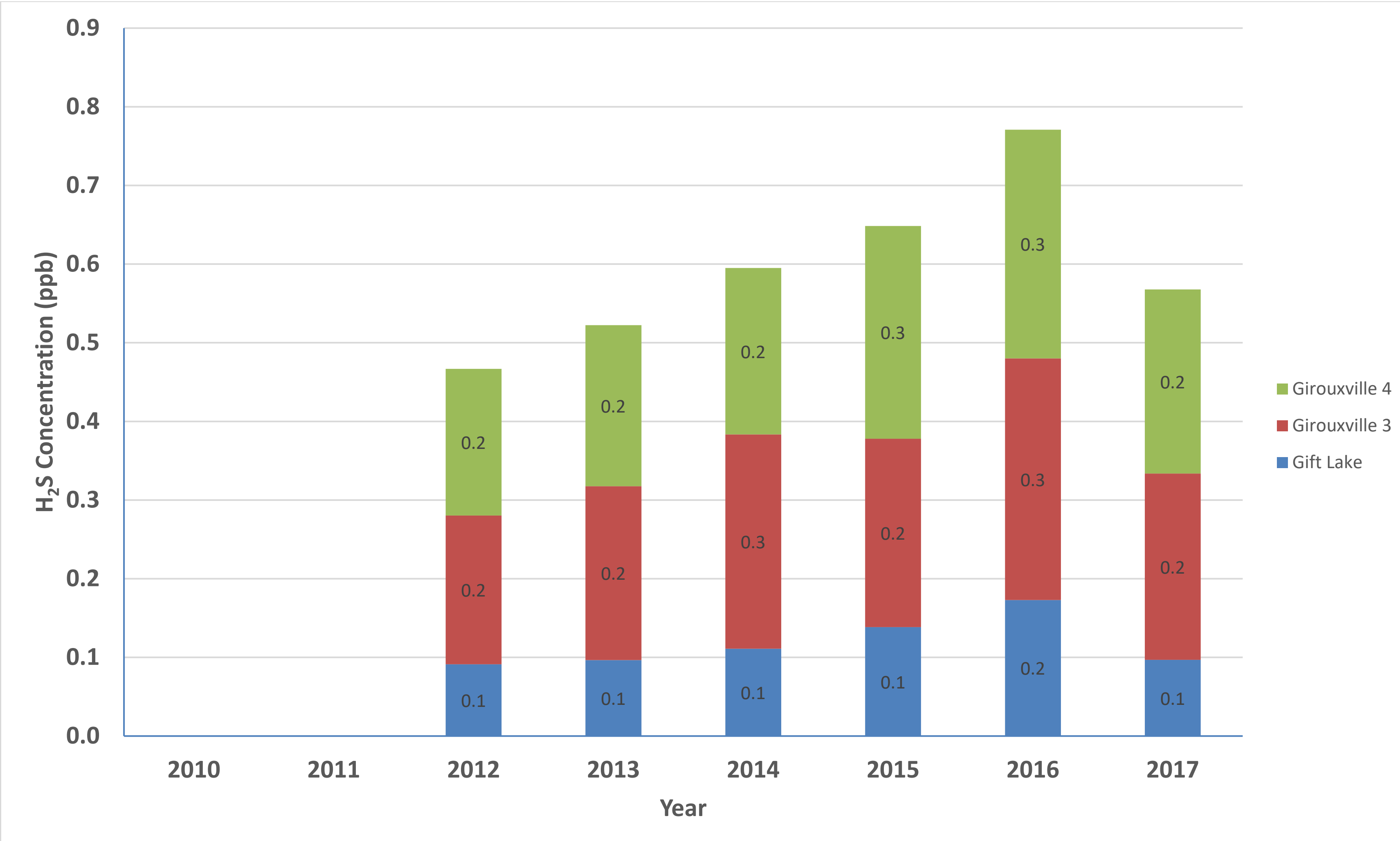

Figure 4.10 Annual H_2S Measurements at 26 PAZA Passive Stations, 2010 - 2017

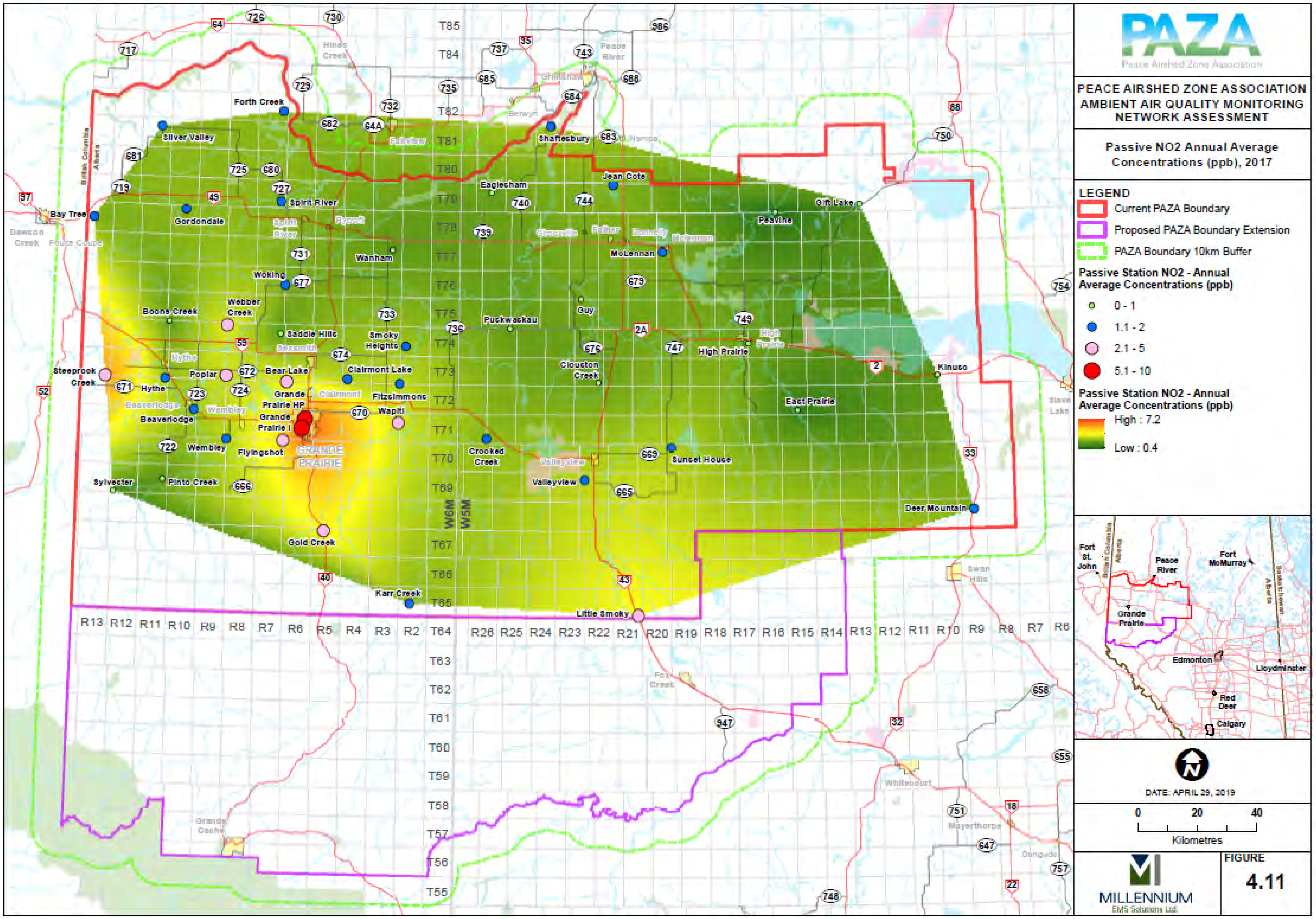

Figure 4.11 Passive NO₂ Annual Average Concentrations (ppb), 2017

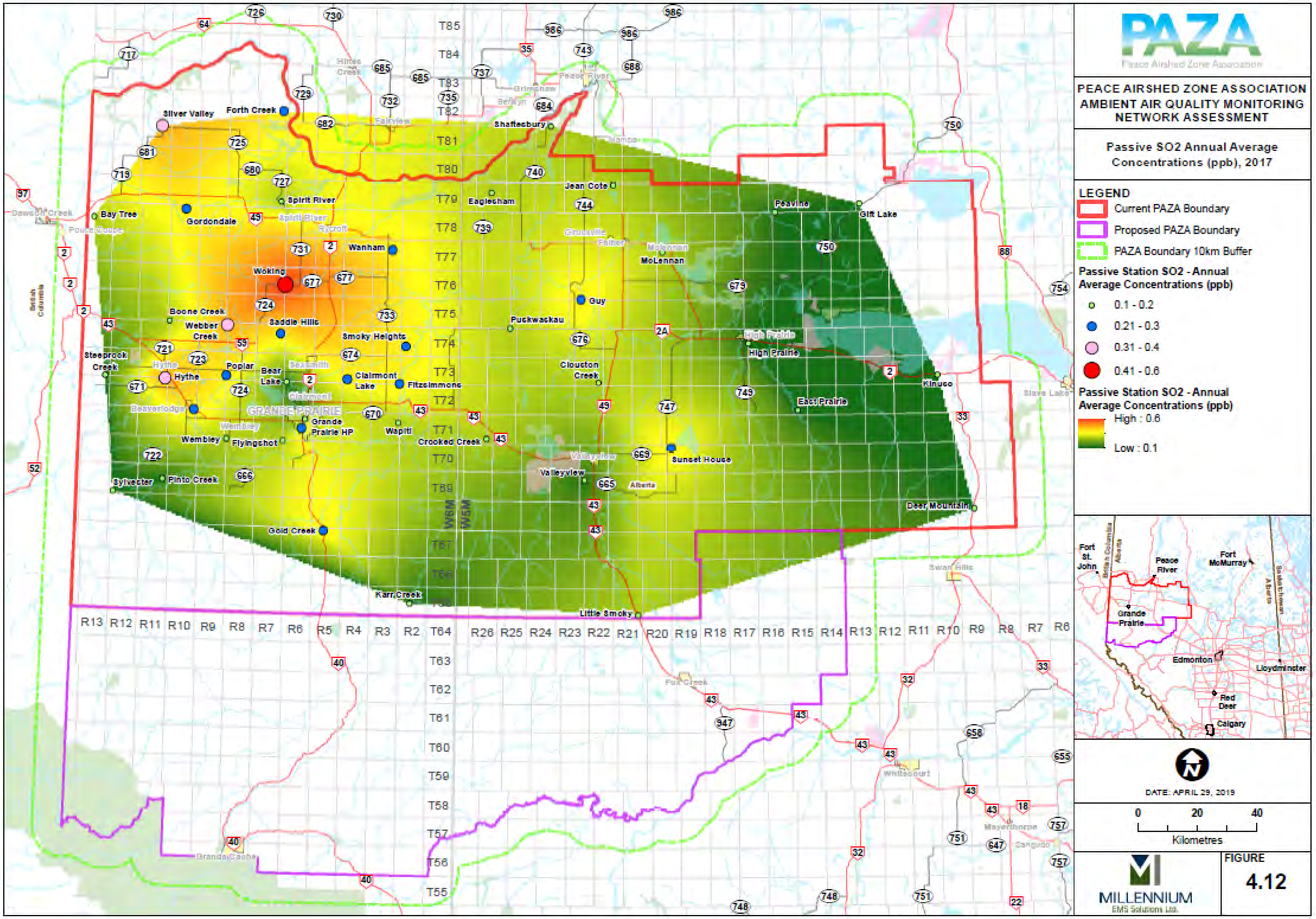

Figure 4.12 Passive SO_2 Annual Average Concentrations (ppb), 2017

4.3 Spatial Distribution of NPRI Emissions

Table 4.4 summarizes 2017 NPRI annual emissions from reporting industrial facilities within PAZA and the proposed Expansion Area. Based on the 2017 NPRI dataset, Figures 4.13 to 4.16 picture the location and annual emissions rate of industry sources in existing and expansion areas for NO_2, SO_2, $PM_{2.5}$ and H_2S, respectively. Dots are scaled for size and colour coded by annual emission rates.

The table indicates that NPRI-reportable emissions are approximately as high in the expansion area as in the current PAZA airshed, supporting an expansion southward.

The figures indicate a broad swath of industrial (oil and gas) activity from the Fox Creek region northwestward into B.C.

Table 4.4 Summary of 2017 NPRI Reported Annual Emissions within PAZA and Expansion Area (tonnes/year)

	SO_2	NO_2	$PM_{2.5}$	H_2S	Total VOC
within Current PAZA Area					
Count of Reported Facilities	26	210	151	8.0	37
Maximum Annual Emission	2,489	1,852	34	3.1	572
Total Annual Emission	7,037	22,040	341	9.1	1898
within PAZA Expansion Area					
Count of Reported Facilities	16	196	144	4.0	54
Maximum Annual Emission	2,697	1,035	16	1.7	123
Total Annual Emission	5,280	25,591	264	5.3	1376

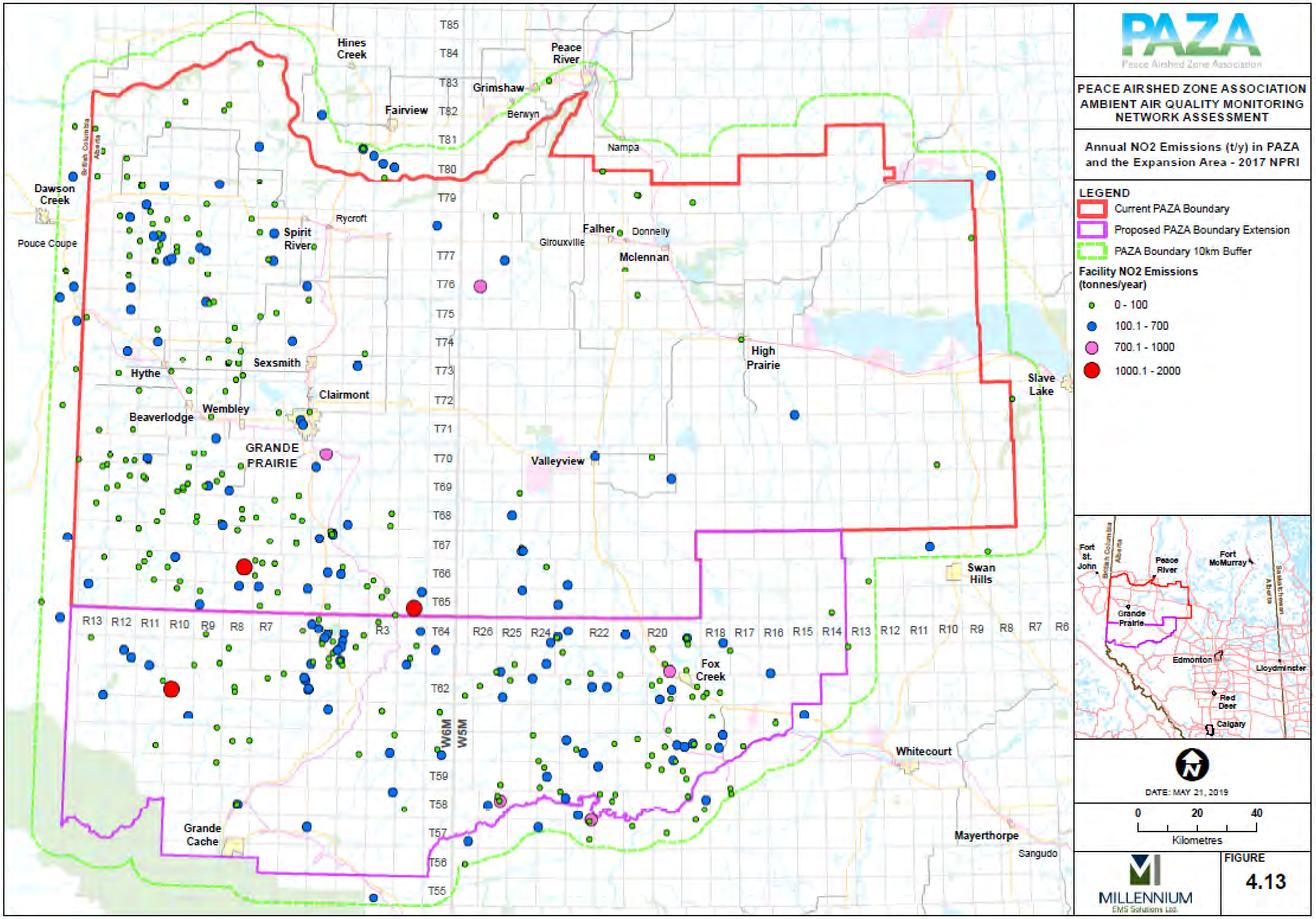

Figure 4.13 Annual NO_2 Emissions (t/y) in PAZA and the Expansion Area - 2017 NPRI

