Figure 5-76: Simulated hourly SO$_2$ concentrations (99th percentile) as a result of baseline emissions
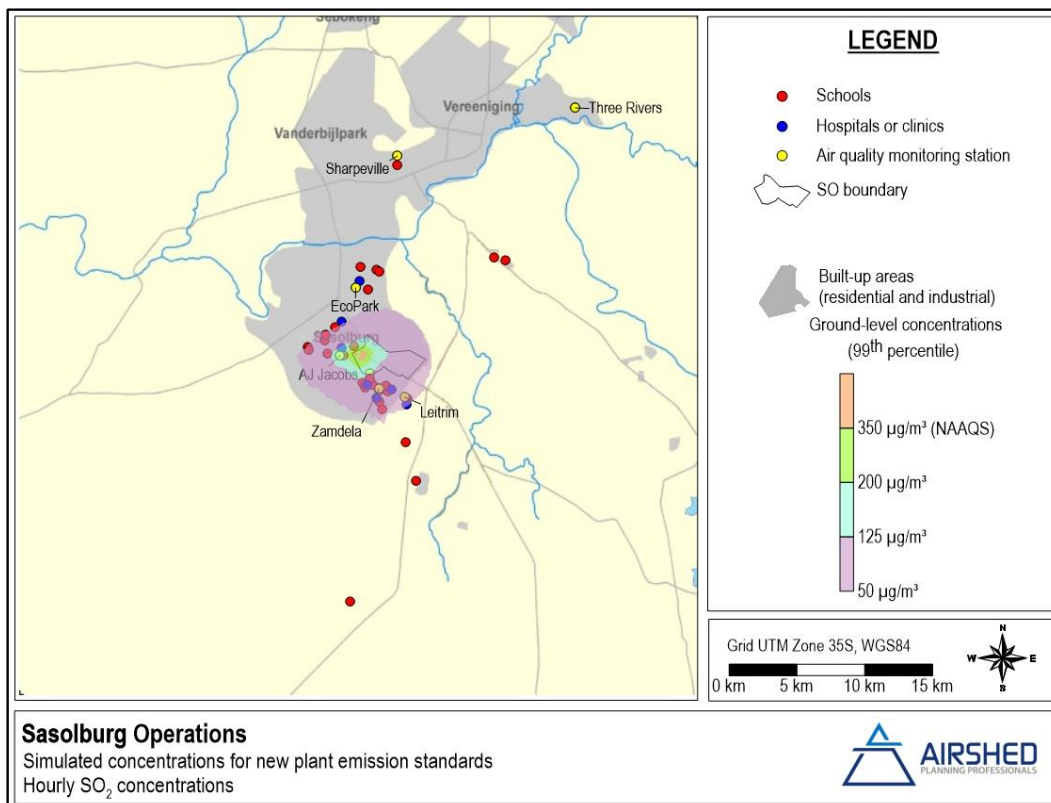

Figure 5-77: Simulated hourly SO$_2$ concentrations (99th percentile) as a result of theoretical compliance with new plant emission standards
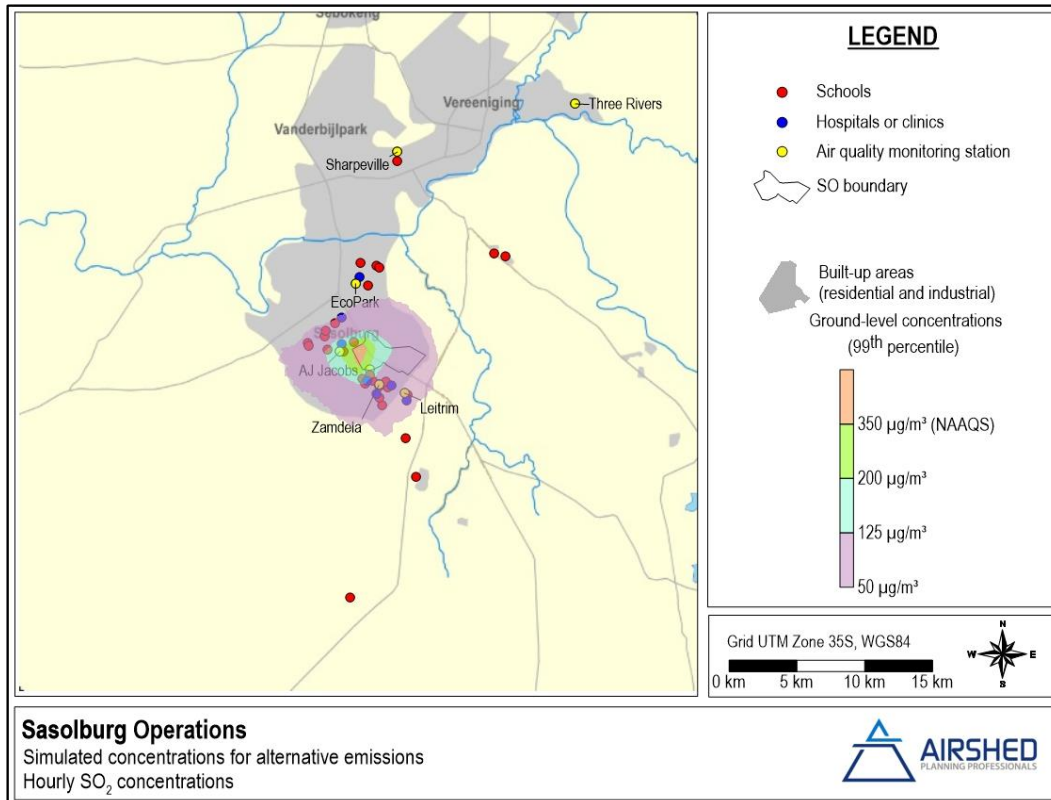
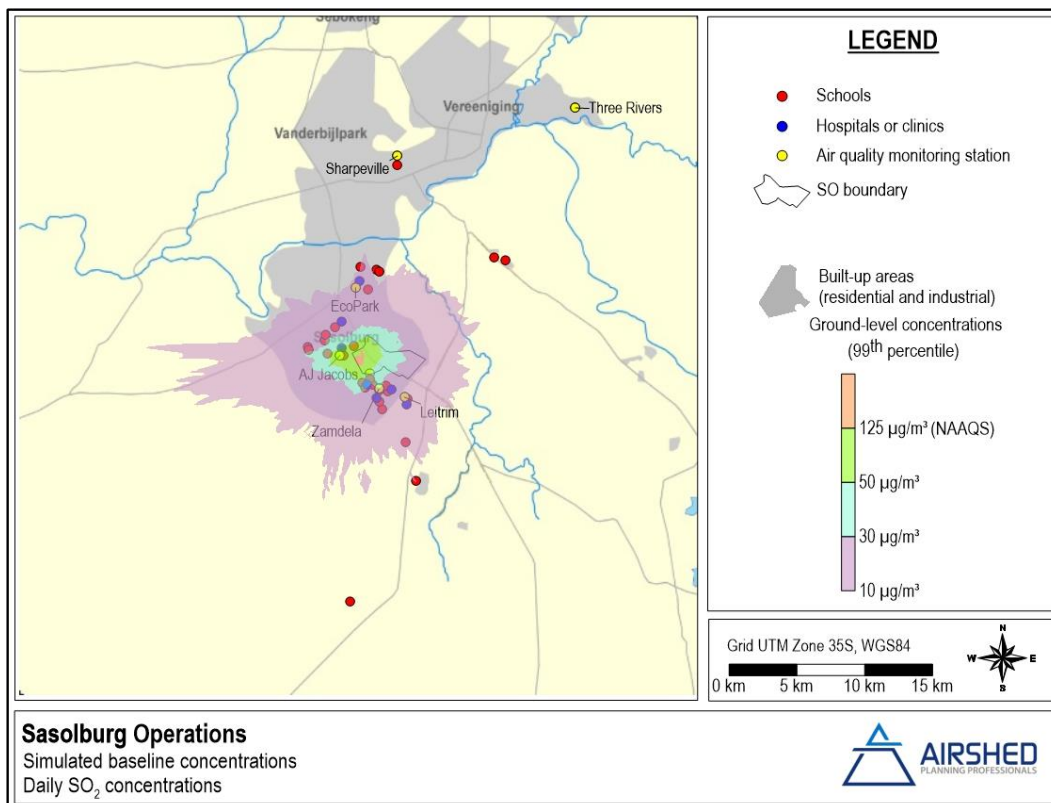Figure 5-78: Simulated hourly SO₂ concentrations (99th percentile) as a result of alternative emissions

Figure 5-79: Simulated daily SO₂ concentrations (99th percentile) as a result of baseline emissions

Figure 5-80: Simulated daily SO₂ concentrations (99th percentile) as a result of theoretical compliance with new plant emission standards

Figure 5-81: Simulated daily SO₂ concentrations (99th percentile) as a result of alternative emissions