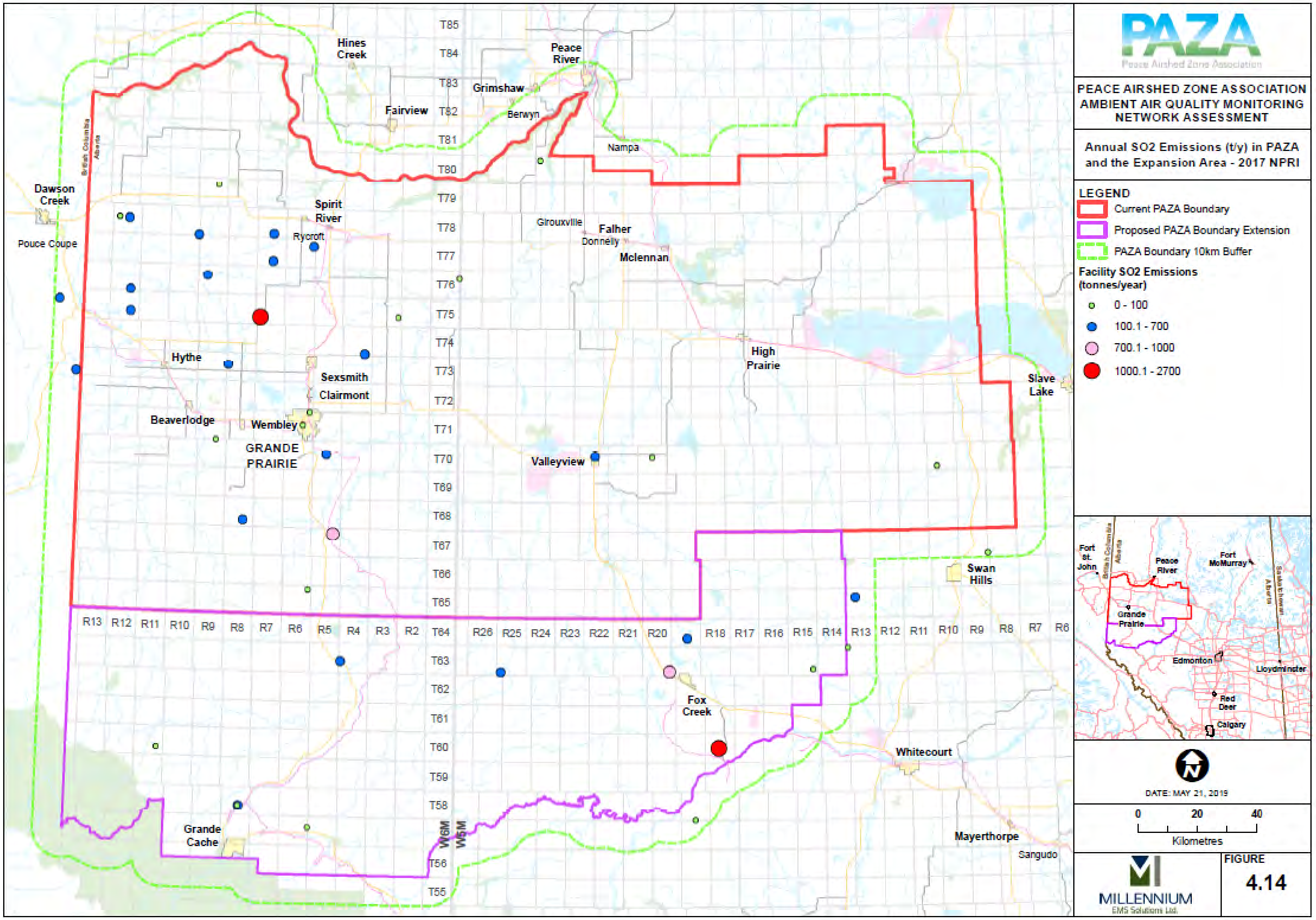

Figure 4.14 Annual SO_2 Emissions (t/y) in PAZA and the Expansion Area - 2017 NPRI

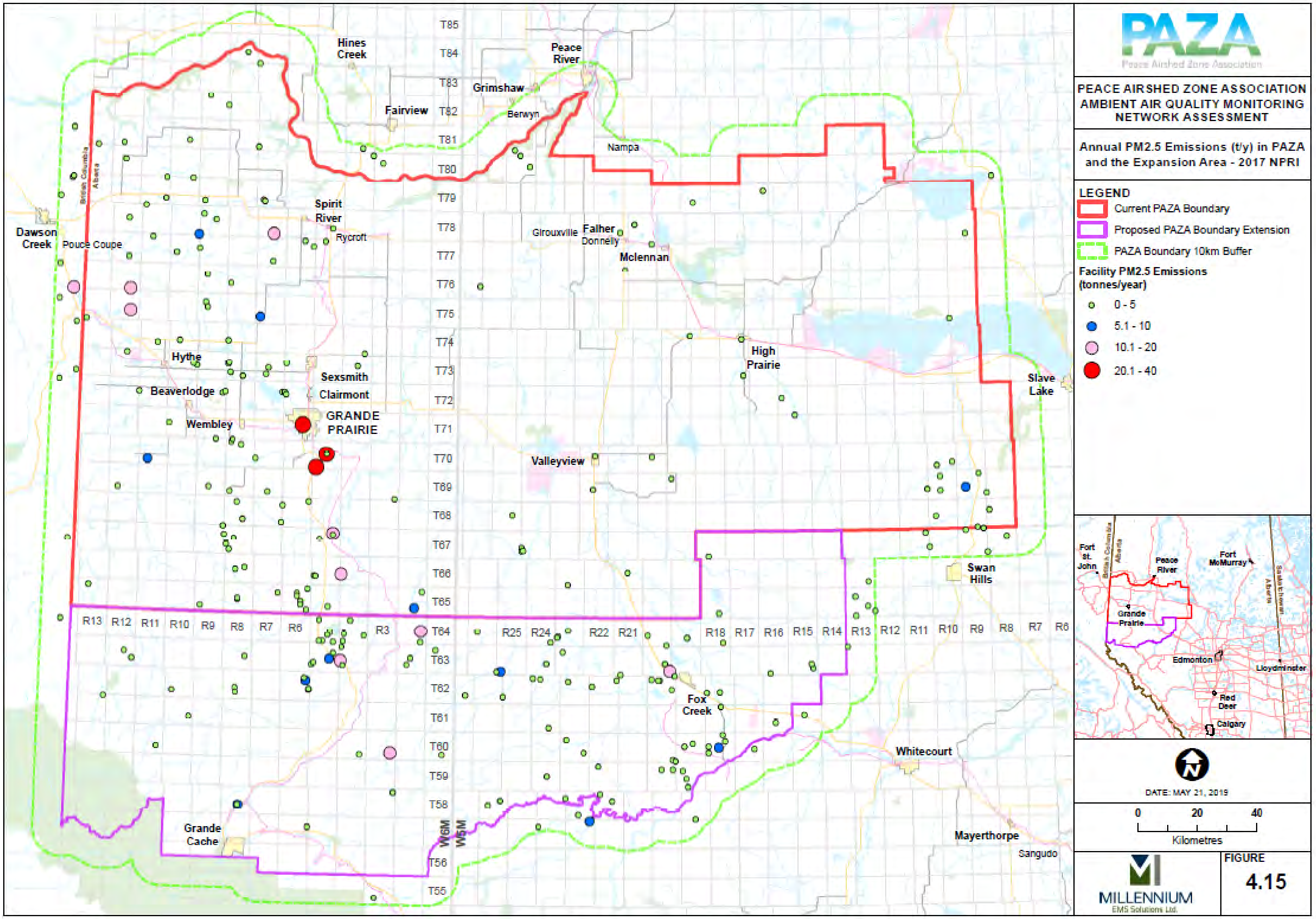

Figure 4.15 Annual $PM_{2.5}$ Emissions (t/y) in PAZA and the Expansion Area - 2017 NPRI

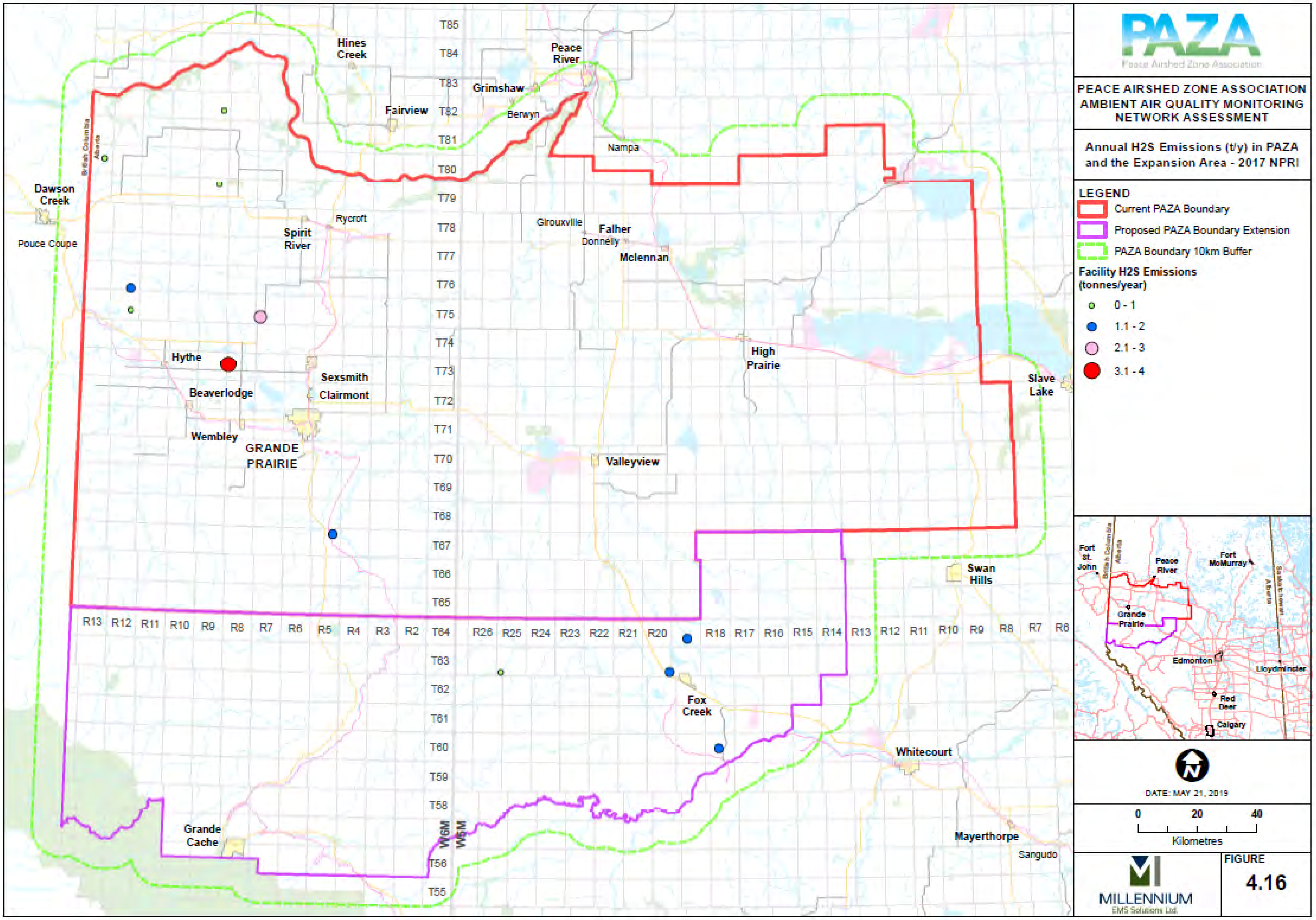

Figure 4.16 Annual H_2S Emissions (t/y) in PAZA and the Expansion Area - 2017 NPRI

4.4 Spatial Distribution of CMAQ Emissions

The CMAQ dataset is an emission dataset developed specifically for provincial-scale photochemical modeling in Alberta. This dataset is based on specific point and area sources and does not provide total facility emissions directly. The database is thorough in that smaller sources are included for facilities that may not be included in NPRI. Data are from the period 2012-2013.

Table 4.5 summarizes annual emissions in PAZA and the Expansion Area based on stack emissions information provided by PAZA as input to the provincial-scale CMAQ modelling provided by PAZA. Emissions in the CMAQ database are larger than in the 2017 NPRI dataset because:

- NPRI has a lower emission threshold below which reporting is not required; and
- Oil and gas activity may have been higher in 2012/2013 than in 2017.

Table 4.5 CMAQ Annual Emissions within PAZA and Expansion Areas (tonnes/year)

	SO_2	NO_2	$PM_{2.5}$	NH_3	Total VOC
Current PAZA Area					
Count of Modelled Stacks	4,288	5,195	3,437	2,925	19,367
Maximum Annual Emission from Stack	1,508	877	467	39	712
Total Annual Emission in the Area	8,662	25,704	980	76	22,452
PAZA Expansion Area					
Count of Modelled Stacks	3,062	3,815	2,746	2,535	11,926
Maximum Annual Emission from Stack	1,539	1,955	153	1.0	1,066
Total Annual Emission in the Area	6,739	26,778	473	5.8	12,157

Figures 4.17 to 4.19 present the locations and annual emissions rate of all the stack sources in existing and expansion areas for NO_2, SO_2 and $PM_{2.5}$, respectively. Dots were scaled for size and colour coded by annual emission rates. Emissions follow the same spatial trends as the NPRI dataset.

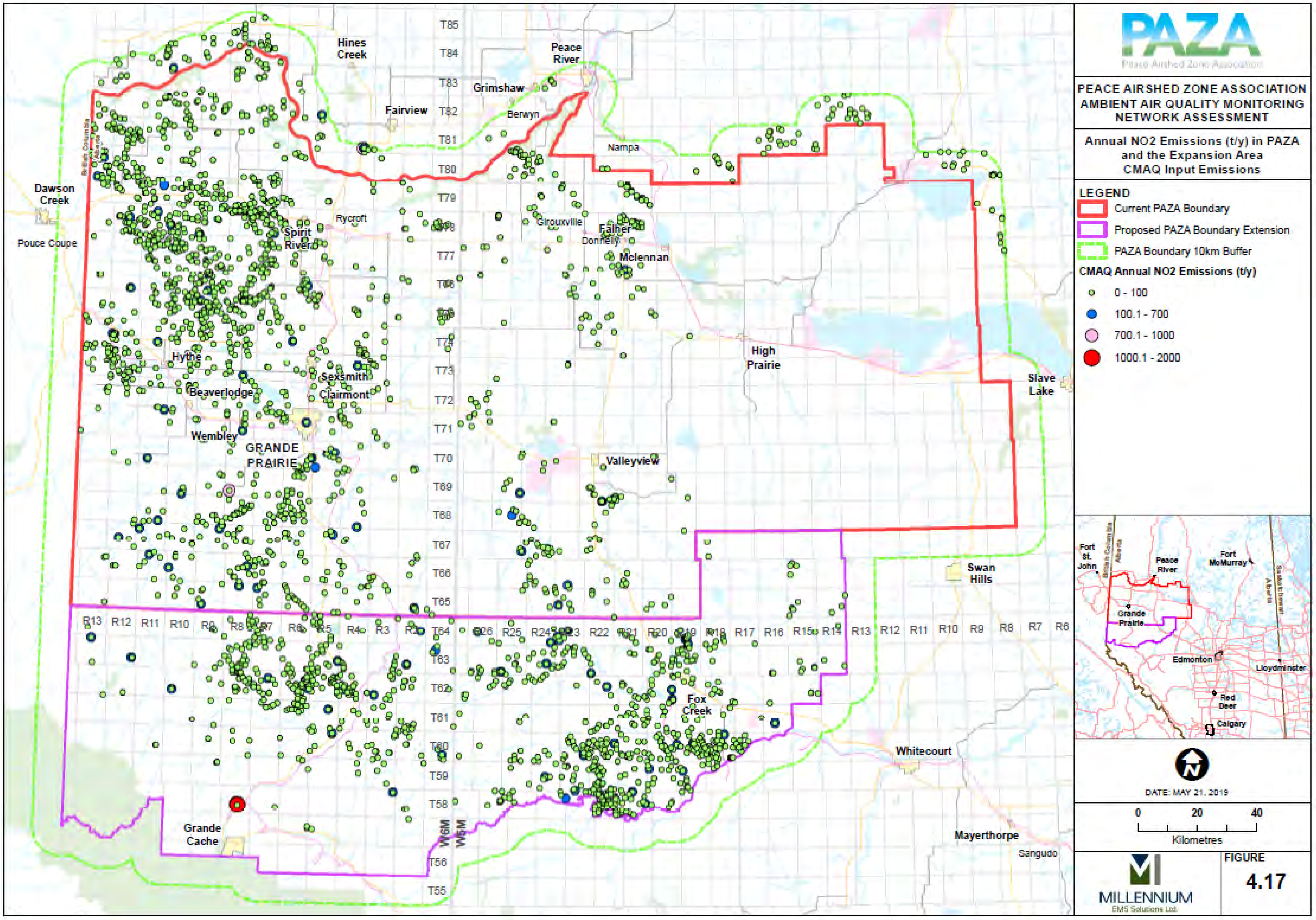

Figure 4.17 Annual NO_2 Emissions (t/y) in PAZA and the Expansion Area – CMAQ Input Emissions

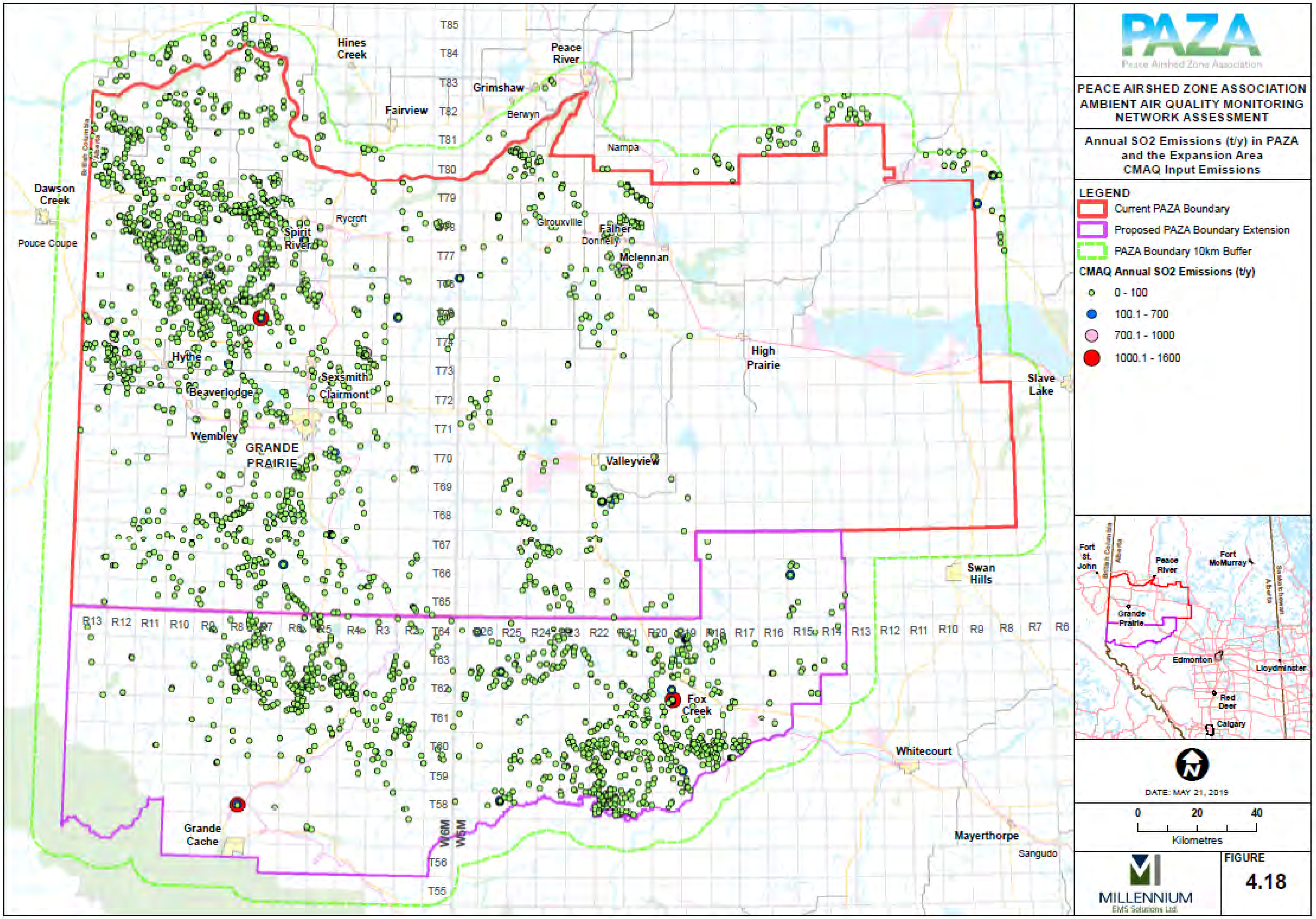

Figure 4.18 Annual SO_2 Emissions (t/y) in PAZA and the Expansion Area – CMAQ Input Emissions

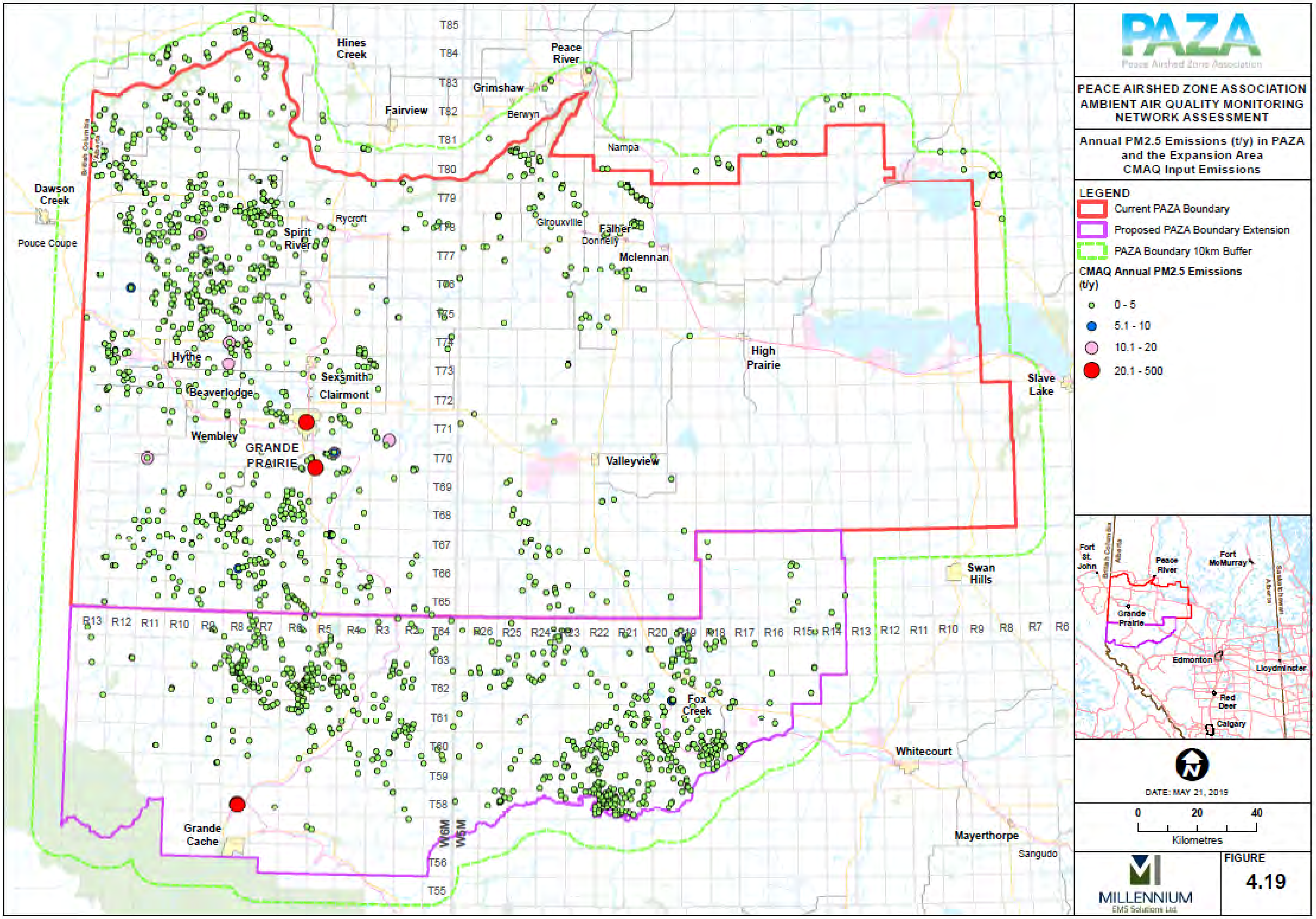

Figure 4.19 Annual PM2.5 Emissions (t/y) in PAZA and the Expansion Area – CMAQ Input Emissions

5.0 ASSESSMENT AND EVALUATION

The ability of the current networks – passive and continuous - to provide information on the key issues was assessed. The ability of the existing network to address the ten objectives of the airshed was assessed.

Based on the key issues and the airshed objectives, the results of the siting suitability model scenarios are evaluated. Each of the key issues was assessed using a specific scenario or by applying alternative approaches (our network experience, our understanding of the monitoring needs to calculate the AQHI, our understanding of the approximate capital and op costs of passive and continuous stations, *etc.*).

5.1 Quantitative Assessment of Passive Monitoring Locations

5.1.1 Correlation Analysis

A Pearson correlation coefficient analysis was conducted for all initial 44 passive monitoring stations with NO_2 and SO_2 passive measurements from 2010 to 2017. For NO_2 and SO_2 passive measurements at each station, correlation coefficients (R) to all other stations within a 50 km radius were calculated and averaged. The radius was chosen so that there was at least one station to correlate (Table 5.1 lists the stations for the SO_2 approach, as an example).

The results of the correlation analysis for the two radii of influence are shown in Table 5.2. The predictions are similar, in most cases with slightly higher correlations when the radius is reduced.

Table 5.1 Radius of influence basis for correlation analysis

SO_2 Site	Other sites within 50 km	Other sites within 30 km	SO_2 Site	Other sites within 50 km	Other sites within 30 km
Silver Valley	4	1	Woking	12	3
Bay Tree	3	0	Webber Creek	15	6
Fourth Creek	3	0	Hythe	13	6
Gordondale	7	1	Sylvester	5	1
Boone Creek	11	4	Beaverlodge	13	4
Steeprock Creek	8	2	Poplar	14	8
Saddle Hills	17	6	Smoky Heights	11	3
Wanham	8	0	Fitzsimmons	11	3
Shaftesbury	2	1	Gold Creek	6	0
Eaglesham	5	0	Wapiti	11	3
Bear Lake	15	8	Puskwaskau	8	1

Table 5.1 Radius of influence basis for correlation analysis					
SO_2 Site	**Other sites within 50 km**	**Other sites within 30 km**	**SO_2 Site**	**Other sites within 50 km**	**Other sites within 30 km**
Wembley	15	8	Jean Cote	4	2
Pinto Creek	7	3	Guy	5	2
Flyingshot	14	6	Crooked Creek	6	0
Grande Prairie 1	15	5	Karr Creek	1	0
Clairmont Lake	13	8	Clouston Creek	6	1
McLennan	5	1	Little Smoky	1	0
Valleyview	4	0	Kinuso	2	0
Sunset House	4	0	Deer Mountain	1	0
High Prairie	4	1	Grande Prairie 2	15	6
Peavine	3	1	East Prairie	3	1
Gift Lake	1	1			

Table 5.2 Results of Correlation analysis within 50 and 30 km					
Site	**Average Correlation with sites within 50km-NO2SO_2**	**Average Correlation with sites within 30km-NO2SO_2**	**Site**	**Average Correlation with sites within 50km-NO2SO_2**	**Average Correlation with sites within 30km-NO2SO_2**
Silver Valley	0.77	0.76	Clairmont Lake	0.80	0.82
Bay Tree	0.71		Smoky Heights	0.75	0.78
Fourth Creek	0.74		Fitzsimmons	0.63	0.67
Gordondale	0.70	0.76	Gold Creek	0.67	
Boone Creek	0.75	0.74	Wapiti	0.78	0.77
Steeprock Creek	0.68	0.69	Puskwaskau	0.52	0.45
Spirit River	0.72	0.76	Jean Cote	0.57	0.58
Woking	0.68	0.67	Guy	0.58	0.49
Webber Creek	0.70	0.71	Crooked Creek	0.73	
Hythe	0.78	0.77	Karr Creek	0.58	
Sylvester	0.70	0.73	Clouston Creek	0.63	0.52
Beaverlodge	0.80	0.83	McLennan	0.59	0.70

Table 5.2 Results of Correlation analysis within 50 and 30 km

Site	Average Correlation with sites within 50km-NO2SO2	Average Correlation with sites within 30km-NO2SO2	Site	Average Correlation with sites within 50km-NO2SO2	Average Correlation with sites within 30km-NO2SO2
Poplar	0.78	0.81	Valleyview	0.71	
Saddle Hills	0.71	0.72	Sunset House	0.65	
Wanham	0.66		High Prairie	0.50	0.35
Shaftesbury	0.47	0.47	Peavine	0.43	0.44
Eaglesham	0.42		Gift Lake	0.44	0.44
Bear Lake	0.77	0.79	Little Smoky	0.60	
Wembley	0.75	0.80	Kinuso	0.52	
Pinto Creek	0.71	0.73	Deer Mountain	0.61	
Flyingshot	0.80	0.85	Grande Prairie 2	0.78	0.82
Grande Prairie 1	0.80	0.86	East Prairie	0.42	0.35
Min	**0.42**	**0.35**			
Max	**0.80**	**0.86**			

The spatial distribution of passive station correlation for NO_2 and SO_2 is illustrated in Figures 5-1 and 5-2. Dots were colour coded by average R values. Passive stations with R values near 1 are considered highly correlated with nearby stations within a 50 km radius and could be considered as candidates for removal. As R values get lower, correlations decrease and the ability to predict concentrations from nearby measurements decreases.

The figures indicate generally high correlation among measurements near Grande Prairie and the surrounding area west of the city. Passive NO_2 measurements had higher correlation than SO_2 measurements likely there are more NO_2 sources. Among the 44 stations, monitoring at 18 sites was discontinued in January 2017 after the passive monitoring network was restructured. Those discontinued sites are shown in the figures. Some discontinued sites, such as Puskwaskau, Shaftesbury, Gift Lake, and Deer Mountain, *etc.*, had low R values for both NO_2 and SO_2 measurements.

The evaluation using correlations indicates:

- Especially for NO_2, the correlations are generally lower in the eastern part of the current PAZA area, suggesting no additional gain in network efficiency is achieved by removing more stations in this region. No further reduction in the number of stations are recommended because of the low correlations. However, because there are few emission sources in the eastern part of the network, no additional sites are recommended.
- The elimination of a small number of low-correlation northern and eastern sites from the network in 2017 appears generally due to lower emissions and proximity to the PAZA border. Lower correlations suggest the sites were not necessarily redundant. No changes to the network (Section 6.1) have been recommended for this reason.
- Largely for NO_2, gaps exist in the northwestern and southwestern parts of the network. Additional sites are recommended in these locations (Section 6.1), recognizing that additional sites in the northwest, where some sites already exist, may increase correlations – the new stations will not necessarily add significant new information but will add data in those regions.
- For SO_2, the network adjustments after January 2017 removed most of the highly and moderately correlated sites, suggesting the adjustments were effective in increasing measurement efficiency. No further changes would be recommended for the SO_2 network, although we see value in having SO_2 measured where NO_2 is measured, for the small additional cost.

The correlation among passive sites was contoured and used as one layer for suitability mapping. Recommendations on the number of stations in the updated passive network are provided in Section 6.1.

5.1.2 Suitability Index Approach

This section evaluates the passive network by means of the findings of the suitability analysis. Figure 5.3 compares the suitability rating applying the passive scenario layers described in Section 3.3.2 and the locations of the 26 current stations. The pattern of suitability at the airshed scale is broadly indicative of the exclusion zones around major emitters.

Figure 5.4 provides a zoomed-in look at the suitability pattern, where the areas of high suitability outside of exclusion zones around facilities are shown. The patterns of suitability are on a very fine scale and are highly dependent on the size of the exclusion zones around sources and roadways. Especially around sources, changes in exclusion zone sizes can change a passive location from unsuitable to highly suitable.