Figure 5-82: Simulated annual SO₂ concentrations as a result of baseline emissions
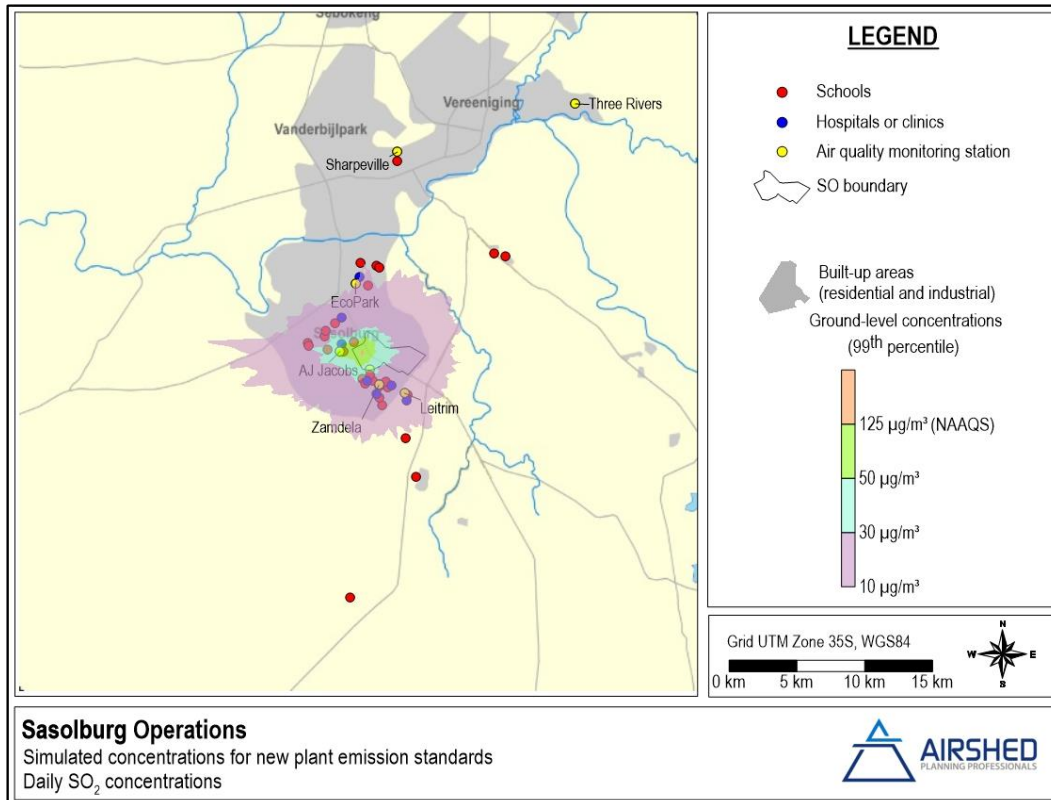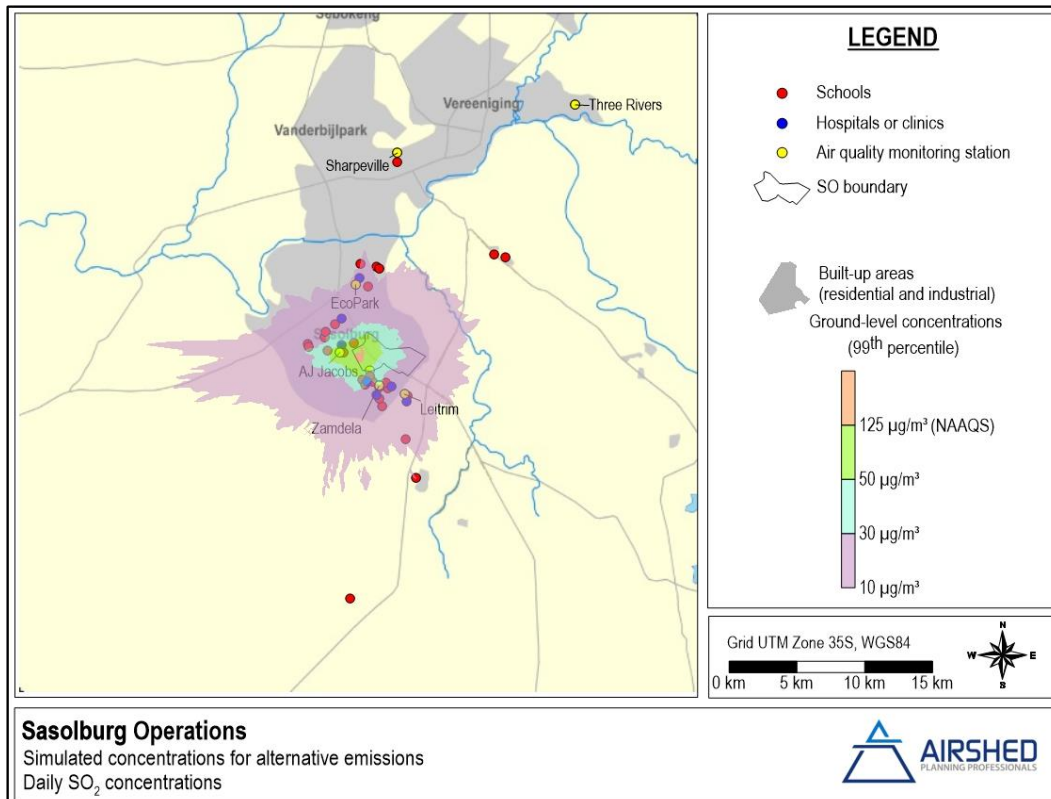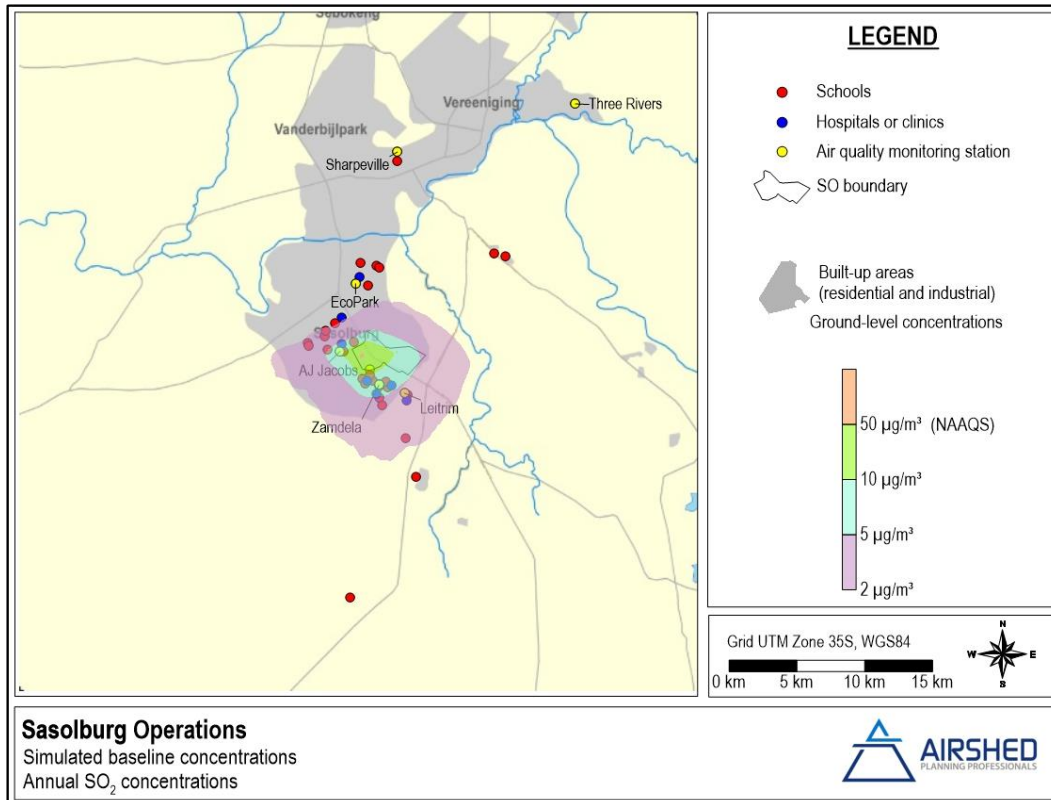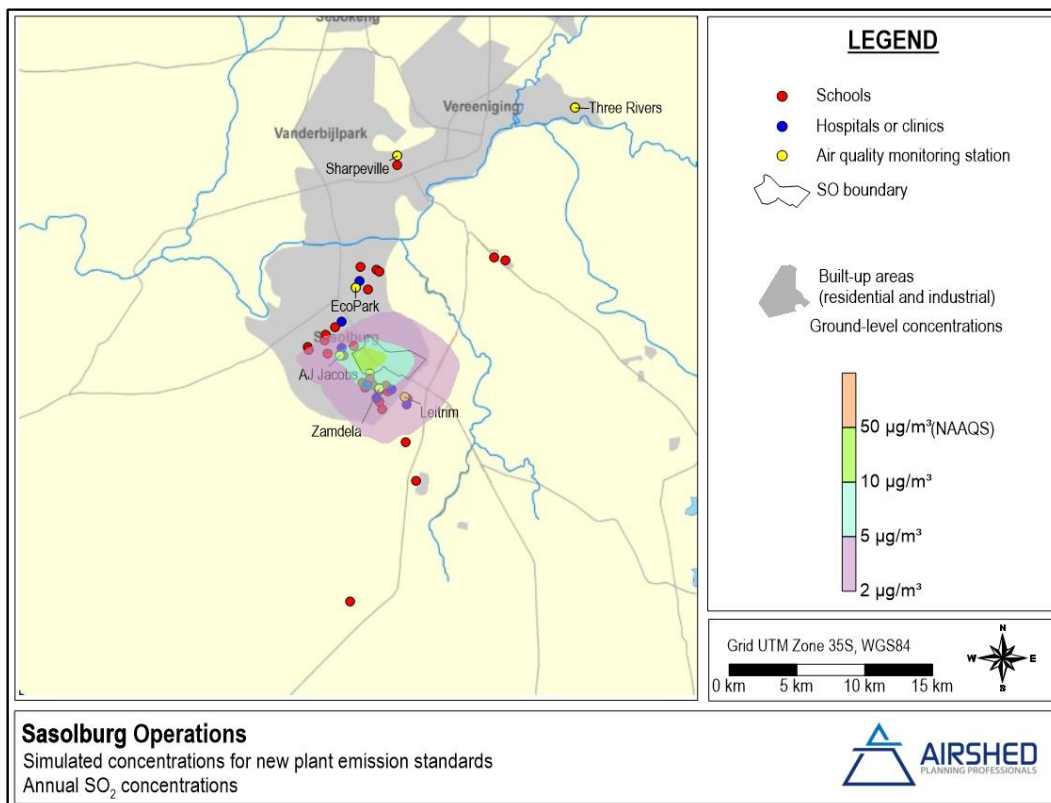