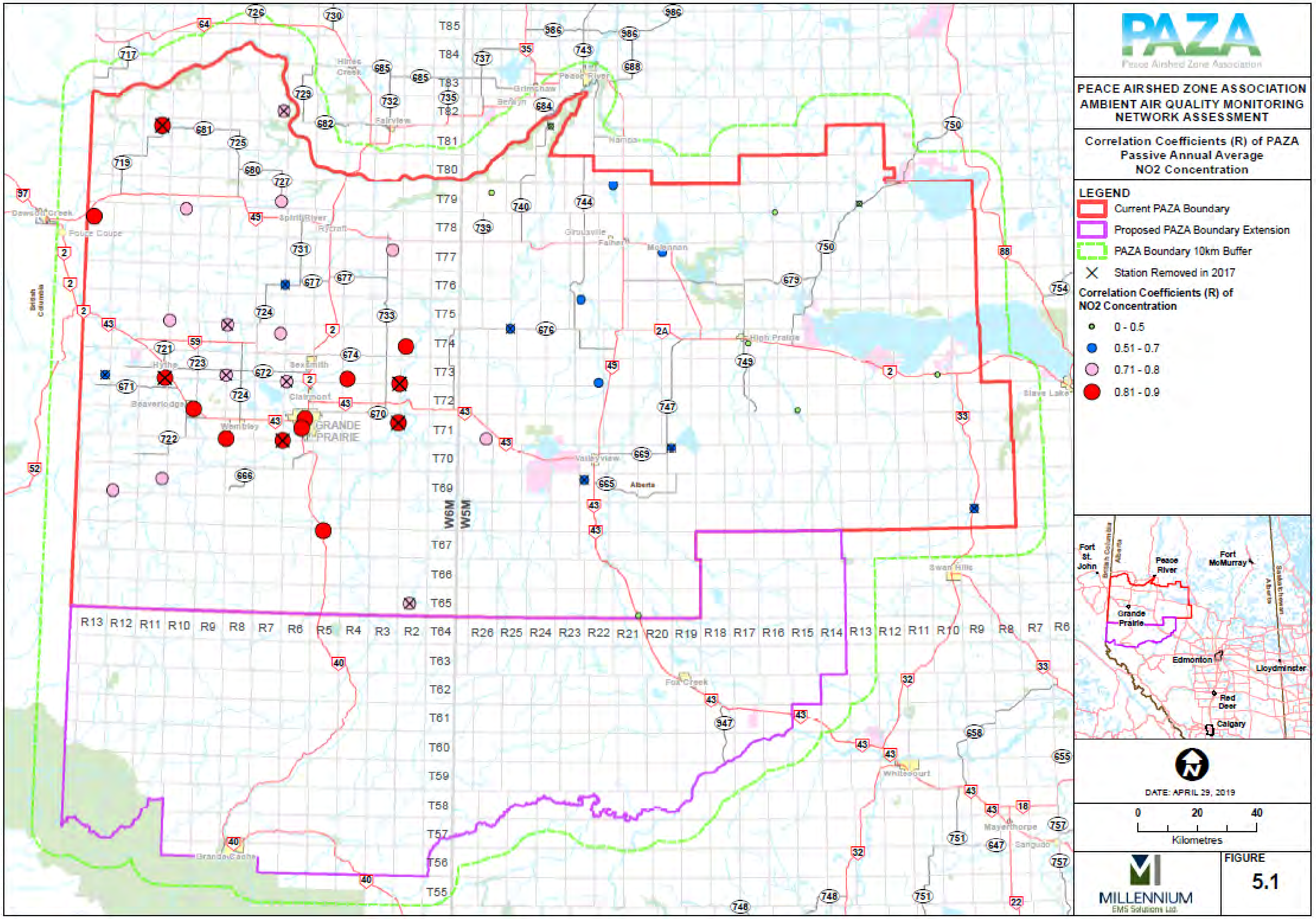

Figure 5.1 Correlation Coefficients (R) of PAZA Passive Annual Average NO_2 Concentration

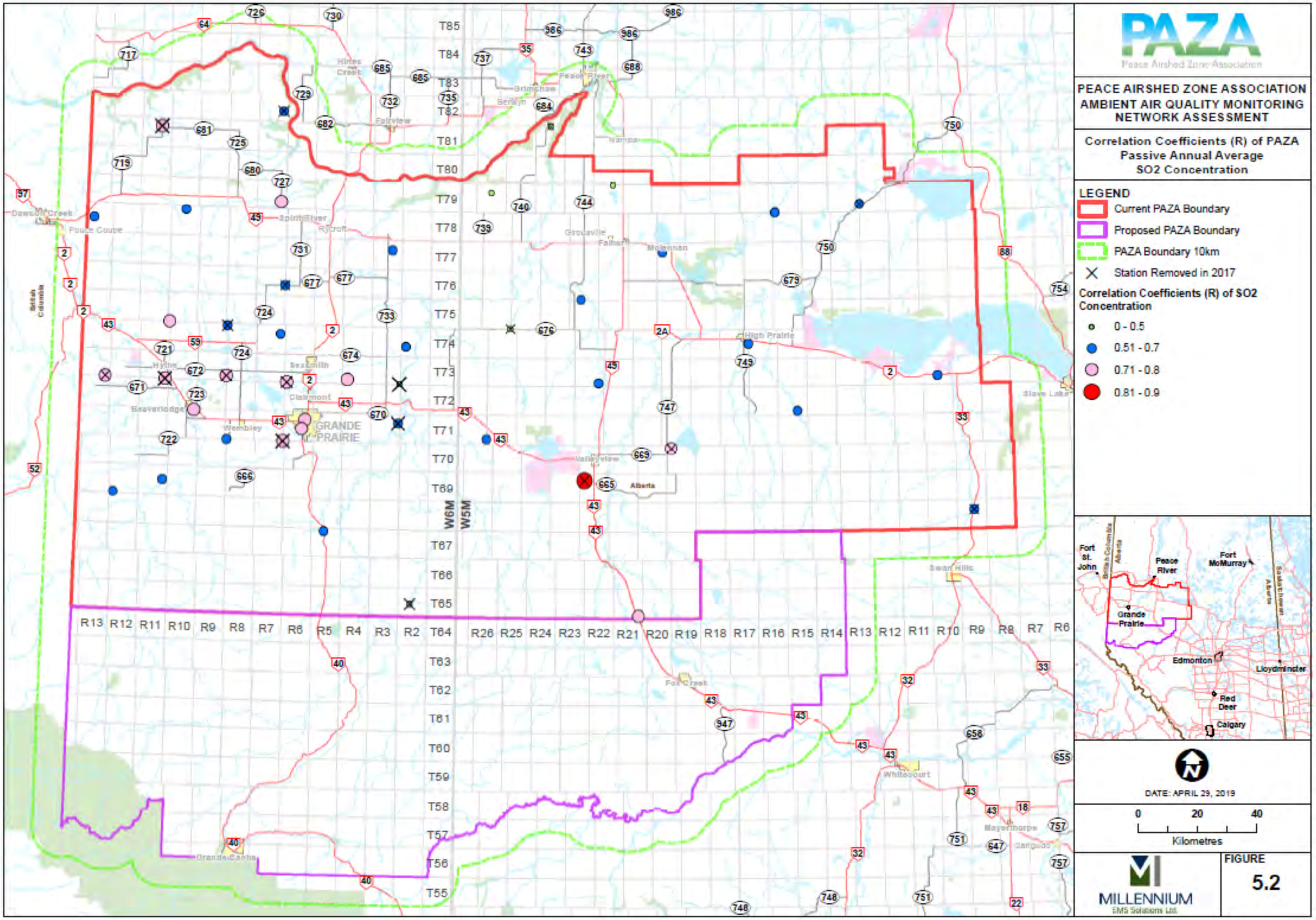

Figure 5.2 Correlation Coefficients (R) of PAZA Passive Annual Average SO_2 Concentrations

Table 5.3 lists the suitability on a scale of 0 (unsuitable) to 10 (highly suitable) from Figure 5.3 at each currently operated passive station. Table 5-3 lists the data underlying the correlation component of the suitability, but not the emission component which had the higher weighting.

Most sites in Table 5.3 have low suitability because they are either in an exclusion zone (suitability = 0) or too far from a secondary road (suitability = 0) or in the eastern part of the network (suitability = 1). The exclusion zone for passive monitoring was set to 500 m for even the smallest source and 750 m for major and secondary roads, to reduce the possibility of site-specific impact. Especially in densely sourced areas (Figure 5.4), or in regions with roads every mile, large areas are effectively sterilized for passive monitoring. A relaxation of these exclusion zones would be required to ensure siting can be practically managed, and especially the reduction in the road exclusion. In addition, knowledge of local roads not included in the provincial road network would allow improved assessment in areas currently considered inaccessible.

Suitability was low (1) mostly in the eastern part of the network (Figure 5.3), because the scenario was also used to identify the need for new monitoring. From this perspective suitability is low because there are few sources in this region, and suitability was enhanced in high-density source regions. In an absolute sense, this region is suitable given the passive scenario is also meant to ensure broad spatial coverage in the airshed; its just not suitable for more passive sites.

Of the remainder of sites, most were in the 7-10 range, meaning their location was moderately to highly suitable, and therefore within an acceptable range for monitoring. Several of the stations that were discontinued in 2017 on the basis of correlations had high suitability when evaluated under the current passive network suitability parameters.

The suitability map in Figure 5.3 was used as input to recommended passive monitoring (Section 6.1). the high-resolution suitability map example in Figure 5.4 suggests that knowledge of facility location in the locale of planning passive sites is needed when making final decisions on siting, as potential emission sources include more than just major gas plants.

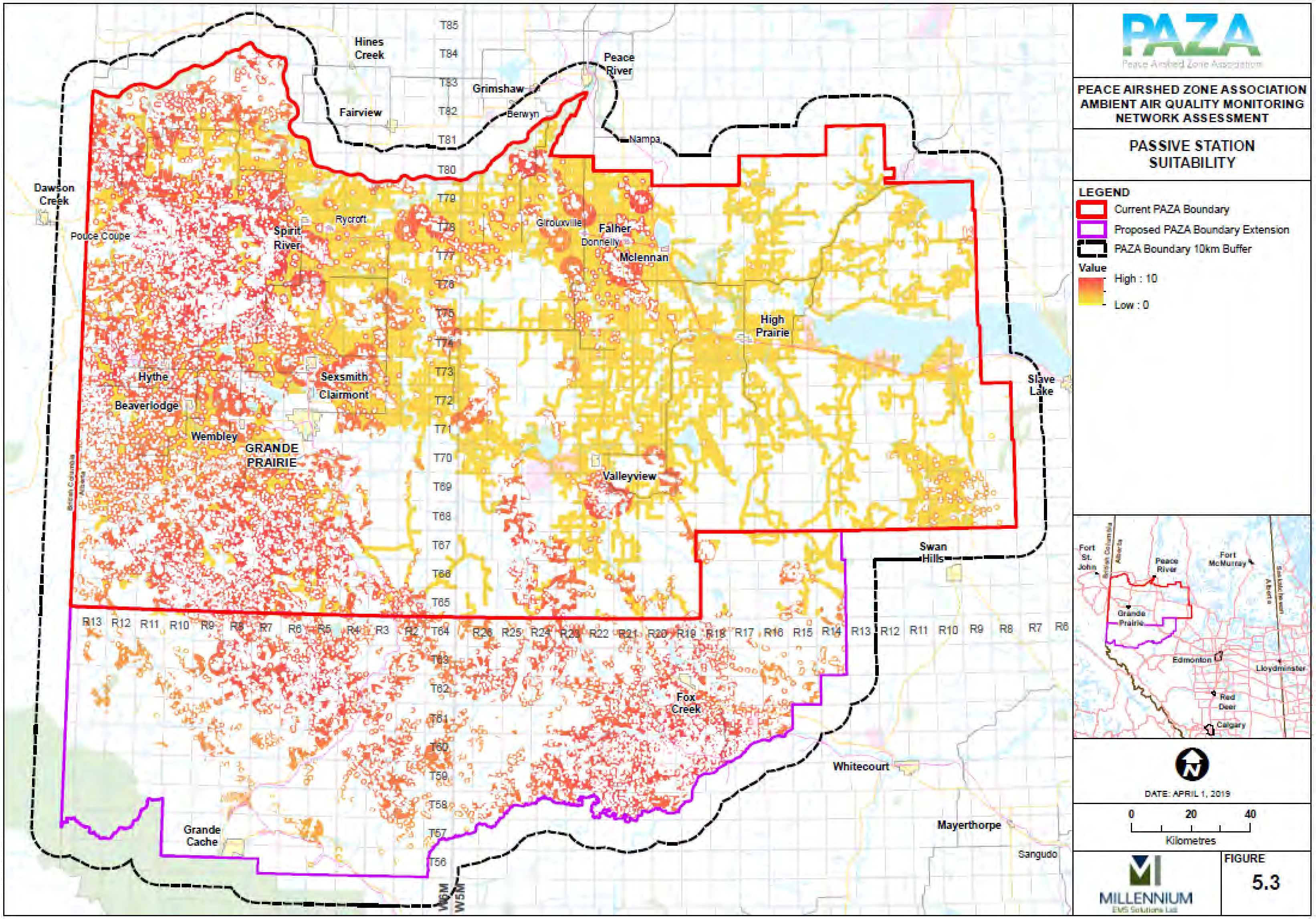

Figure 5.3 **Passive Layer Suitability**

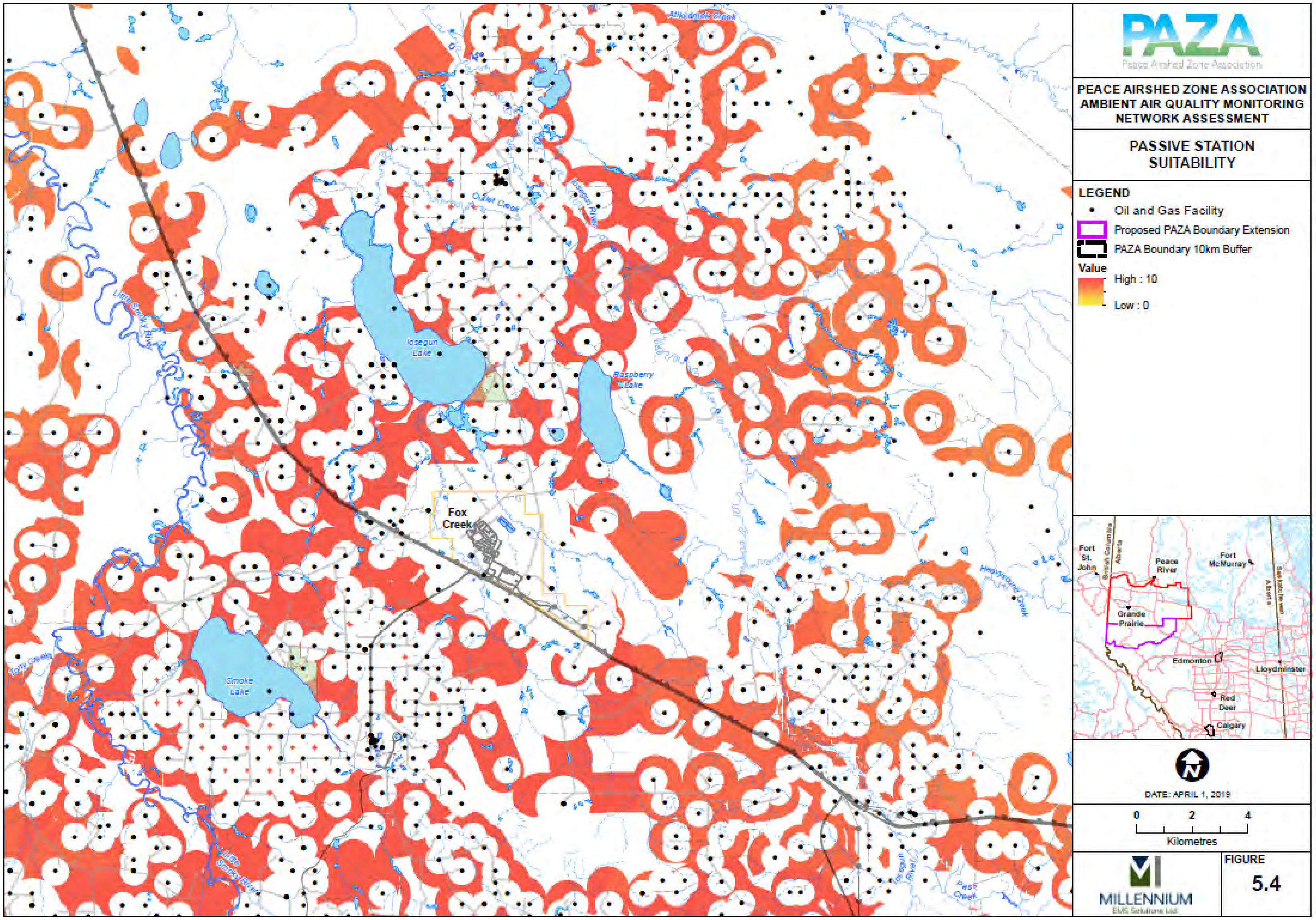

Figure 5.4 Passive Layer Suitability Detail

Table 5.3 Passive Network Suitability

Site Number	Name	Discontinued in Jan 2017?	SO_2 Correlation	NO_2 Correlation	Average Correlation	SUITABILITY
2	Bay Tree	N	0.6	0.82	0.71	1
23	Bear Lake	Y	0.77	0.76	0.765	7
16	Beaverlodge	N	0.77	0.84	0.805	0
5	Boone Creek	N	0.73	0.76	0.745	9
28	Clairmont Lake	N	0.76	0.84	0.8	7
39	Clouston Creek	N	0.69	0.58	0.635	1
37	Crooked Creek	N	0.69	0.78	0.735	1
48	Deer Mountain	Y	0.51	0.7	0.605	1
21	Eaglesham	N	0.38	0.46	0.42	1
50	East Prairie	N	0.66	0.18	0.42	1
30	Fitzsimmons	Y	0.45	0.82	0.635	1
26	Flyingshot	Y	0.74	0.87	0.805	0
3	Forth Creek	Y	0.69	0.78	0.735	6
45	Gift Lake	Y	0.55	0.33	0.44	1
	Girouxville 3	N				6
	Girouxville 4	N				0
32	Gold Creek	N	0.52	0.83	0.675	0
4	Gordondale	N	0.59	0.8	0.695	10
49	Grande Prairie HP	N	0.76	0.81	0.785	0
27	Grande Prairie I	N	0.75	0.84	0.795	0
36	Guy	N	0.6	0.55	0.575	7
43	High Prairie	N	0.58	0.43	0.505	0
12	Hythe	Y	0.74	0.81	0.775	8
35	Jean Cote	N	0.49	0.65	0.57	1
38	Karr Creek	Y	0.41	0.76	0.585	0
47	Kinuso	N	0.59	0.45	0.52	1
46	Little Smoky	N	0.75	0.45	0.6	1
40	McLennan	N	0.55	0.64	0.595	0
44	Peavine	N	0.52	0.34	0.43	1
25	Pinto Creek	N	0.66	0.77	0.715	7
17	Poplar	Y	0.78	0.79	0.785	0
34	Puskwaskau	Y	0.44	0.6	0.52	1
18	Saddle Hills	N	0.68	0.73	0.705	8

Table 5.3 Passive Network Suitability

Site Number	Name	Discontinued in Jan 2017?	SO_2 Correlation	NO_2 Correlation	Average Correlation	SUITABILITY
20	Shaftesbury	Y	0.5	0.43	0.465	1
1	Silver Valley	Y	0.71	0.83	0.77	8
29	Smoky Heights	N	0.67	0.83	0.75	1
9	Spirit River	N	0.71	0.72	0.715	9
7	Steeprock Creek	Y	0.75	0.61	0.68	10
42	Sunset House	Y	0.73	0.57	0.65	1
14	Sylvester	N	0.65	0.75	0.7	0
41	Valleyview	Y	0.82	0.6	0.71	1
19	Wanham	N	0.6	0.73	0.665	1
33	Wapiti	Y	0.7	0.86	0.78	1
11	Webber Creek	Y	0.65	0.75	0.7	0
24	Wembley	N	0.68	0.82	0.75	7
10	Woking	Y	0.7	0.66	0.68	0

5.2 Quantitative Assessment of Continuous Stations

The suitability model was used to assess the current continuous network. Figure 3.4 compares the suitability rating applying the continuous network scenario layers described in Section 3.3 and the locations of the current stations. The pattern of suitability at the airshed scale is broadly indicative of the exclusion zones around major emitters. Note this exclusion zone is reduced for major industrial emitters. There is no exclusion zone for populated areas.

Figure 3.5 provides a zoomed-in look at the suitability pattern for two large emitters and a community, where the areas of high suitability outside exclusion zones around facilities are shown. The patterns of suitability are on a very fine scale and are highly dependent on the size of the exclusion zones around sources and roadways. Suitability is weighted to the community, which has a higher suitability than the neighbouring plants. With the road layers in the region (which would not include resource access roads), preferred locations of monitoring near the sources can be identified.

Figure 5.5 based on CMAQ stack emissions and Figure 5.6 compare the locations of the highest emitters and the locations of continuous monitoring. For this assessment, the emissions of SO_2, NO_2 and $PM_{2.5}$ were summed at each site to provide an indicator of total emissions. Figure 5.5 shows current continuous monitoring is located near the very suitable locations of Grande Prairie and the Kaybob Amalgamated plant and the moderately suitable Donnelly facility. Environment Canada monitoring is conducted near Beaverlodge as part of a national network.

Additional information is available in Figure 5.6 based on 2017 NPRI emissions. Continuous monitoring is conducted near two major emitters in the expansion zone, although the KA plant is a comparatively smaller source and the monitoring distance from the facilities is relatively large. In the existing PAZA airshed, monitoring is currently not conducted near any major industrial emitter based on their 2017 emissions.

Recommendations for siting of continuous monitors are provided in Section 6.

5.3 Application of Suitability Model to Network Expansion

5.3.1 Passive Network

The suitability model approach was used to identify passive network locations within the expansion area by application of the passive scenario as seen in Figure 5.3. This scenario was based on the passive scenario model and the GIS layers identifying the current location of emissions from NPRI and CMAQ data sources as well as the oil and gas facility locations in the AER database.

Of note within this figure is that a substantial portion of the expansion area has been eliminated from siting. There appear to be several reasons:

- One is the limited road network compared to the current airshed (see Figure 3.3 in Section 3). Access was based on the current road network. It is recognized that with ongoing oil and gas activity, new access will be created.
- A second is the terrain (slope or elevation) constraints imposed on the scenario. The slope constraint was relatively generous (40% slope). In fact, it may be that real access in slopes this steep would be limited, and that larger areas would be excluded in slopes of say 10% or more. Should PAZA wish to site stations within the area of terrain constraints, site specific investigations would be needed.

Despite these access limitations, Table 4.4 and Table 4.5 indicate emissions in the expansion zone are comparable to the current airshed and emitting locations are denser in the Fox Creek area than in the rest of the expansion area. This suggests a comparable number of monitoring stations or at least comparable density of passive stations in the expansion area.

The areas of the current airshed and expansion areas are 45,700 and 19,300 km^2, respectively. The current density of passive stations in the PAZA airshed is 0.6 per 1000 km^2. There is no “right” density, but the current density is reasonable given the balance between the correlation and suitability analyses, apart from filling gaps (see Section 6.1). Scaling by area, this suggests about 12 passive sites in the expansion area. Table 5.6 indicates there are more sites than this already in operation in the expansion area; however, they are clustered around several facilities as required under their EPEA approvals. Consideration is given to redistributing those stations in Section 5.4.1 and Section 6.1.

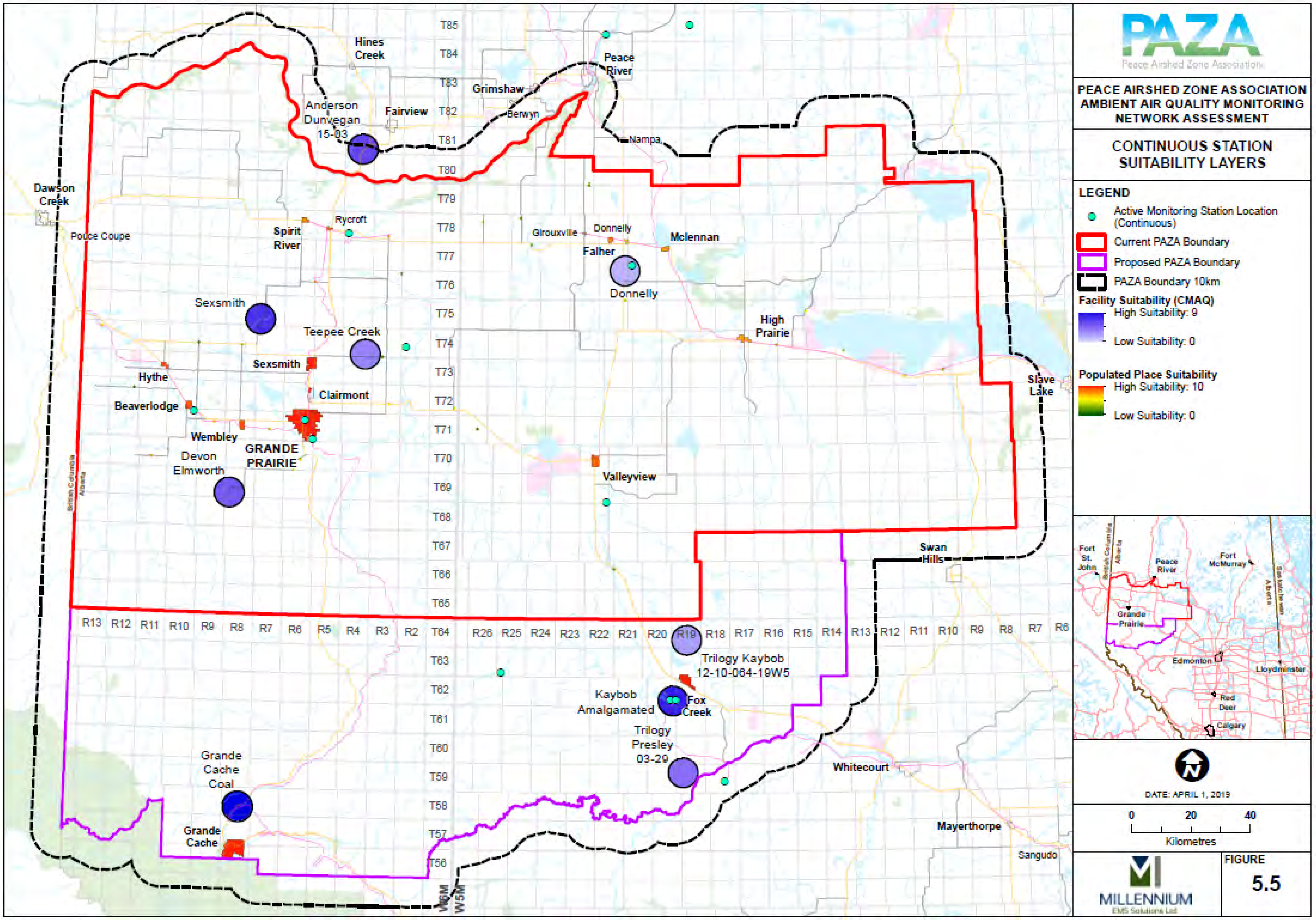

Figure 5.5 Continuous Scenario Suitability – CMAQ data

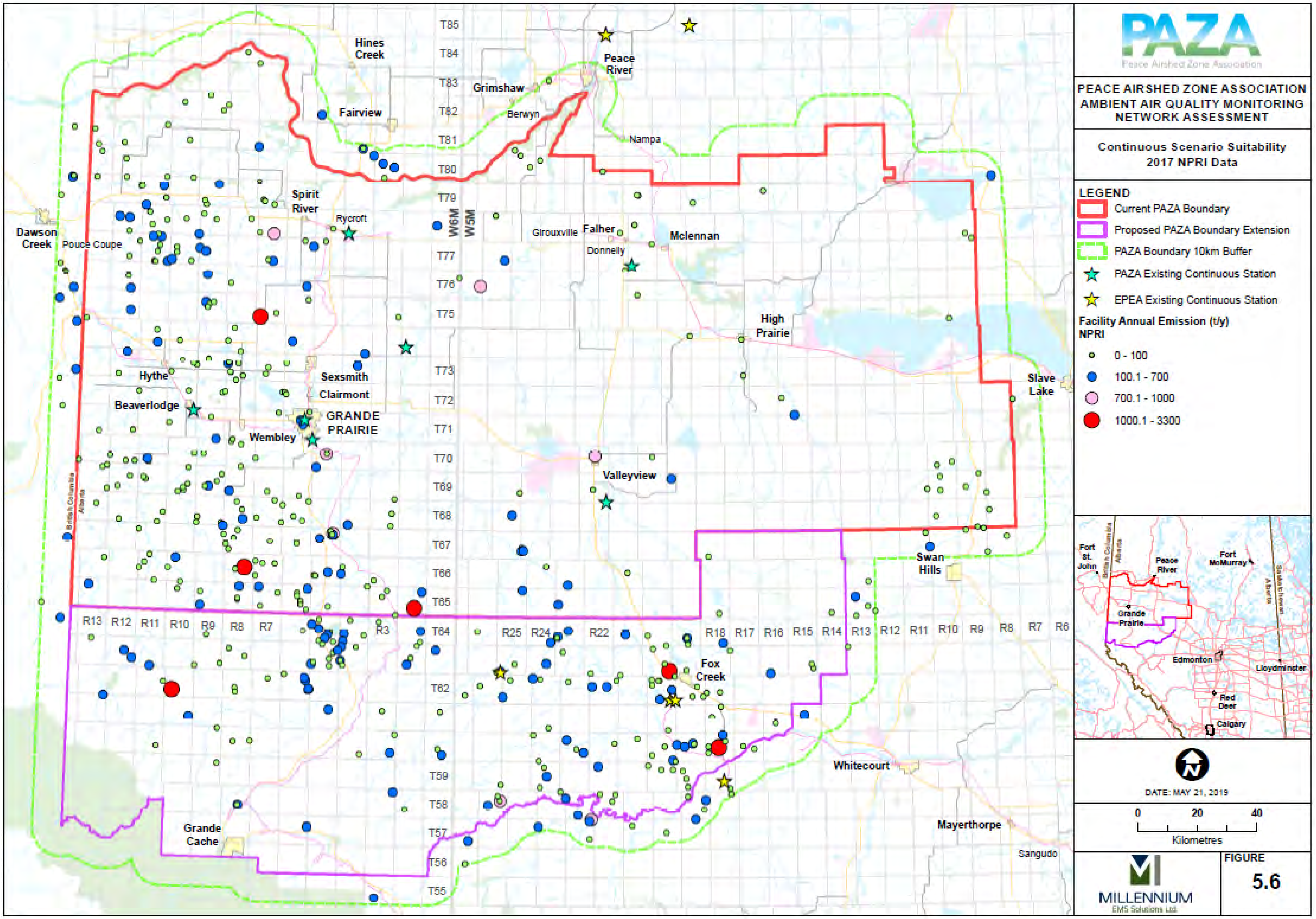

Figure 5.6 **Continuous Scenario Suitability – 2017 NPRI data**

5.3.2 Continuous Network

The suitability model approach was used to identify continuous network locations within the expansion area by application of the continuous scenario as seen in Figure 5.3. This scenario was based on the current location of population centres in the area and on the locations of the highest emitting sources from the CMAQ database. This scenario is weighted to potential human health issues, as represented both by emissions and population.

Figures 5-5 and 5-6 show three sites in the expansion currently requiring continuous monitoring as conditions of their EPEA approvals, with an additional site within about 5 km of the expansion boundary. Two are located in the vicinity of larger emitters.

It is not recommended at present that additional continuous stations, beyond those already in place, be added to the network in the expansion area. The siting of those stations is discussed in Section 6, under the assumption that industry will be required to be a member of PAZA and that it is PAZA's responsibility to ensure there is adequate monitoring.

5.4 Network Changes

5.4.1 Passive Network Changes to Understand Spatial Distribution

This section examines whether network changes are needed to determine the spatial pattern of pollutants in the current airshed, as the expansion area was considered in the previous report section.

There are two potentially conflicting factors underlying this section. One is the intuitive expectation that more monitoring ought to occur in areas in which emissions are higher, whether in principle because the area has more or higher emitting sources and people living in the area would be subject to poorer air quality. Emissions on which this evaluation is based are found in Figure 3.1. Countering this is the observation in Section 5.1.1 that fewer measurement sites are needed if they are highly correlated. Lower correlation is generally observed in the eastern portion of the network, especially for NO_2 and therefore this area would be considered more suitable for additional monitoring sites. The pattern of CMAQ emission suitability underlain by correlation in the passive network is shown in Figure 3.2.

This section applies the suitability index approach considering both factors. In this assessment, the weighting of the emission layer was 4 times higher than the correlation layer, essentially "forcing" more monitoring in high emission areas, somewhat counter-balanced by observed correlation values. To illustrate the results in Figure 5.7, area-weighted suitability was summed within 20 x 20 km blocks based on NO_2 emissions and divided by the area within each block outside of exclusion zones. Colours indicate the areas where passive monitoring ought to be concentrated. With this weighting to emissions in the existing PAZA area, the most suitable areas are in the western part of the network, west of Grande Prairie. If the weighting of the correlation layer was increased, the regional differences would decrease. If the weighting was increased, there would be greater polarization.