Figure 5-83: Simulated annual SO₂ concentrations as a result of theoretical compliance with new plant emission standards
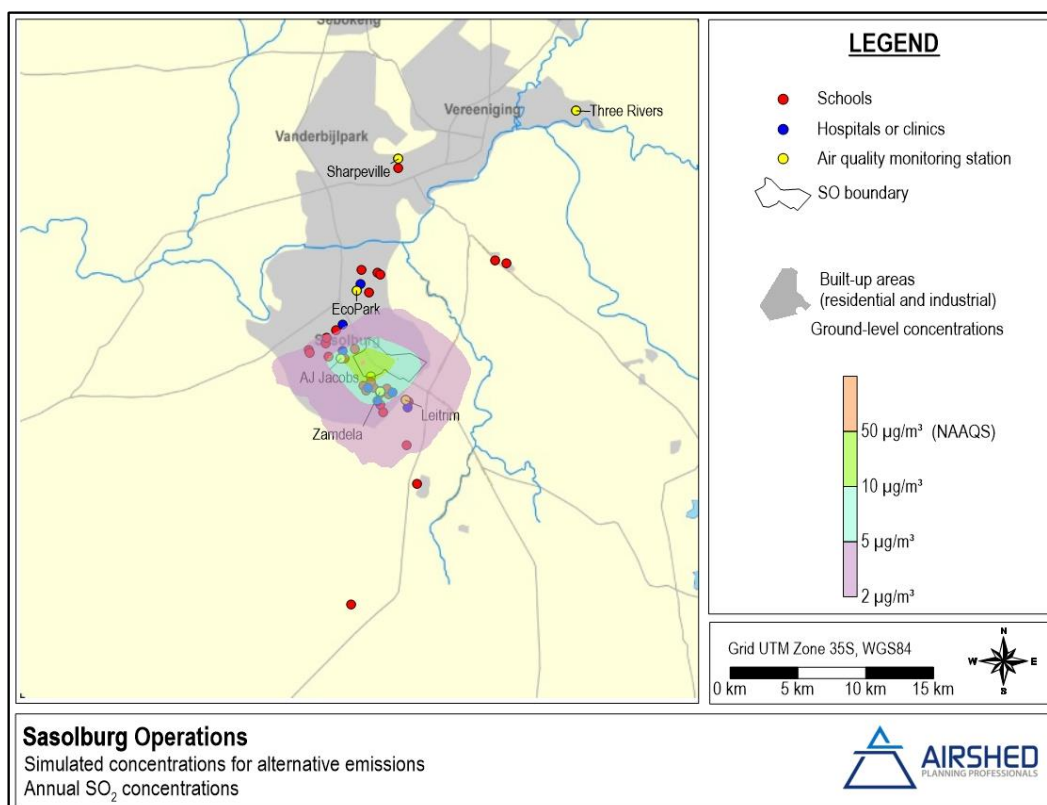
Figure 5-84: Simulated annual SO₂ concentrations as a result of alternative emissions

5.1.8.1.2   Nitrogen dioxide (NO₂)

Compliance with the hourly and annual NAAQS is simulated at the AQMS (Figure 5-85 and Figure 5-86) and receptors (Table 5-25 and Table 5-26) for all scenarios. Theoretical compliance with the new plant emission standards will result in a reduction in ground-level concentrations by up to a maximum of 26% (Table 5-25 and Table 5-26). On average the reduction is 20% at the AQMS and receptors (based on the annual concentrations). The alternative emission scenario is the same as the baseline scenario.

For AJ Jacobs and Leitrim higher concentrations were simulated than the observed peak and 99th percentile concentrations. This may be due to the rather simplistic methodology of applying a constant conversion rate from NO_x to NO_2 (Section 5.1.4.3).

Isopleth plots are presented for all averaging periods ground-level NO₂ concentrations as a result of all emission scenarios for SO, as per the figure numbers below:

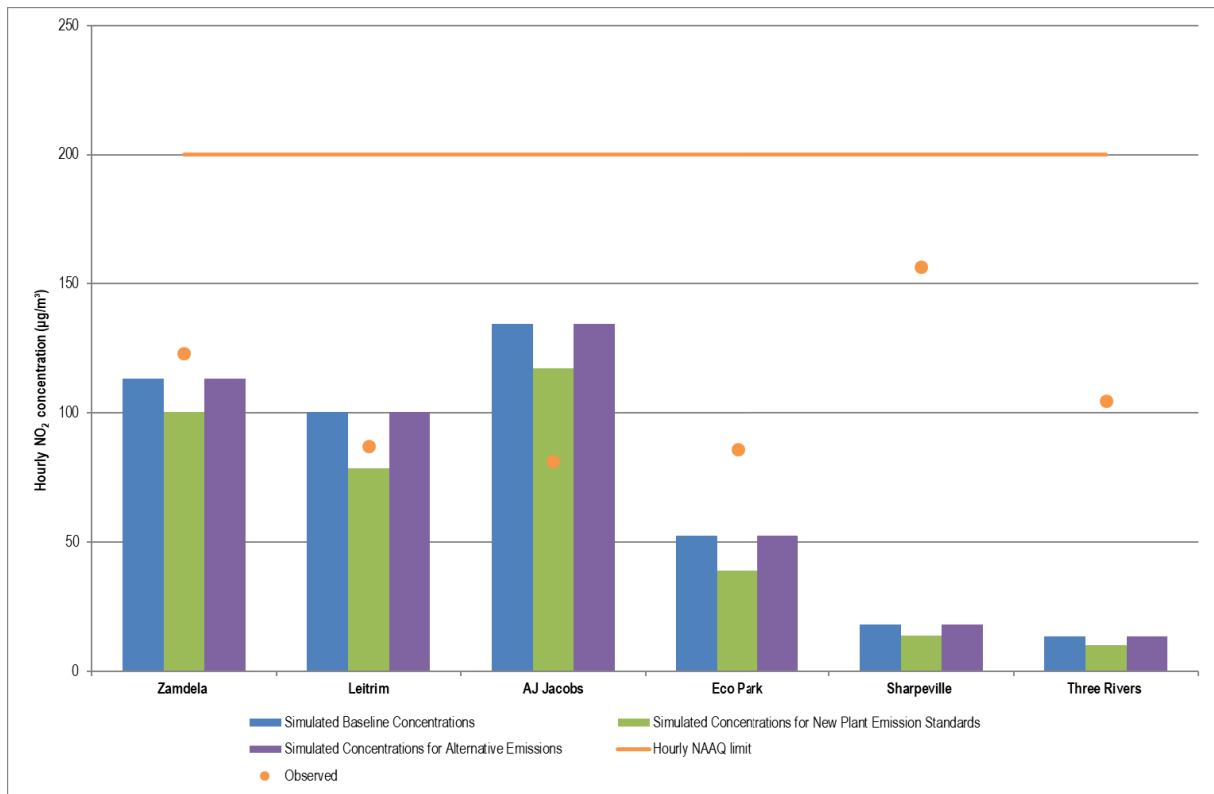| Scenario	Hourly	Annual
Baseline concentrations	Figure 5-87	Figure 5-90
New Plant standards	Figure 5-88	Figure 5-91
Alternative emissions	Figure 5-89	Figure 5-92