Figure 5.7 suggests that growth in passive network sites ought to occur in specific parts of the current network, pending the identification of suitable and accessible sites. These additional passive sites should be considered in the current airshed, that balance the location and emissions from current sources with the finding that correlations (a measure of network efficiency) are higher in areas with more dense sources.

Figure 5.7 identifies the priority locations based on the emissions-correlation weighting and numbers the highest ranked blocks. Sites in the expansion area did not have a correlation component, and this partly explains the preponderance of highly ranked blocks in the area, although the expansion area has a relatively higher density of emissions compared to the existing airshed.

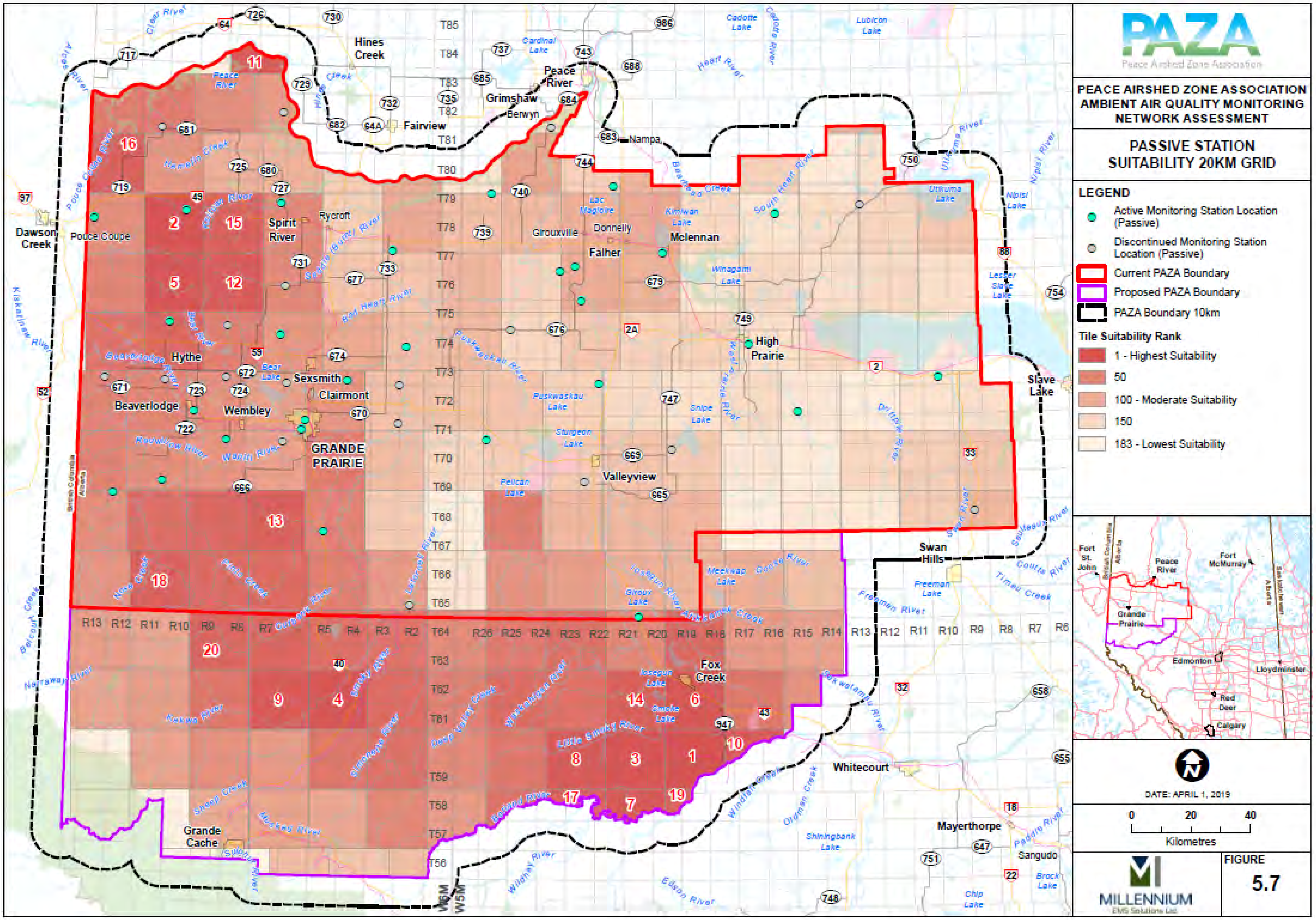

Figure 5.7 Passive Suitability in 20 by 20 km Blocks

5.4.2 Network Changes to Address Emerging Issues

Other than changes resulting from expansion of the airshed which was addressed in Section 5.3, no changes have been proposed to the network because of emerging issues. Section 3.2.1 identifies the data layer and suitability model considerations regarding emerging issues.

Emerging issues were incorporated into the suitability analysis as follows:

- The Wembley-area development was added as an exclusion zone within which monitoring was unsuitable and outside of which was highly suitable.
- The Fox Creek area was added as part of the expansion zone and emissions, access, *etc.*, in the region were included in the suitability analysis.
- All sources within 10 km of the PAZA boundary were identified (*e.g.,* near Dawson Creek). However, at present no monitoring has been recommended in this buffer. One continuous station exists in the 10-km buffer near Fox Creek. This station would be part of an expanded West Central airshed, and its location is ideal for documenting transboundary transport between the two airsheds.
- Transboundary sources. It was not attempted to use a suitability model approach to establish background monitoring, for distance sources whose plumes might affect the PAZA airshed (*e.g.,* forest fires).
- Population growth, and emissions associated with growth, was assumed to occur in current population centres, which are already identified as suitable for continuous stations (based on population). The suitability model was not used to examine the need for additional stations within population centres or the siting of continuous or passive sites within Grande Prairie.
- Impacts of diffuse, unregulated sources was not included in the model, as emissions from NPRI and CMAQ emission databases, based on regulated industrial sources, were used. For a suitability model to be applied, these sources would need to be established in some geographic area, and ideally with some indication of emission strength,

5.4.3 Network Changes to Evaluate Population Exposure

The AQHI is based on continuous measurements of NO_2, $PM_{2.5}$, and O_3. Environment Canada forecasts the AQHI at Grande Prairie only. Current continuous stations in the airshed measure NO_2, SO_2 and $PM_{2.5}$ and therefore do not provide the ability to directly calculate the AQHI as O_3 must be estimated. The PAZA website provides estimates of AQHI at Beaverlodge and Wembley as well as Grande Prairie.

If the following pollutant thresholds are exceeded, the AQHI value is overridden with the appropriate High or Very High risk-value (7 or greater). Not all these chemicals are monitored by PAZA so the override may not be possible.

- 80 $\mu g/m^3$ for $PM_{2.5}$;
- 172 ppb for SO_2;
- 159 ppb for NO_2;
- 82 ppb for O_3;
- 13 ppm for CO; and
- 1 ppm for H_2S and TRS (based on occupational health and safety standards, not ambient objectives).

The issue is how the basic parameters of the AQHI could be measured or estimated for smaller communities in the PAZA airshed. In terms of measurements, it is likely that less expensive instruments that those currently mandated for use in Alberta airsheds could be used, as technology is advancing to incorporate new and innovative instrumentation.

The use of satellite measurements might be another possibility; it is expected that ground level concentrations in the community, averaged over the target area of the satellite, may be too low to provide useful information.

In terms of estimating air quality, it would be possible to provide a continuous air quality model forecast service specifically for the airshed. To provide real time or forecast local air quality, real time measurements of emissions would be needed, or high-quality estimates. The value of this service compared to cost would need to be evaluated.

5.4.4 Network Changes to Support Dispersion Modelling

Dispersion modellers typically use monitoring data to provide background concentrations, to which the effects of specific modelled sources are added. For site specific modelling, all industrial sources within 5 km of the plant of interest are modelled. So, the background should represent air quality apart from those sources. For regional modelling, emissions over much wider areas would be considered, and extended to non-industry sources as well.

To model development in communities, it is appropriate that a community station be used as the background concentration, as the use of modelling to predict concentrations within communities, resulting from community emissions, is of higher uncertainty. For development in rural areas, it is appropriate that a rural measurement station be used. As short-term predictions require maximum or 90^{th} percentile concentrations to be used, continuous stations are preferred to be used to determine background concentrations.

It can't be predicted what additional chemicals may be needed in future modelling. Current industrial expansion in the airshed is centred on oil and gas, and the products of combustion and natural gas processing are those currently measured in the continuous and passive network. Population growth also adds combustion products. Should growth be in industry that adds unmeasured chemicals – ammonia associated with large livestock operations, for example – and that requires measured background concentrations of these chemicals, changes to the network would need to be considered.

The existing network area includes air quality and meteorological measurements, including stations in communities, at suitable background locations, and near industry. The expansion area adds new stations to the network with data to meet the need to support modelling.

5.4.5 Network Changes to Support Multiple Uses

The network currently supports multiple uses, and any changes to the network *e.g.*, through expansion, do not change this utility.

The ongoing development in new technologies applied to drones is of current interest. Should the technology become sufficiently developed, some of or all the existing passive network could be replaced with low cost stations collecting continuous data. The continuous data would create additional uses (such as more local AQHI estimates).

5.4.6 Network Changes to Identify Monitoring Beyond Boundaries

Monitoring beyond boundaries can provide information suitable for establishing the quality of air flowing into or out of the PAZA boundary. Considering the patterns of emissions in the NPRI and CMAQ databases and the location of emissions in the AER database, there is potential for cross border flow, to the west from oil and gas operations near Dawson Creek and to the SW from similar operations near Fox Creek.

Currently, there are no continuous stations near the western border of the PAZA airshed. This report has not investigated whether B.C. has monitoring sites in this region to which PAZA might get access. Given the continuity in industry across the border in B.C. and the relatively high correlation between passive monitors in the western part of the current PAZA airshed, it is not expected the addition of passive sites on the B.C. border would add new information.

The expansion area contains new continuous and passive stations (Figure 5.9 and Table 5.6). Three stations, including the Swan Hills Treatment Centre are about 10 km outside the current or expanded airshed (sites H, I, J in Table 5.6) are not considered further. Of the remainder, 64 are passive and four are continuous.

One continuous location is outside but within about 5 km of the boundary (A). This station can provide information on transboundary flow, when analyzed as a function of wind direction, which would benefit both PAZA and an expanded WCAS.

From a network operation perspective, there is potential for consolidation, as it would not require three stations near the PAZA boundary to understand transboundary flow. Coordination with WCAS is recommended to facilitate consolidation.

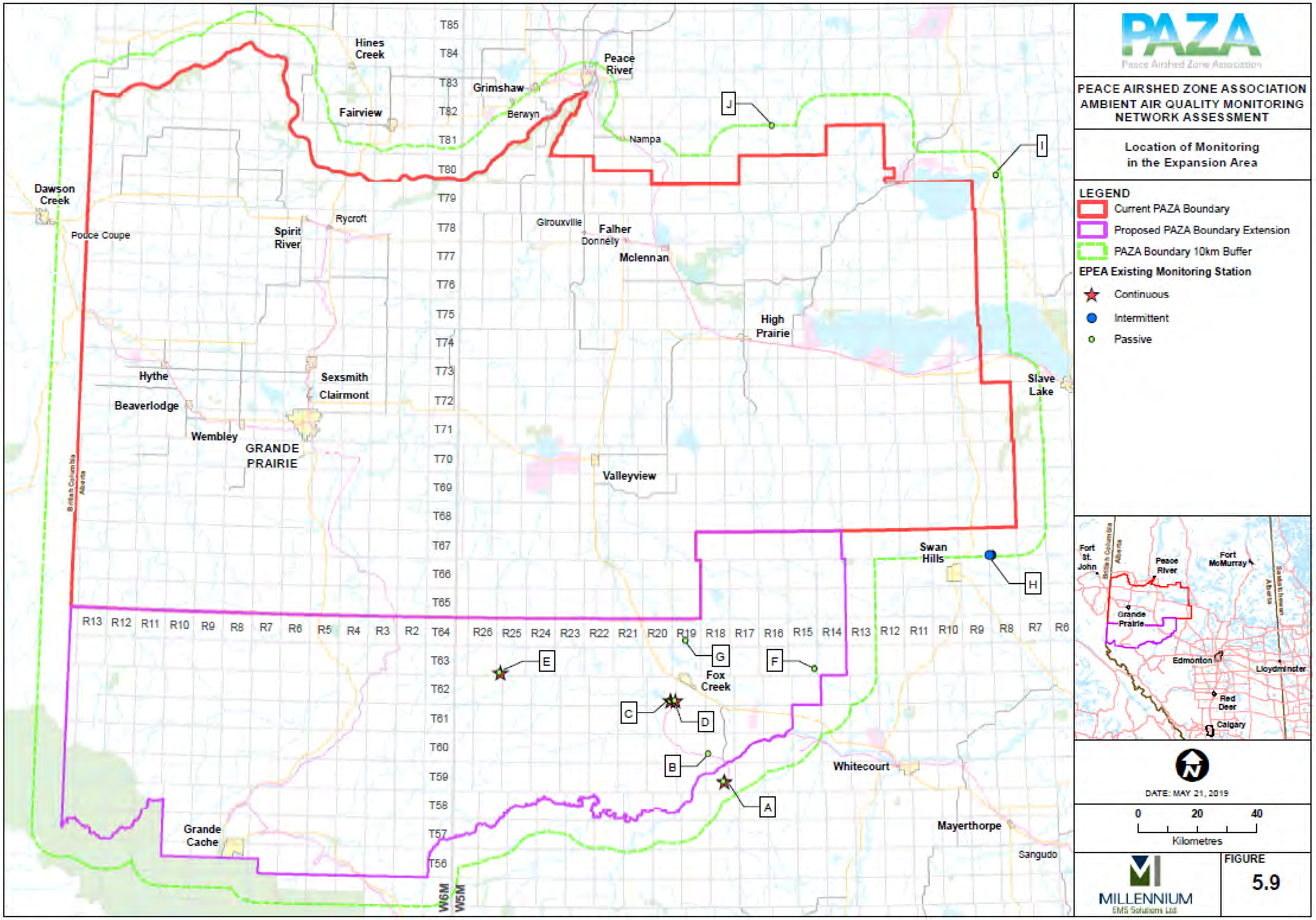

Figure 5.9 Location of Monitoring in the Expansion Area

Table 5.6 Current Expansion Area (EPEA Approval) Monitoring

LABEL	OPERATOR	NAME	Start DATE	Measurement	TYPE	MONTHS / Year	Number of STATIONS
A	Semcams Ulc	Kaybob South #3	01/11/2014	SO_2, NO_2, H_2S, wind	Continuous	12	1
	Semcams Ulc	Kaybob South #3	01/11/2014	SO_2, NO_2, H_2S	Passive	12	11
B	Xto Energy Canada Ulc	Kaybob Sour Gas Plant	01/08/2014	SO_2, H_2S	Passive	12	4
C	Semcams Ulc	Smoke Lake Sour Gas Processing Plant	18/07/2018	SO_2, H_2S, wind	Continuous	12	1
	Semcams Ulc	Smoke Lake Sour Gas Processing Plant	18/07/2018	SO_2, H_2S	Passive	12	4
D	Semcams Ulc	Kaybob Amalgamated	01/06/1992	SO_2, H_2S, wind	Continuous	12	1
	Semcams Ulc	Kaybob Amalgamated	01/10/2006	SO_2, H2S	Passive	12	19
E	Keyera Energy Ltd	Simonette	01/01/1984	SO_2, H_2S, wind	Continuous	6	1
	Keyera Energy Ltd	Simonette	01/02/2003	SO_2, H_2S	Passive	12	12
F	Enercapita Energy Ltd.	Sakwatamau	15/01/2014	SO_2, H_2S	Passive	12	2
G	Trilogy Resources Ltd.	Kaybob	01/09/2006	SO_2, H_2S	Passive	12	12
H	Suez Canada Waste Services Inc.	Swan Hills Alberta Special Waste Treatment Centre	01/11/2005	THC, VOC	Intermittent	1	1
	Suez Canada Waste Services Inc.	Swan Hills Alberta Special Waste Treatment Centre	01/11/1995	TSP	Intermittent	12	2
	Suez Canada Waste Services Inc.	Swan Hills Alberta Special Waste Treatment Centre	01/11/2005	PCBs - Polychlorinated biphenyls (Total)	Intermittent	12	6
I	Canadian Natural Resources	Nipisi	01/09/2006	SO_2, H_2S	Passive	12	2
J	Obsidian Energy Ltd	Seal Main Hcss Pilot Project	01/08/2013	SO_2, NO_2, H_2S	Passive	12	4

5.5 Application to Monitoring Objectives

This section provides approaches to apply the suitability model output to addressing monitoring objectives. Other qualitative approaches are also identified that would contribute.