Figure 5-85: Simulated hourly NO$_2$ concentrations (99th percentile) at AQMS for Sasolburg Operations
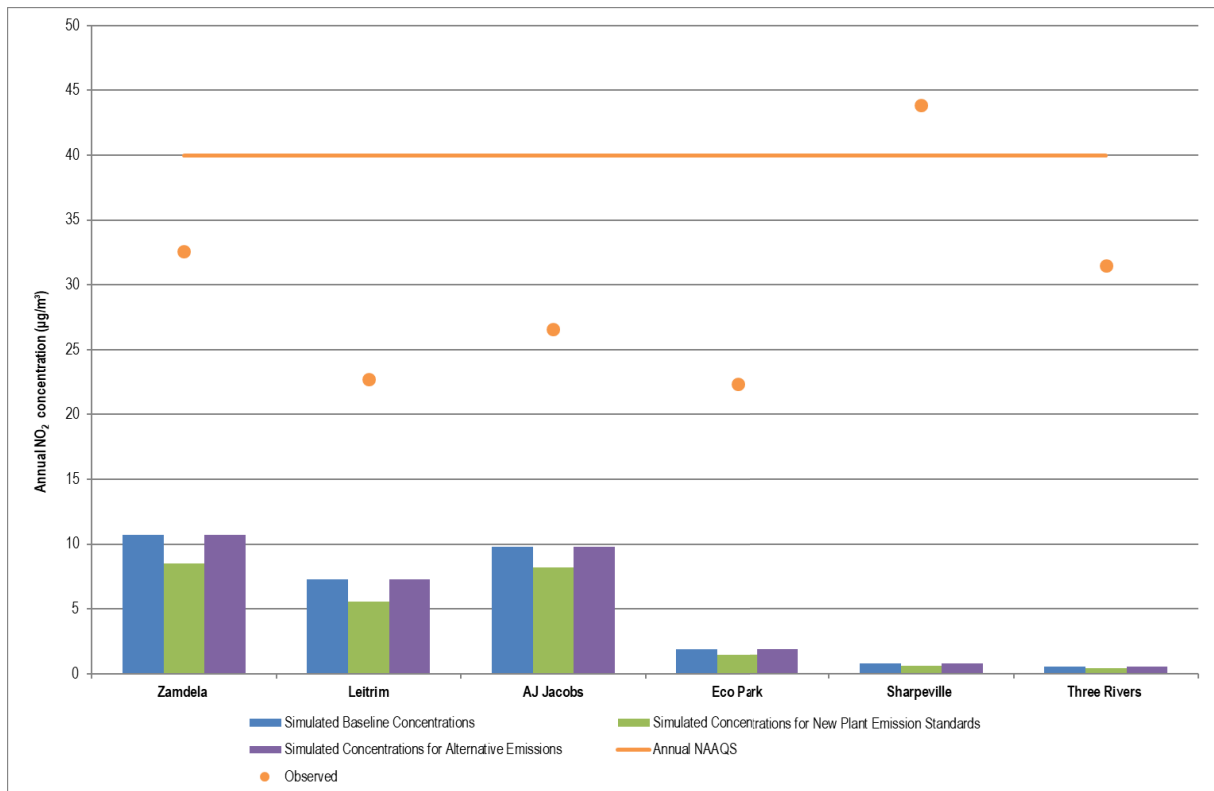

Figure 5-86: Simulated annual NO$_2$ concentrations at AQMS for Sasolburg Operations

Table 5-25: Simulated baseline hourly NO$_2$ concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors

Receptor	Hourly NO$_2$ (99th percentile)				
	Baseline	New		Alternative	
	Concentration (µg/m³)	Concentration (µg/m³)	Relative change	Concentration (µg/m³)	Relative change
Zamdela AQMS	112.1	97.7	-12.9%	112.1	0%
Leitrim AQMS	98.6	77.1	-21.8%	98.6	0%
AJ Jacobs AQMS	118.6	116.2	-2.1%	118.6	0%
Eco Park AQMS	47.1	34.8	-26.2%	47.1	0%
Sharpeville AQMS	17.1	13.0	-23.7%	17.1	0%
Three Rivers AQMS	12.3	9.2	-25.1%	12.3	0%
Malakabeng Primary School	116.1	110.9	-4.5%	116.1	0%
Cedar Secondary School	111.2	96.3	-13.5%	111.2	0%
Bofula- Tshepe Primary School	111.8	96.0	-14.1%	111.8	0%
Clinic A Zamdela	112.5	98.7	-12.2%	112.5	0%
Zamdela Hospital Zumayear	114.7	106.6	-7.1%	114.7	0%
Iketsetseng Secondary School	111.8	96.0	-14.1%	111.8	0%
Clinic B Zamdela	108.9	90.5	-16.9%	108.9	0%
Tsatsi Primary School	117.1	111.9	-4.4%	117.1	0%
Isaac Mhlambi Primary School	109.0	91.8	-15.8%	109.0	0%
Nkopoleng Secondary School	114.6	105.0	-8.4%	114.6	0%
HTS Secondary School	123.8	117.1	-5.4%	123.8	0%
Zamdela Community Clinic	106.7	85.5	-19.9%	106.7	0%
AJ Jacobs Primary School	130.8	117.2	-10.4%	130.8	0%
Theha Setjhaba Primary School	104.3	84.1	-19.4%	104.3	0%
Sasolburg Clinic	117.8	114.8	-2.6%	117.8	0%
Credo Primary School	94.7	73.9	-22.0%	94.7	0%
Lehutso Primary School	100.0	79.5	-20.5%	100.0	0%
Harry Gwala Clinic	Creche	92.0	71.9	-21.8%	92.0	0%
Kahobotjha-Sakubusha Secondary School	114.6	108.2	-5.6%	114.6	0%
Sasolburg Provincial Hospital	82.6	61.9	-25.1%	82.6	0%

Table 5-26: Simulated baseline annual NO_2 concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors

Receptor	Annual NO_2				
	Baseline	New		Alternative	
	Concentration	Concentration	Relative change	Concentration	Relative change
Zamdela AQMS	10.5	8.3	-21.2%	10.5	0%
Leitrim AQMS	7.2	5.5	-22.9%	7.2	0%
AJ Jacobs AQMS	8.0	6.7	-16.0%	8.0	0%
Eco Park AQMS	1.7	1.3	-24.5%	1.7	0%
Sharpeville AQMS	0.8	0.6	-24.2%	0.8	0%
Three Rivers AQMS	0.5	0.4	-25.5%	0.5	0%
Malakabeng Primary School	14.1	11.7	-17.1%	14.1	0%
Cedar Secondary School	10.8	8.6	-20.6%	10.8	0%
Bofula- Tshepe Primary School	10.2	8.0	-21.3%	10.2	0%
Clinic A Zamdela	10.7	8.4	-21.1%	10.7	0%
Zamdela Hospital Zumayear	11.1	9.0	-18.7%	11.1	0%
Iketsetseng Secondary School	10.2	8.0	-21.3%	10.2	0%
Clinic B Zamdela	9.6	7.5	-21.2%	9.6	0%
Tsatsi Primary School	11.1	9.3	-15.9%	11.1	0%
Isaac Mhlambi Primary School	9.5	7.5	-21.7%	9.5	0%
Nkopoleng Secondary School	9.9	8.0	-19.2%	9.9	0%
HTS Secondary School	7.7	6.7	-12.7%	7.7	0%
Szamdela Community Clinic	8.3	6.4	-22.3%	8.3	0%
AJ Jacobs Primary School	8.9	7.5	-16.0%	8.9	0%
Theha Setjhaba Primary School	7.7	5.9	-22.6%	7.7	0%
Sasolburg Clinic	6.4	5.6	-13.1%	6.4	0%
Credo Primary School	6.8	5.2	-22.9%	6.8	0%
Lehutso Primary School	6.7	5.2	-22.9%	6.7	0%
Harry Gwala Clinic	Creche	6.5	5.0	-22.9%	6.5	0%
Kahobotjha-sakubusha Secondary School	5.7	4.7	-17.1%	5.7	0%
Sasolburg Provincial Hospital	2.6	2.1	-21.2%	2.6	0%

Figure 5-87: Simulated hourly NO₂ concentrations (99th percentile) as a result of baseline emissions

Figure 5-88: Simulated hourly NO₂ concentrations (99th percentile) as a result of theoretical compliance with new plant emission standards

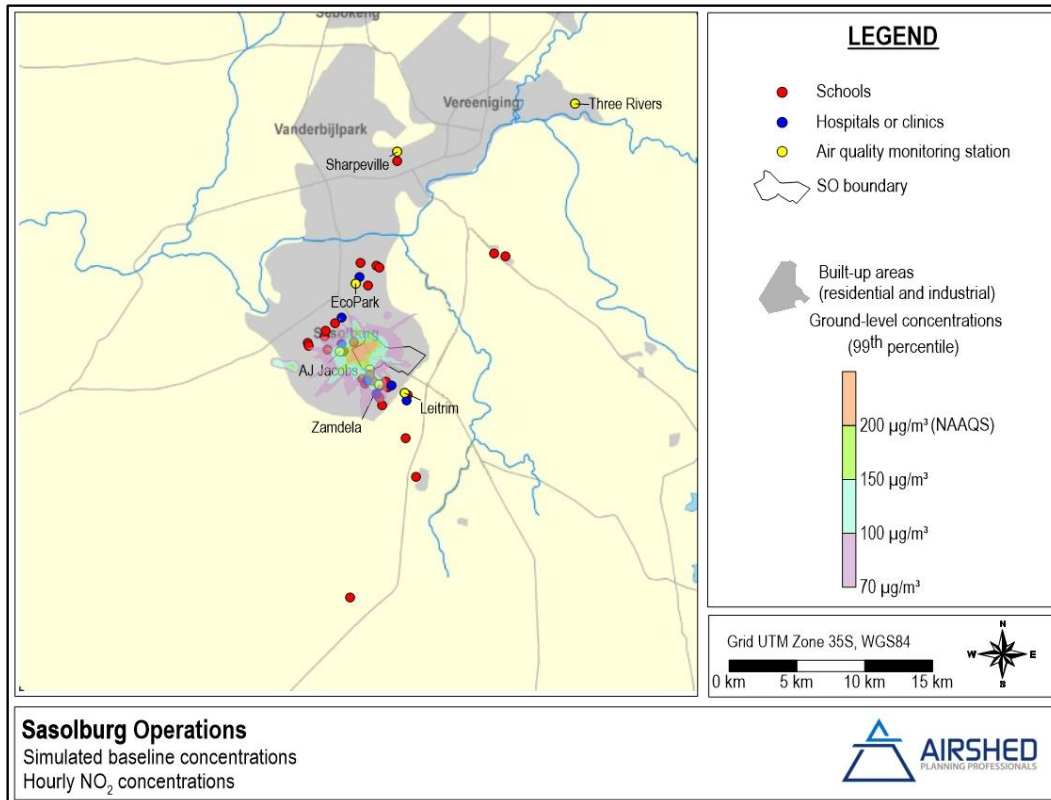Figure 5-89: Simulated hourly NO₂ concentrations (99th percentile) as a result of alternative emissions