5.5.1 Objective 1: Monitor to ensure compliance to EPEA Approvals

This objective is not directly affected by the outcomes of suitability modelling. The effort to address this objective must be accomplished by a well-executed monitoring program by PAZA staff. This report has compiled inventories of industry monitoring in the expansion area and a buffer, and of current airshed monitoring.

The suitability modelling provides suitable locations in the Fox Creek area for monitoring should industry approvals be amended in future to include membership in an expanded PAZA and should regional monitoring locations be acceptable alternatives to monitoring locations in industry hotspots.

5.5.2 Objective 2: Measure and assess air quality relevant to AAAQOs and CAAQS

To assess air quality relative to AAAQOs and CAAQS requires continuously measured data. Currently, and in the expansion area, continuous monitors are placed in the major population centre and near the largest emission sources.

EPEA approvals typically require monitoring to be conducted in locations determined to be most affected by emissions from individual facilities to facilitate comparison to AAAQOs and the facilities' ability to comply with them. Airshed (passive) monitoring is generally located such that regional air quality is measured and managed, by comparison to AAAQOs and by providing data for input to CAAQS comparisons. The only passive data that can be compared to AAAQOs is 30-day SO_2, so the passive network is not useful for Objective 2.

The outcomes of the suitability modelling provided information on where to locate stations under either of the above approaches. In particular, Section 5.2 ranked suitable monitoring sites under the weighting assumption population: emissions were 75:25 and which also considered the influence of industrial emissions within 3 km of communities.

This assessment determined that passive monitoring does not provide this ability, and nor do most forms of integrative monitoring. New technologies that provide continuous measurements (which might also be input to the AQHI) should continue to be investigated and offer the most likely means of developing cost-effective tools for this purpose, bearing in mind it will take a period of time before the new technologies are accepted by the province.

5.5.3 Objective 3: Understand the spatial distribution of monitored pollutants in the region

The spatial distribution of emissions in the current airshed and the expansion were identified in Sections 4.3 and 4.4.

The outcomes of the suitability model provided locations of the most desirable monitoring locations to meet the needs of the passive monitor scenario, in the expansion area and in the existing area, based on these emissions. Section 5.4.1 of this report identifies the recommended network changes to meet Objective 3, considering the competing interests of increasing density in high-emission areas and the results of the correlation analysis.

Objective 3 was addressed by preparing contour maps of passive monitoring in the current network (Section 4.2). The contour maps provide broad trends and likely do not define the fine scale in trends that would be expected from the large number of sources in the region. To provide more insight, the annual average NO2 and SO_2 concentrations from continuous monitors were compared to passive concentrations extrapolated to continuous monitoring locations. Results are shown in Table 5.7. Some differences are expected because of measurement technology, which might explain much of the differences in NO2 at Beaverlodge and Henry Pirker where passive and active monitors are co-located. At Rycroft, it may be that local NO_x emissions are higher than would be indicated by interpolation of passive measurements. The explanation for SO_2 is less clear, with passive measurements near its detection limits (0.1 ppb).

Table 5.7 Comparison of Annual Average Passive and Continuous Concentrations (ppb) at Continuous Network Locations, 2017

Continuous Station	Continuous NO_2	Passive NO_2	Continuous SO_2	Passive SO_2
Beaverlodge	3.36	1.7	0.29	0.3
Evergreen Park	-	-	0.20	0.3
Grande Prairie (Henry Pirker)	9.61	5.7	0.25	0.1
Smoky Heights	-	-	0.36	0.3
Valleyview	-	-	0.69	0.1
Rycroft - Portable	2.39	0.8	0.26	0.3

The correlation analysis on its own, based on the passive network, provided additional insight into the spatial distribution of pollutants and in particular to the potentially redundant information provided (redundancy as defined in relation to high correlation among measurements of the nearest stations in the airshed).

5.5.4 Objective 4: Identify regional air quality trends and emerging issues

Temporal trends in air quality were identified in Section 4.1, for the period 2010 to 2018 for the passive network and 2013 to 2018 for the continuous network. Broad trends in the passive network were shown in Figures 4.6 and 4.7, with decreasing concentrations of SO_2 and increasing concentrations of NO_2. Seasonal patterns were evident.

Continuous station temporal trends (3 sites for NO2; 6 sites for SO2; 5 sites for PM2.5) were shown in Figures 4.1 to 4.3 demonstrating, with the averaging times considered, consistent patterns in air quality trends at all sites for all chemicals. NO_2, measured at fewer sites, showed most clearly the difference among sites as well as the commonality of trends. All stations clearly showed the increase in $PM_{2.5}$ concentrations during the August 2018 B.C. forest fires. These observations suggest that the current network of stations provides the information to meet this monitoring objective.

Section 5.4.2 identified the approach taken to incorporate emerging issues into the network assessment. Based on this approach, no new areas of additional monitoring were identified.

5.5.5 Objective 5: Characterize specific geographic locations or sources

The continuous emission scenario provided input on this objective, by ranking emissions of major source according to the stack emissions of the CMAQ database. In this scenario, emissions of SO_2, NO_2 and $PM_{2.5}$ from each source were summed, to create a hybrid emission profile for ranking.

By including population as a layer in the continuous scenario, monitoring in Grande Prairie was highly ranked, which is designed to provide trends information in the largest community in the area. The suitability model also included a road layer with a 100 m setback. This would provide guidance on locating the Henry Pirker site within the city (additional local emission information not part of the industrial emission databases should be added for a more complete objective assessment).

This assessment did not examine specific sources (*e.g.*, an intensive livestock operation or a municipal sewage treatment plant) whose emissions were not included in CMAQ. For these, alternative means of locating monitors should be considered. Prime among them would be the use of dispersion models to more accurately represent emissions coupled with meteorological information measured on or interpolated to the location of interest.

5.5.6 Objective 6: Provide information required to understand potential population impacts to ambient air quality

Population effects on air quality can be of several aspects:

- air quality in the largest communities affected by population changes;
- air quality in smaller communities; and
- air quality less directly affected by population but perhaps also by economic conditions – *e.g.*, along major roadways, expanded infrastructure, *etc.*

Currently, monitoring is conducted in Grande Prairie (one continuous and two passive monitors). No other sites are considered urban or measuring urban emissions.

The continuous suitability scenario focused on the effects on population, from large industrial emitters, and for communities with large emitters nearby. Suitability was higher for the largest communities and emitters. Under this scenario, smaller communities were ranked lower than larger industry. The highest ranked site was Grande Prairie. The next highest ranks were assigned to the largest emitters because of the population gap for communities smaller than Grande Prairie.

U.S. EPA (2008) recommends at least 1 station for each 350,000 people on which to calculate AQHI but more than one per city if urban monitoring is the goal. The total population within urban of PAZA (including extension) is 113,000 so this guidance is not applicable to PAZA.

CASA's (2009) guidance on urban monitoring is to assess the need for two monitoring stations in municipalities with a population greater than 50,000 and for one permanent monitoring station in municipalities with a population greater than 20,000. Residents may be underserved in an airshed with PAZA's population, having one permanent site in Grande Prairie and no urban monitoring elsewhere.

To address the costs of urban monitoring, and the preparation of local AQHIs, progress is being made to provide high quality, low cost ambient monitoring technology. The U.S. EPA (2013) has proposed tiers of monitoring that are accessible to a wider variety of users based on cost (Table 5.8). Europe has established quality monitoring objectives for "indicative" monitoring technologies where the goal is not regulatory or research quality data (*e.g.*, Aleixandre and Gergoles 2012). These more cost-effective approaches provide a means to better understand the impact of populated areas on air quality.

Table 5.8 Instrument Tier Definitions by Cost and Anticipated User

Tier	Target Cost Range ($US)	Anticipated User
Tier V (most sophisticated)	10 – 50 K	Regulators (supplement existing monitoring – ambient and source)
Tier IV	5 to 10 K	Regulators (supplement existing monitoring – ambient and source)
Tier III	2 to 5 K	Community groups and regulators (supplement existing monitoring – ambient and source)
Tier II	100 dollars to 2 K	Community Groups
Tier I (more limited)	Less than 100 dollars	Citizens (educational and personal health purposes)

Source: U.S. EPA (2013)

5.5.7 Objective 7: Provide information required to understand potential air quality impacts on the environment and population

The discussion in Sections 5.4.3 and 5.5.6 provide insight into monitoring to understand the effects on population. The AQHI is typically updated on an hourly basis and therefore uses continuous measurements, which are currently made at three stations in the airshed, and in communities currently limited to Grande Prairie. The minimum data requirements are NO_2, ozone, and $PM_{2.5}$. It is expected more continuous measurement sites will be added as part of the planned expansion and new technologies are under development that aim to reduce the cost while addressing key chemicals in the AQHI $PM_{2.5}$, O_3 and NO_2, as well as others.

The suitability analysis has not explicitly addressed environmental impact, but information is available to enhance information for stakeholders. For example, ground-level O_3 can reduce the growth and productivity of some crops and injure flowers and shrubs and may contribute to forest decline. O_3 is measured in the passive network and could be used to determine growing season averages of long-term use to agriculturalists. Similarly, NO_2 and SO_2 (among other measurements) contribute to acidification over the long term and potential acid input could be calculated from measurements and used as an indictor of potential harm to vegetation in the airshed. The current study did not establish these indicators or indices. The parameters to monitor would be based on a review of environmental indicators relevant to the airshed.

5.5.8 Objective 8: Improve the ability to identify and apportion pollutant sources for purposes of air quality management

Source apportionment is important for maintaining air quality within established limits such as those for the AAAQOs or CAAQS. This is particularly important when airsheds become stressed or when action is needed in response to complaints. Source apportionment could be improved through several approaches:

1. improved emission testing and reporting;
2. a higher density of continuous monitoring sites coupled with a larger number of parameters measured; and
3. special studies that measure and track specific emissions (*e.g.*, in the form of a tracer study or high-density passive stations.

The suitability model did not provide guidance on the second approach as the continuous monitoring scenario was weighted toward communities and large emitters rather than generally increased density. The passive scenario which focussed more on monitoring in large parts of the airshed with increased concentration of sites in areas of many sources could be adopted to increasing station density.

The current continuous scenario that focused on the largest emission sources was one step in the process. The inputs to this model include source location and emissions from CMAQ, wellsite locations from the AER dataset (although this dataset didn't provide emission strength) and population as a surrogate for residential emissions.

The scenario could be focused on emissions or formation of the individual pollutants $PM_{2.5}$ and O_3 as a driver of CAAQS but was in fact focussed on summed emissions of SO_2, NO_x and $PM_{2.5}$ to provide a broad view.

5.5.9 Objective 9: Provide adequate input and validation information for dispersion modeling.

Dispersion models rely on air monitoring data to provide background concentrations, to which model results are added. These modelling requirements typically require that an adequate number of continuous stations are in an airshed, and not in areas most affected by specific facilities.

Section 5.4.4 discussed in a broad sense what changes to the network might need to be considered to support future dispersion modelling. Those needs vary depending on the kind of modelling conducted. For regulatory purposes, continuous monitoring is needed to provide maximum or 90th percentile hourly concentrations of most measured chemicals (particulate is an exception which requires daily concentrations, as well as hourly).

The outcomes of the suitability modelling could be used in the siting of continuous stations to support measurements that are representative of the region rather than in hotspots of specific facilities. However, that was not the approach adopted for continuous stations in this assessment which weighted continuous measurements to communities and large emitters.

5.5.10 Objective 10: Monitoring will be conducted using best available technology economically achievable.

This objective was not directly affected by the current work as the choice of technology to apply is a decision of PAZA. One outcome of this work was the location of potential monitoring sites ranked by suitability in the existing and expansion areas of PAZA. A BATEA approach would balance the need for broad coverage with the need for continuous measurements.

As part of an examination of AQHI, information on the direction of community or indicative-level monitoring was investigated. This report recommends that PAZA conduct further information gathering in this area, as there is no particular reason why monitoring need be conducted only with instrumentation approved by regulators. With knowledge of PAZA's budget and vision for the expanded network, MEMS could provide further input to this objective.

6.0 RECOMMENDATIONS

6.1 Passive Network

6.1.1 Add three more stations to the passive network in the existing PAZA area

The current and the 2015 analysis (STI 2015) has shown that correlations are high in the western part of the airshed, meaning that more sites will not necessarily add more information. As development continues, correlations between nearby stations for NO_2 and to a lesser extent SO_2 will remain high. This was the rationale to reduce the density of the network in 2017. Nonetheless, the current network has some spatial gaps in coverage and it is proposed to fill in the gaps based on the analysis in Figure 5.7 and as shown in Figure 6.1. It is recommended that the Steeprock Creek site be reactivated, and that new sites be added in the northwest and southwest corners of the existing area.

6.1.2 Redistribute stations in the expansion area

Figure 6.1 also provides a recommended distribution of 12 new sites in the southern expansion area, based on Figure 5.7. It is not recommended that new passive sites be added but rather that the existing passive stations in the expansion area (Table 5.6) be redistributed based on emission density and the NPRI "heat map" in Figure 5.6. The suggested approach is:

- Review the existing passive data in the expansion. Look at spatial and temporal trends at each site. Consider a correlation analysis to support the rationalization/redistribution proposal, if needed.
- Contact AER to discuss the rationale for the current monitoring configuration. It may be there are valid regulatory reasons for a higher density of stations around some facilities.
- Confirm access around the recommended locations in Figure 6.1. These locations are best guesses only and there is no problem moving them by one or more kilometres.

The siting of the 12 new locations generally follows the approaches identified in Section 3.3.1. Setbacks from roads need to be less than the 750 m used in this assessment; more than 100 m is ideal but shorter distances may be required given access limitations at specific sites.

No changes in measured parameters are suggested for the passive network.

6.2 Continuous Network

It is our view that the network should focus on emissions that impact residents in the airshed and be cognizant of the potential effects of high emitting sources and sensitive aspects of the environment. There is limited value in "regional" stations that do not provide information relevant to the population, high emitters or sensitive environmental features. Furthermore, the network should be composed of a core of continuous stations with more portable stations that can be moved where questions or concerns arise. Finally, the network should be looking to new technology to further support its mandate.

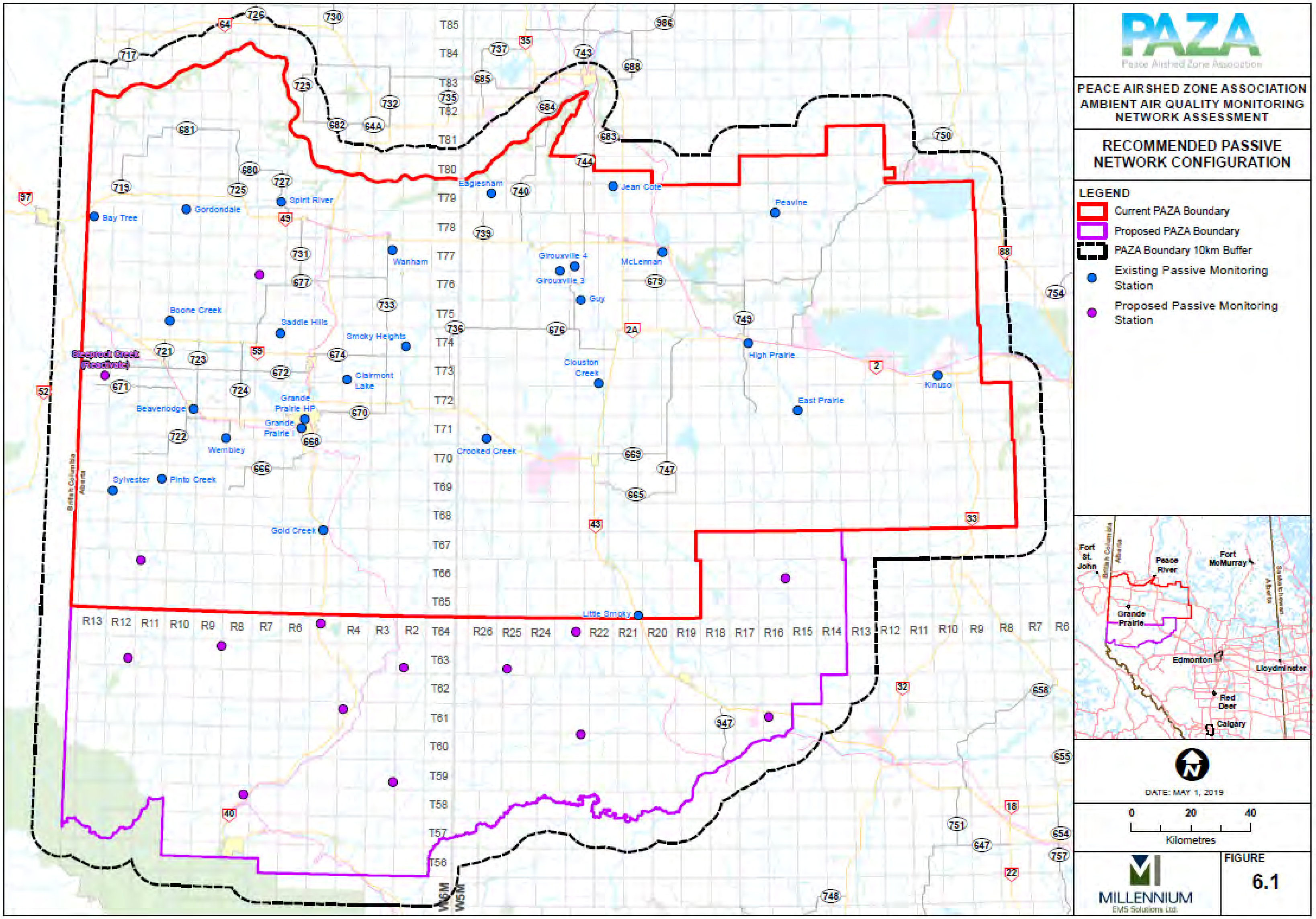

Figure 6.1 Recommended Passive Network Configuration

6.2.1 Current Airshed

6.2.1.1 Core Stations

The following is recommended based on the above considerations. A core of 4 stations in the current airshed is recommended, with three stations used as portables (Figure 6.2). No changes in measured parameters are recommended for the core stations.