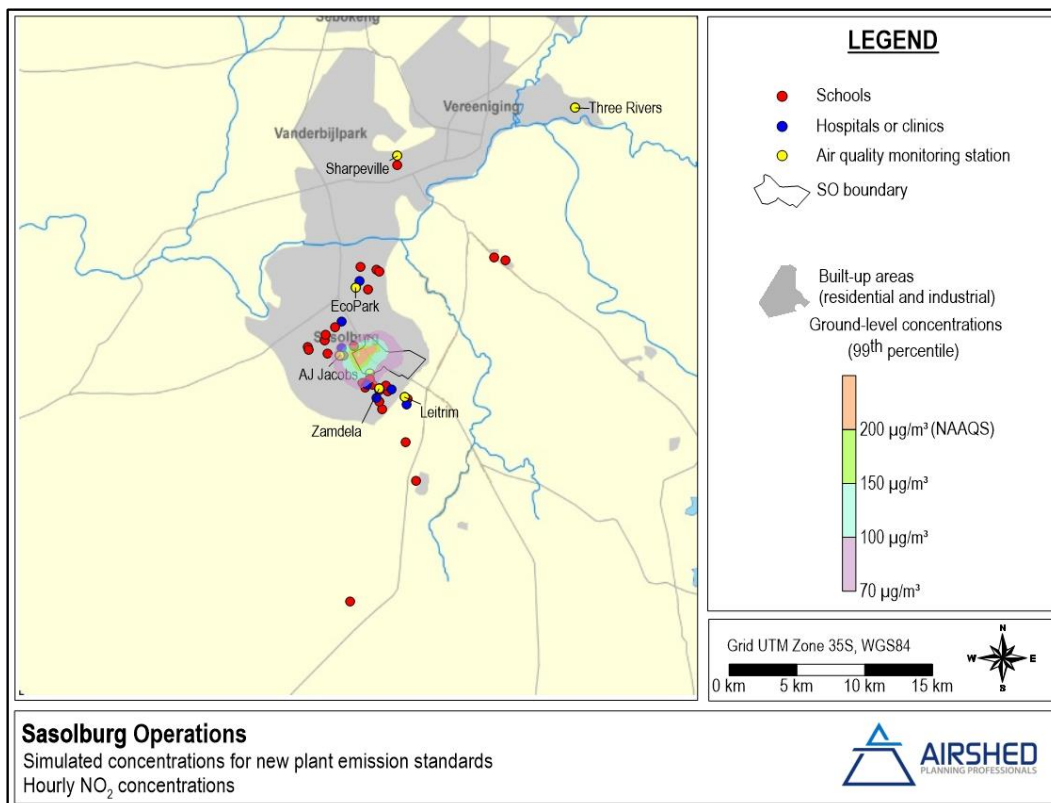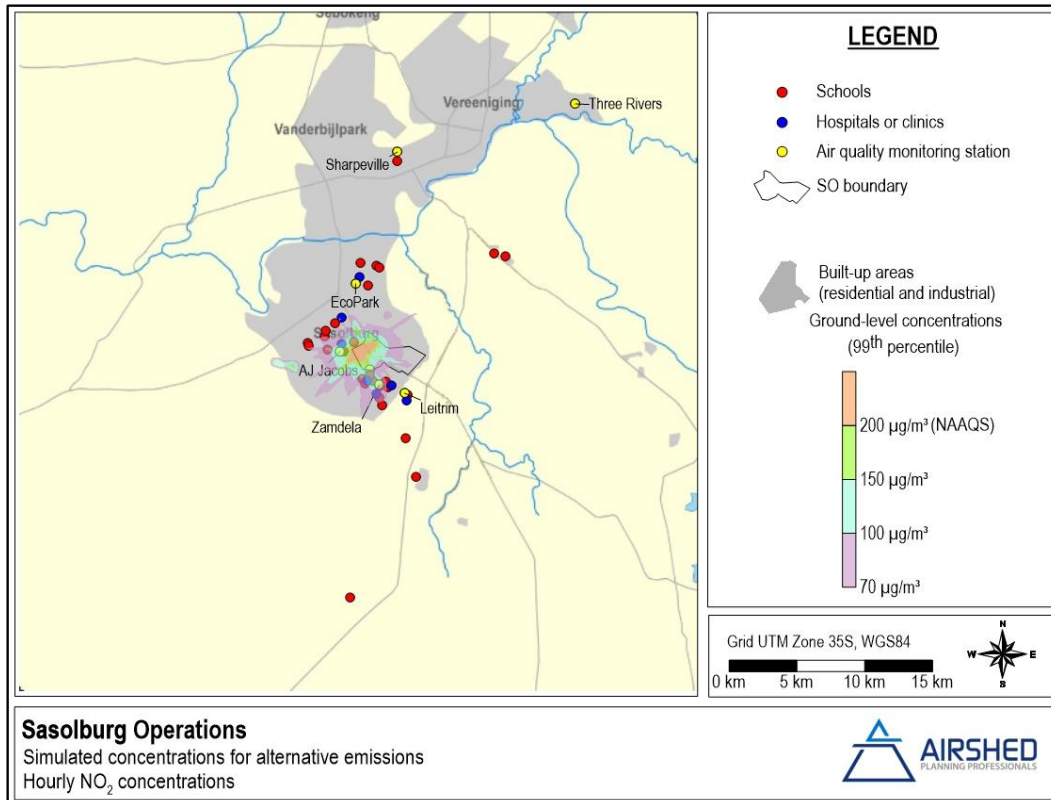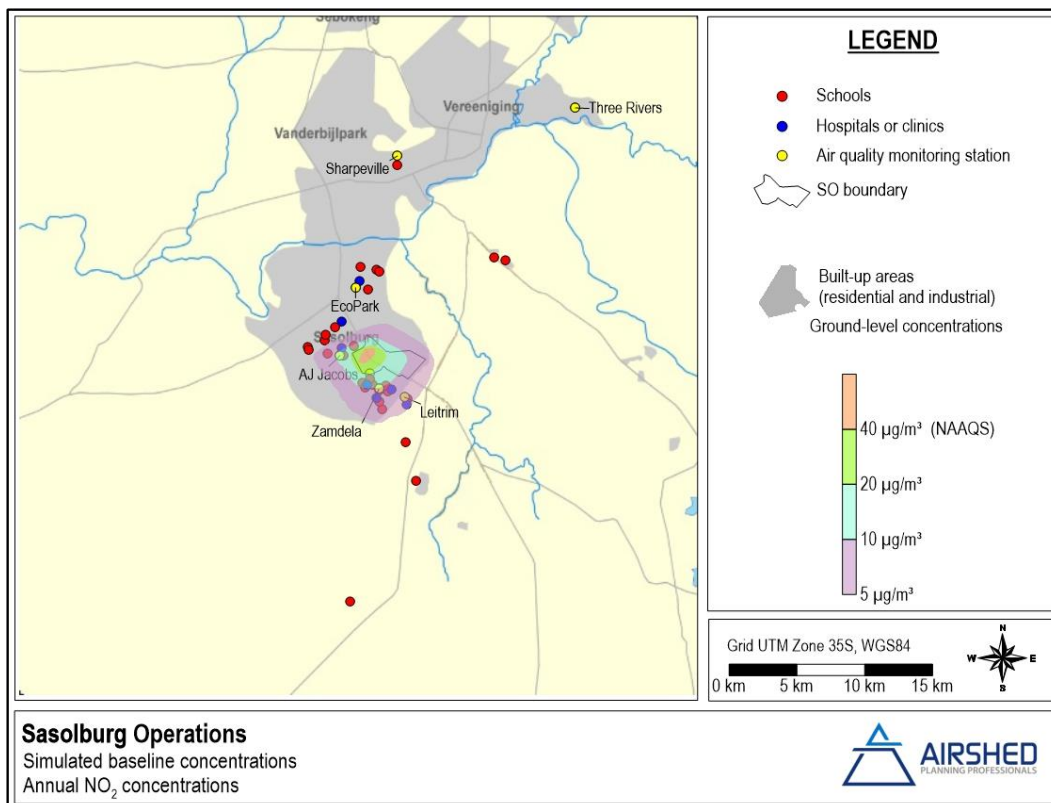Figure 5-90: Simulated annual NO₂ concentrations as a result of baseline emissions
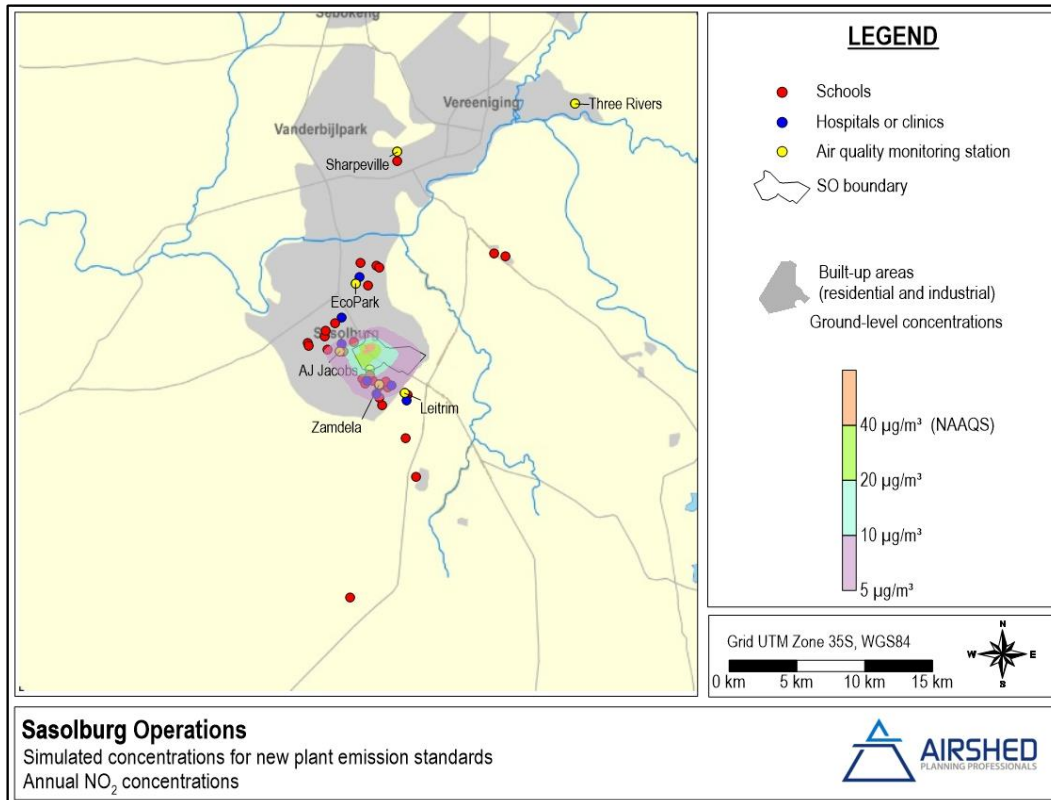
Figure 5-91: Simulated annual NO₂ concentrations as a result of theoretical compliance with new plant emission standards
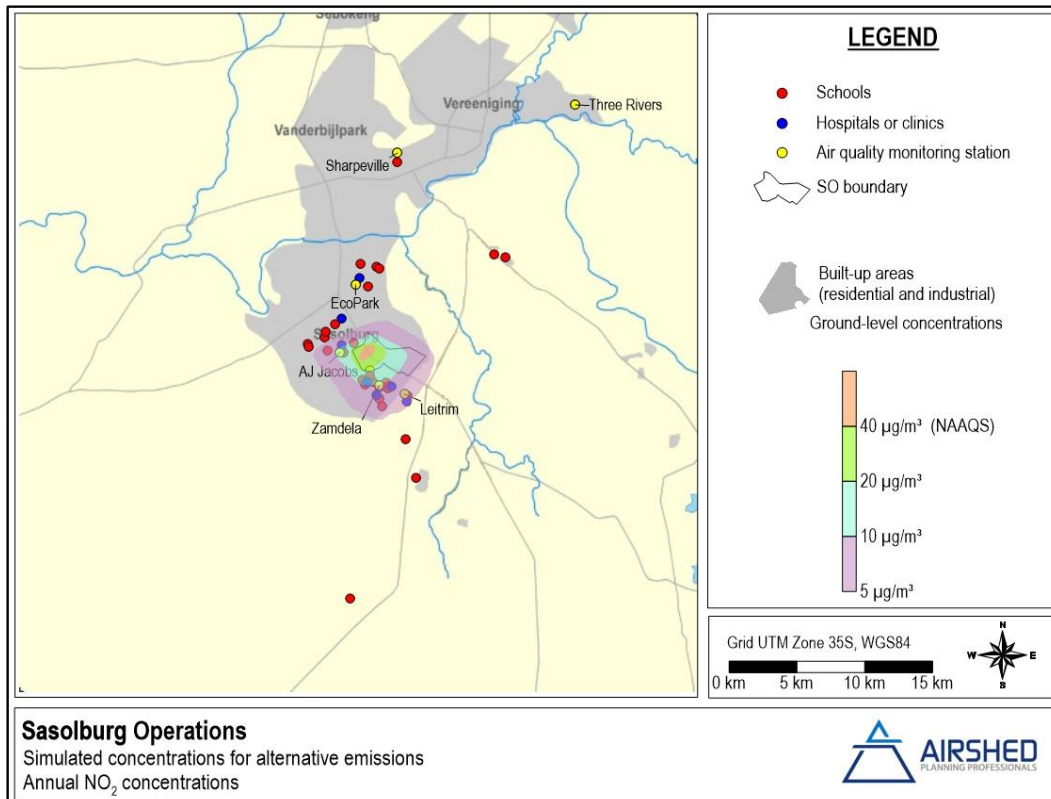