1. **Beaverlodge** –The station is part of the National Air Pollution Surveillance (NAPS) network and should be unchanged.
2. **Evergreen Park** – The station is near a gravel pit and re-siting away from it should be considered. There are other facilities operating or planned for the region. Consideration should be given to transitioning the station to be a quasi-compliance site.
3. **Donnelly** – This station should be rebranded as a **portable** and considered for short-term service elsewhere.
4. **Henry Pirker** – A station in Grande Prairie is critical given its population. The site appears to be near a construction zone and therefore is limited in its ability to provide representative data for the community. Access can also be an issue. Relocation within the city is recommended.
5. **Smoky Heights School** – The station should be re-purposed as a **portable** station and relocated for short-term service.
6. **Valleyview** – The Valleyview station is located near several industrial plants. Its precise location within the influence of these plants should be checked; however, it is recommended the station continue its role as a quasi-compliance site in the general area.
7. **Portable** – The portable site is currently 7.5 km south of the Town of Wembley. The portable monitor should continue to be relocated as needed to investigate air quality in different areas.

6.2.1.2 Portables

Reconfiguration of some stations might be needed to provide a broader range of instrumentation for portable units, as the need may arise for specific locations. Expanding the portable fleet adds flexibility to operations and allows more airshed issues to be addressed but requires more active management by airshed committees and liaison with communities, and regulators regarding high emitters. Portables using current technology may also be more expensive as siting requirements would include electrical power. It is possible that some temporary sites be considered for future permanent measurement, depending on the circumstance. Uses to which portable sites can be used include the following:

- Population effects. There are many small communities in the airshed that may be affected by emissions, or that may cause emissions (*e.g.,* wood burning). Monitoring for short periods, say 1-2 years, would identify whether there is a need for other action.
- High industrial emitters.
- Emerging issues 1. Onsite during site-preparation, construction and post-commissioning of major new emission sources. Suggested duration 1-2 years. See Figure 6.2 for potential initial deployment of portable stations.
- Emerging issues 2. New ambient air quality objectives are planned for NO_2 and SO_2 and industry response may be needed at some facilities. Fenceline monitoring in support of engineering retrofit may be helpful to confirm compliance.
- Air quality complaint management. This could include odour, dust, *etc.* Suggested duration 1 year or less.
- Cross boundary issues, upwind and downwind.

Figure 6.2 identifies that several of the newly available portable stations could be located in the Wembley area given the planned facilities in the area. Other sites should be considered, including the following.

Near the Nauticol and International Paper (IP) facilities southeast of Grande Prairie (a potential relocation of the Evergreen Park station). For siting of the station, PAZA should refer to the air quality section of the recent Nauticol environmental assessment, which would also include the effects of the IP facility. This document has not been referred to as part of the network evaluation. However, while winds in the area are rarely from the SE and it is unlikely that emissions would be blown toward the city, given the proximity of the facilities to the city, siting should consider a location between the facilities and the nearest residences in the city. The Nautical facility is in development and IP is currently undergoing a renewal of its approval. Unless otherwise indicated in the updated approval, continuous monitoring at the location should consider $PM_{2.5}$, SO_2, total VOCs and TRS.

Near the planned Tri-Municipal Industrial Partnership (TMIP) about 45km south of Grande Prairie on Hwy 40. There are currently a few existing gas plants (CNRL Gold Creek is the largest, a Secure Energy water disposal facility, CN rail line, and various other petroleum leases and facilities. Given TMIP's plans for additional development, a temporary (one year) set of measurements should be considered. Winds are expected to be predominantly from the AW, so a location NE of the current facilities would be recommended. Without knowledge of planned developments, a station measuring NO_2 and $PM_{2.5}$ is suggested.

The complete network of passive and continuous stations as well as potential locations for portable monitors, is shown in Figure 6.3.

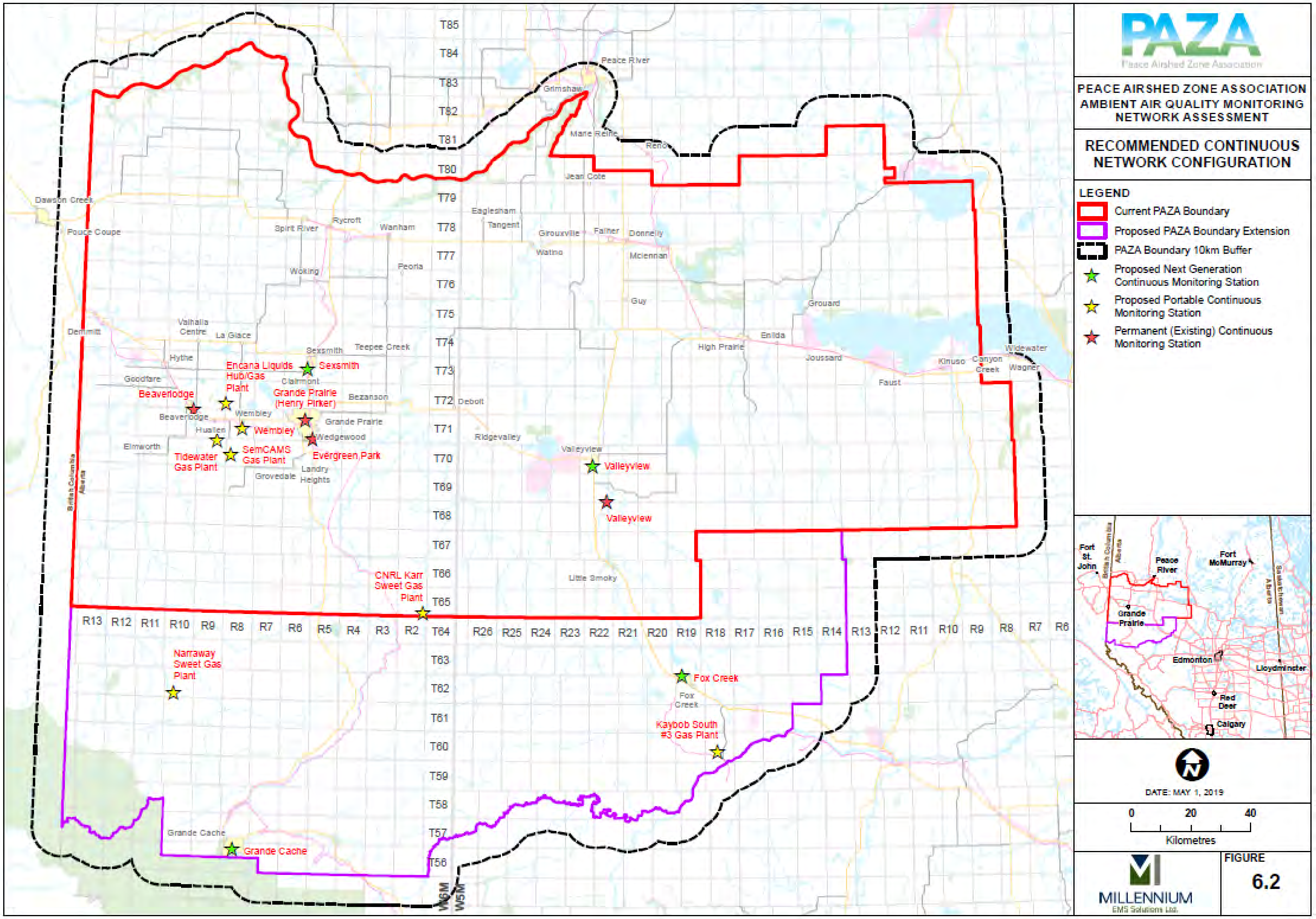

Figure 6.2. Recommended Continuous Network Configuration

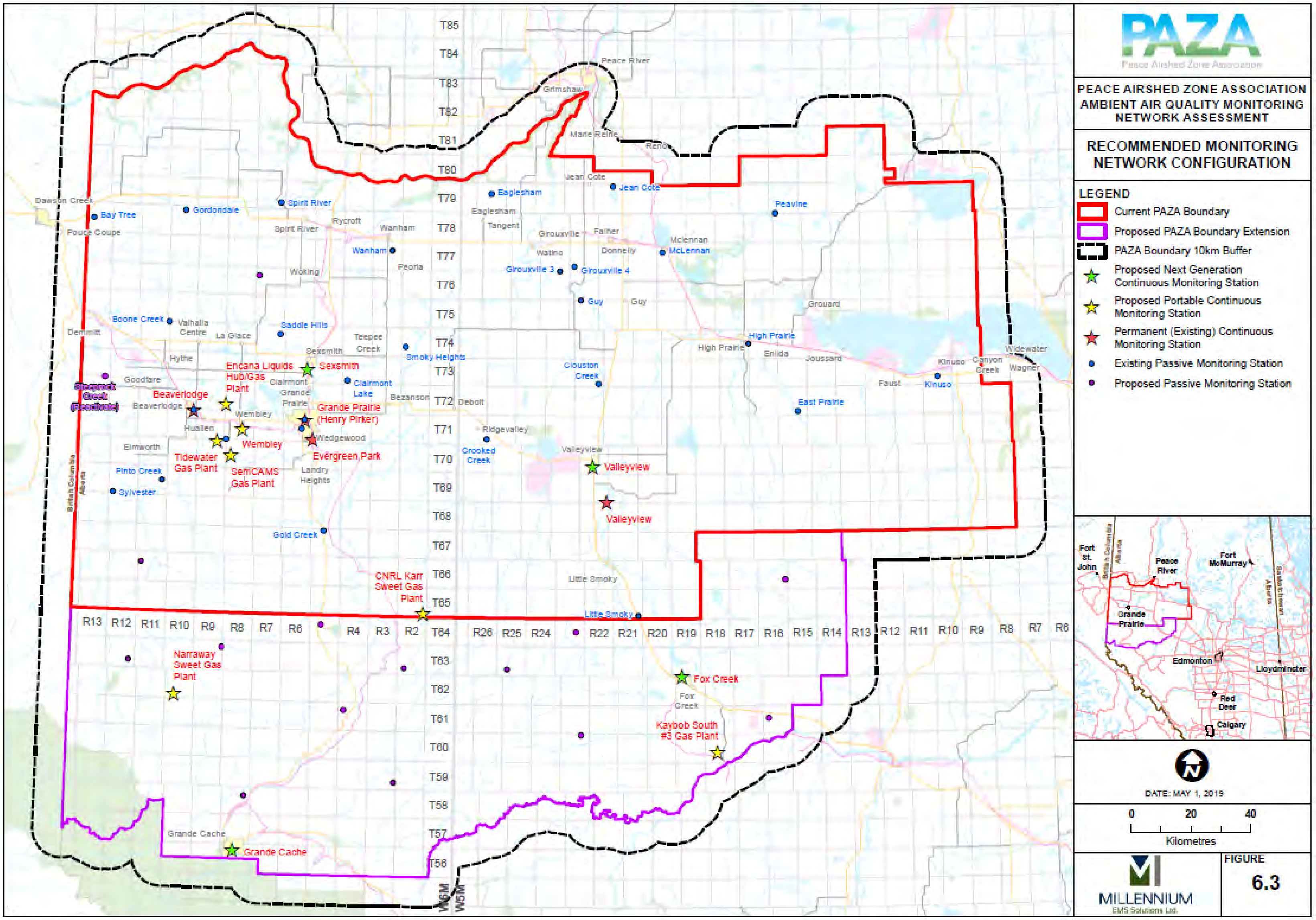

Figure 6.3. Recommended Monitoring Network Configuration

6.2.2 Expansion Airshed

It is not recommended that additional continuous stations, beyond those already in place, be added to the network in the expansion area; however, the locations should be reconsidered. The review of network locations should be based on monitoring near residents in the airshed with consideration of the potential effects of high emitting sources and sensitive aspects of the environment.

Like the passive network reconfiguration, specific steps should be taken:

- Review the monitoring data at the current locations. Recent measurements (post-2014) with high values (approaching current and planned ambient air quality objectives) may indicate the station locations should not change.
- Contact AER to discuss the rationale for the current monitoring configuration. It may be there are valid reasons for the current locations based on current operations at the nearest facilities.
- Confirm access around the recommended locations in Figure 6.2. These locations are best guesses only and reference may need to be made to the dispersion modelling studies that accompanied the most recent applications.

The recommended locations are those of high emitters and as such should not be necessarily considered as permanent sites. Rather, the duration of monitoring at these locations ought to be driven by the data generated. Long term operation of a site, far from population centres or sensitive environmental features, that demonstrates relatively low concentrations should not be undertaken.

In the next section, recommendations are made for monitoring in communities. These recommendations do not consider cost and it may be that one or more of the current-technology monitors recommended for high emitters should be first deployed to communities. Fox Creek is a community that comes to mind as a priority.

Overall, the rationalization of the continuous network is expected to lead to the "freeing up" of more stations than are reasonably needed for use as portables to address issues and concerns. Asset retirement should be considered for several stations.

6.2.3 Next Generation Analyzers

Further consideration should be given to the "next generation" of continuous low-cost monitors. As part of an examination of AQHI, information on the direction of community or indicative-level monitoring was investigated. This report recommends that PAZA conduct further information gathering in this area, including the automatic generation of the AQHI in smaller communities, and using these monitors as portables given they are very compact and operate on solar/battery.

Furthermore, they measure more chemicals than is currently monitored in the network and therefore add versatility as well.

Because this generation of sampler measures more parameters, it is recommended that first installation ought to be in the larger communities in the region on a permanent basis: Sexsmith, Valleyview, Grande Cache, and Fox Creek (Figure 6.2).

It is noted that some of these analyzers are currently undergoing testing within Alberta Environmental Protection and should not be considered for compliance purposes. It is our view that measuring in communities should not be considered as compliance monitoring.

6.3 Recommended Additional Work

Additional follow-up work is needed to implement some of the recommendations in Section 6.2. In particular:

- The Henry Pirker site should be relocated. A shortlist of potential sites in the community should be developed considering the siting guidance in the Air Monitoring Directive.
- The location of the Valleyview site should be reviewed relative to nearby major emitters. The review should consider the current emissions from the facilities and the local winds. Siting would benefit from a dispersion model study as well. A shortlist of sites would be developed.
- The Evergreen Park site should be reviewed, considering the potential to provided information from new and established industry in the vicinity. Siting would benefit from reference to a local dispersion model study. A shortlist of sites would be developed.
- Reviews of passive and continuous data in the expansion area were recommended. Where available this would be based on annual reports or information provided in Approval applications. The review would identify whether continued monitoring at current locations is needed or whether redeployment of stations, as recommended, is reasonable.

When decisions on redeployment have been made, additional work will be required to obtain necessary authorizations for siting, review of site-specific access and power, *etc.*

7.0 REFERENCES

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