Figure 5-92: Simulated annual NO₂ concentrations as a result of alternative emissions

5.1.8.1.3 Particulate Matter (PM$_{10}$ and PM$_{2.5}$)

The baseline emissions from SO result in low ground-level concentrations of PM; less than 20 **µg/m³** daily concentrations at all AQMS (Figure 5-93). Simulated annual PM concentrations are less than 5 **µg/m³** at all AQMS (Figure 5-94). Theoretical compliance with the new plant standards will result in reduction of ground-level PM concentrations by up to 60%, while the alternative emissions stay the same as the baseline emissions (Table 5-27 and Table 5-28).

For particulate matter, NAAQS are available for PM$_{10}$ and PM$_{2.5}$. Ambient air quality impacts for both particulate fractions (i.e. PM$_{10}$ and PM$_{2.5}$) thus need to be considered. Simulated concentrations of particulate matter (PM) are conservatively assumed to be PM$_{2.5}$ since it is not possible to establish the PM$_{2.5}$/PM$_{10}$ split of emissions from SO only. Figure 5-93 and Figure 5-94 present predicted PM concentrations at the AQMS relative to both the PM$_{10}$ and PM$_{2.5}$ NAAQS.

PM$_{10}$ and PM$_{2.5}$ measurements at the AQMS suggest a 50% contribution of PM$_{2.5}$ to PM$_{10}$; however, the sources contributing to the PM signature at the AQMS are varied, including the SO sources, other industrial sources, windblown particulates, vehicles, domestic fuel burning, mining, agriculture, and power generation. The range of the 2015 – 2017 PM$_{2.5}$:PM$_{10}$ ratios at the AQMS in the Sasolburg domain ranged between 0.31 and 0.59 (Section 5.1.5.4); while the urban population-weighted average across South Africa in 2000 - reported by Norman *et al.* (2007) - was 0.57. A study in the Vaal Triangle used the PM$_{2.5}$:PM$_{10}$ ratio of 0.59 based on the concentrated industrial activity in the area (Witi, 2005). This value (0.59) is slightly more conservative than the measured ambient data and the population-weighted country average.

Based on the conservative assumption that all PM is in the PM$_{2.5}$ fraction, the simulated daily and annual PM$_{2.5}$ concentrations comply with the current daily PM$_{2.5}$ NAAQS (40 **µg/m³**), for all scenarios (Table 5-27 and Table 5-28).

Isopleth plots are presented for all averaging periods ground-level PM concentrations as a result of all emission scenarios for SO, as per the figure numbers below:

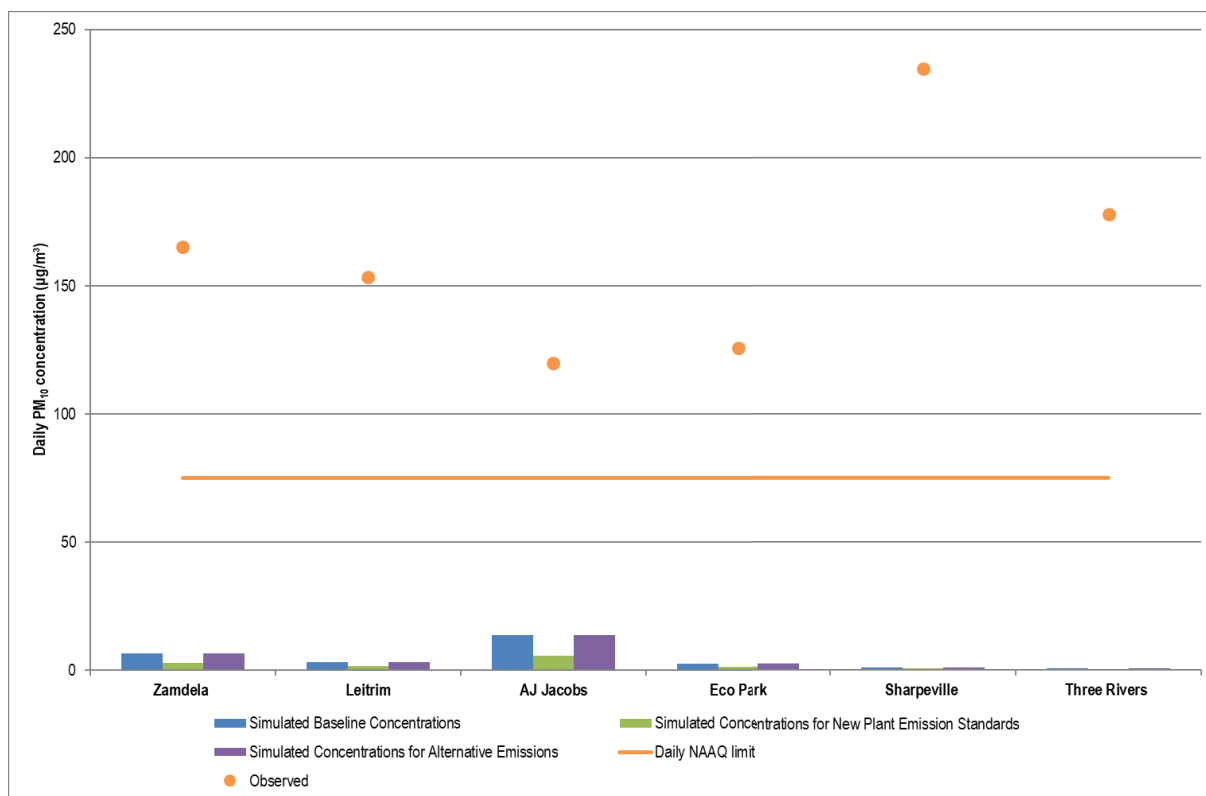| Scenario	Daily	Annual
Baseline concentrations	Figure 5-95	Figure 5-98
New Plant standards	Figure 5-96	Figure 5-99
Alternative emissions	Figure 5-97	Figure 5-100

Figure 5-93: Simulated daily PM concentrations (99th percentile) at AQMS for Sasolburg Operations
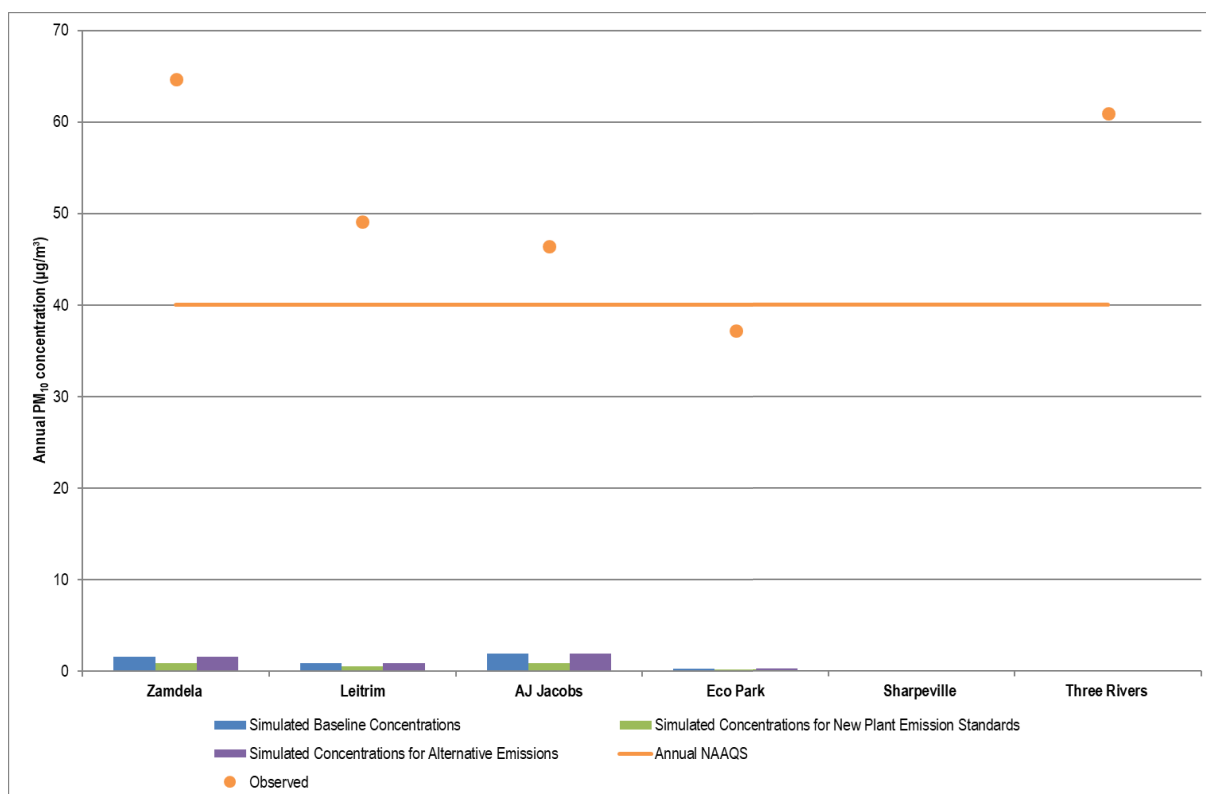

Figure 5-94: Simulated annual PM concentrations at AQMS for Sasolburg Operations

Table 5-27: Simulated baseline daily PM concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors

Receptor	Daily PM (99th percentile)				
	Baseline	New		Alternative	
	Concentration (µg/m³)	Concentration (µg/m³)	Relative change	Concentration (µg/m³)	Relative change
Zamdela AQMS[a]	6.0	2.8	-53.1%	6.0	0%
Leitrim AQMS[a]	3.2	1.7	-47.7%	3.2	0%
AJ Jacobs AQMS[a]	13.0	5.4	-58.3%	13.0	0%
Eco Park AQMS[a]	2.3	1.2	-48.1%	2.3	0%
Sharpeville AQMS[a]	1.0	0.5	-45.8%	1.0	0%
Three Rivers AQMS[a]	0.6	0.4	-34.6%	0.6	0%
Malakabeng Primary School[a]	8.8	4.7	-47.0%	8.8	0%
Cedar Secondary School[a]	5.3	2.6	-50.3%	5.3	0%
Bofula- Tshepe Primary School[a]	6.0	2.7	-54.3%	6.0	0%
Clinic A Zamdela[a]	6.0	2.8	-53.1%	6.0	0%
Zamdela Hospital Zumayear[a]	6.8	3.9	-43.1%	6.8	0%
Iketsetseng Secondary School[a]	6.0	2.7	-54.3%	6.0	0%
Clinic B Zamdela[a]	4.3	2.4	-45.0%	4.3	0%
Tsatsi Primary School[a]	8.5	4.4	-49.1%	8.5	0%
Isaac Mhlambi Primary School[a]	4.8	2.4	-49.0%	4.8	0%
Nkopoleng Secondary School[a]	6.3	3.3	-47.5%	6.3	0%
HTS Secondary School[a]	10.7	4.6	-56.6%	10.7	0%
Zamdela Community Clinic[a]	4.6	2.4	-48.7%	4.6	0%
AJ Jacobs Primary School[a]	14.3	5.7	-60.4%	14.3	0%
Theha Setjhaba Primary School[a]	4.2	2.1	-49.2%	4.2	0%
Sasolburg Clinic[a]	10.2	4.6	-54.9%	10.2	0%
Credo Primary School[a]	3.1	1.6	-46.7%	3.1	0%
Lehutso Primary School[a]	3.8	1.9	-50.5%	3.8	0%
Harry Gwala Clinic	Creche[a]	3.0	1.7	-44.5%	3.0	0%
Kahobotjha-Sakubusha Secondary School[a]	8.5	3.7	-56.3%	8.5	0%
Sasolburg Provincial Hospital[a]	3.3	1.7	-50.2%	3.3	0%

Note:
(a)   Conservatively assumes all PM is either PM_{10} or $PM_{2.5}$.

Table 5-28: Simulated baseline annual PM concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors

| Receptor | Annual PM | | | | |
| | Baseline | New | | Alternative | |
	Concentration (µg/m³)	Concentration (µg/m³)	Relative change	Concentration (µg/m³)	Relative change
Zamdela AQMS	1.6	0.8	-46.7%	1.6	0%
Leitrim AQMS	0.9	0.5	-44.5%	0.9	0%
AJ Jacobs AQMS	1.5	0.7	-51.8%	1.5	0%
Eco Park AQMS	0.2	0.1	-43.1%	0.2	0%
Sharpeville AQMS	0.1	0.1	-40.4%	0.1	0%
Three Rivers AQMS	0.1	0.0	-40.6%	0.1	0%
Malakabeng Primary School	2.5	1.4	-44.4%	2.5	0%
Cedar Secondary School	1.5	0.8	-46.0%	1.5	0%
Bofula- Tshepe Primary School	1.5	0.8	-46.6%	1.5	0%
Clinic A Zamdela	1.6	0.9	-46.8%	1.6	0%
Zamdela Hospital Zumayear	1.9	1.0	-45.1%	1.9	0%
Iketsetseng Secondary School	1.5	0.8	-46.6%	1.5	0%
Clinic B Zamdela	1.3	0.7	-44.9%	1.3	0%
Tsatsi Primary School	2.2	1.2	-43.7%	2.2	0%
Isaac Mhlambi Primary School	1.3	0.7	-45.5%	1.3	0%
Nkopoleng Secondary School	1.7	0.9	-45.7%	1.7	0%
HTS Secondary School	1.4	0.7	-47.6%	1.4	0%
Zamdela Community Clinic	1.2	0.7	-45.6%	1.2	0%
AJ Jacobs Primary School	1.8	0.8	-52.9%	1.8	0%
Theha Setjhaba Primary School	1.1	0.6	-45.3%	1.1	0%
Sasolburg Clinic	1.1	0.6	-47.4%	1.1	0%
Credo Primary School	0.8	0.5	-44.3%	0.8	0%
Lehutso Primary School	0.9	0.5	-45.0%	0.9	0%
Harry Gwala Clinic	Creche	0.8	0.5	-43.6%	0.8	0%
Kahobotjha-Sakubusha Secondary School	0.9	0.5	-48.7%	0.9	0%
Sasolburg Provincial Hospital	0.4	0.2	-43.5%	0.4	0%

Figure 5-95: Simulated daily PM concentrations (99th percentile) as a result of baseline emissions

Figure 5-96: Simulated daily PM concentrations (99th percentile) as a result of theoretical compliance with new plant emission standards
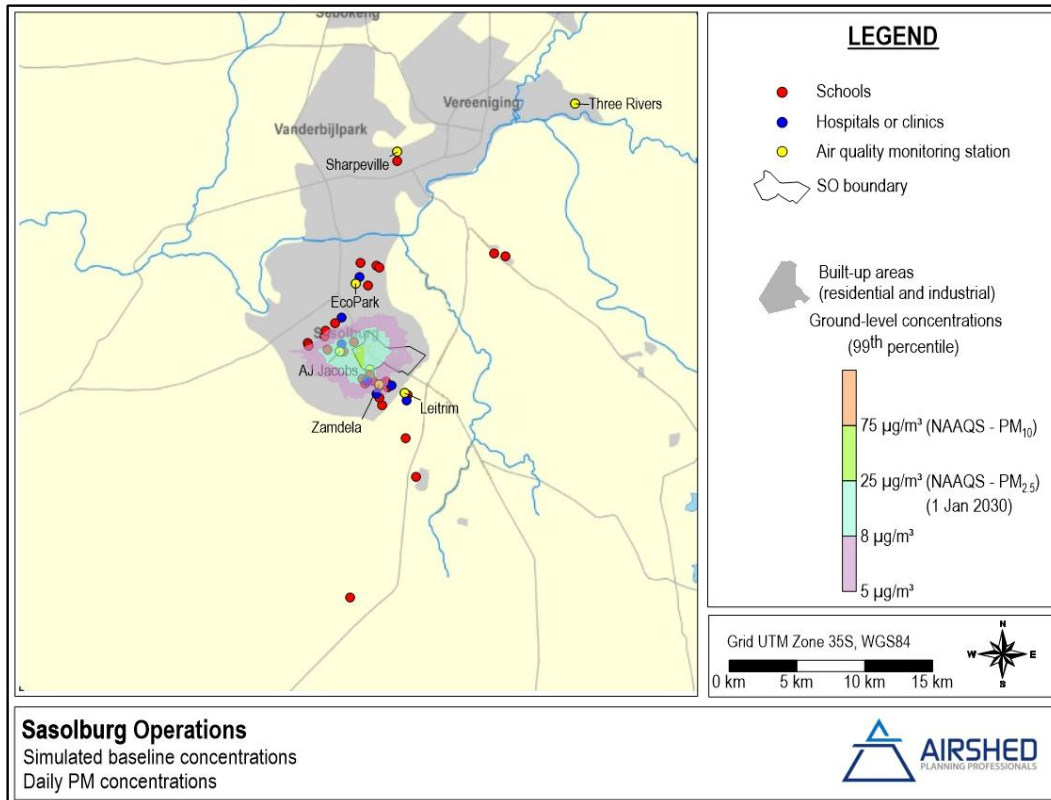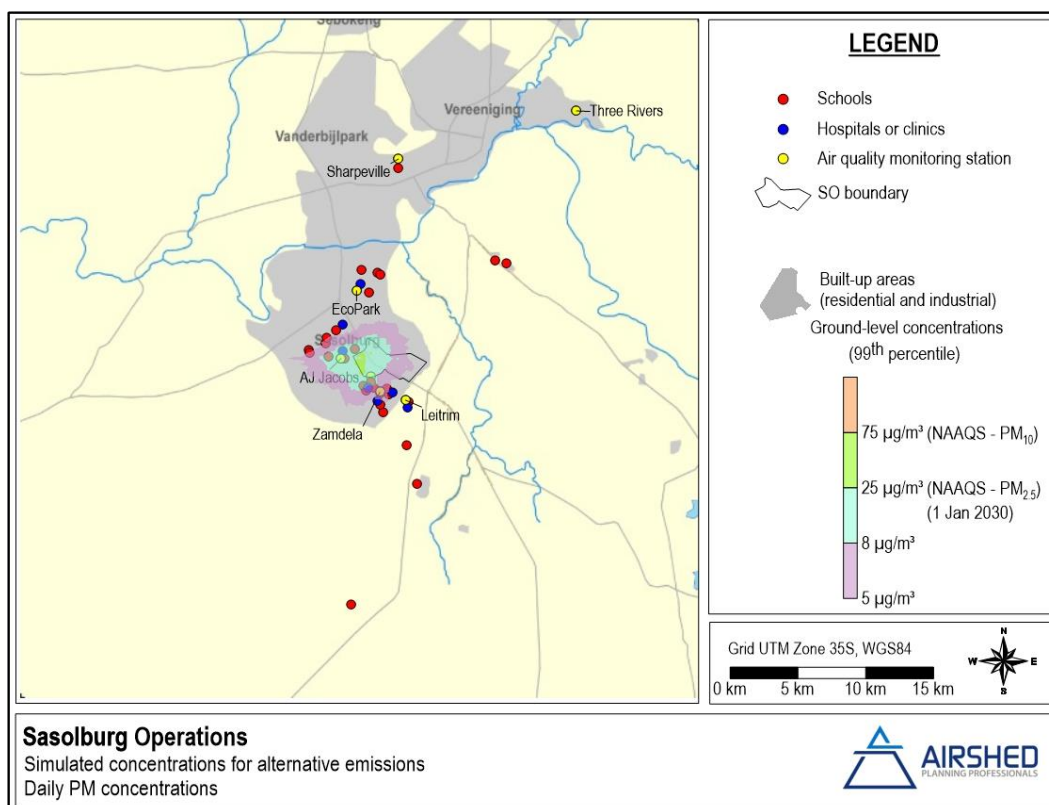
Figure 5-97: Simulated daily PM concentrations (99th percentile) as a result of alternative emissions
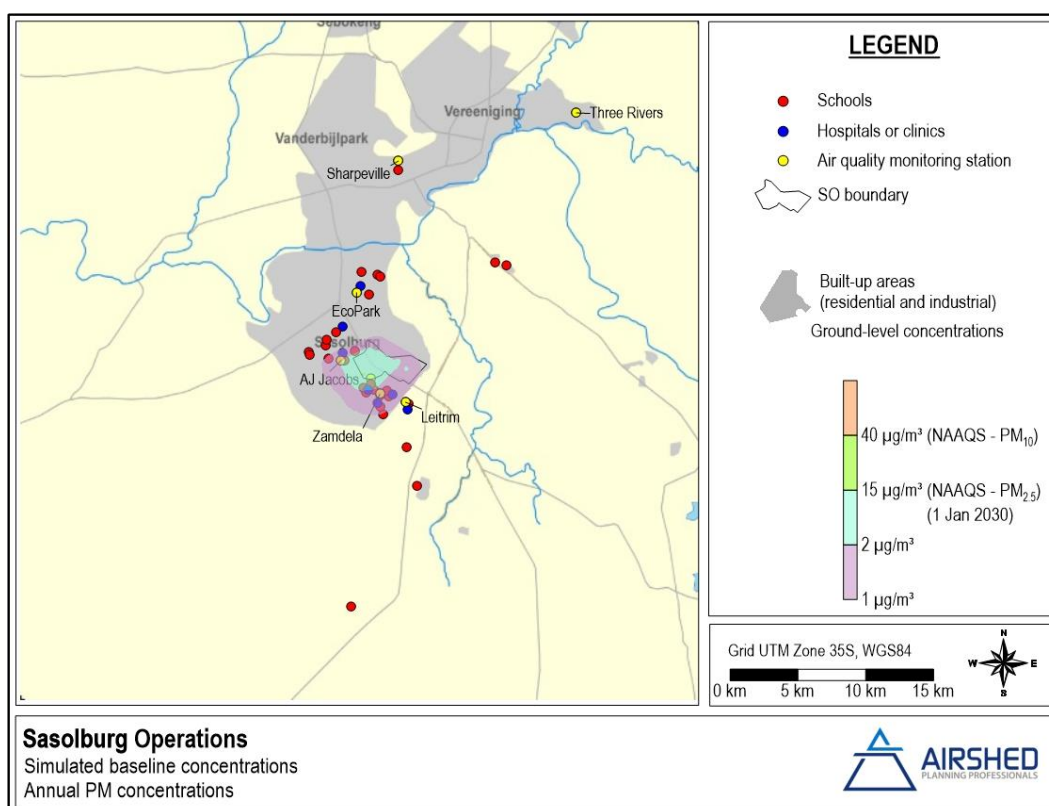
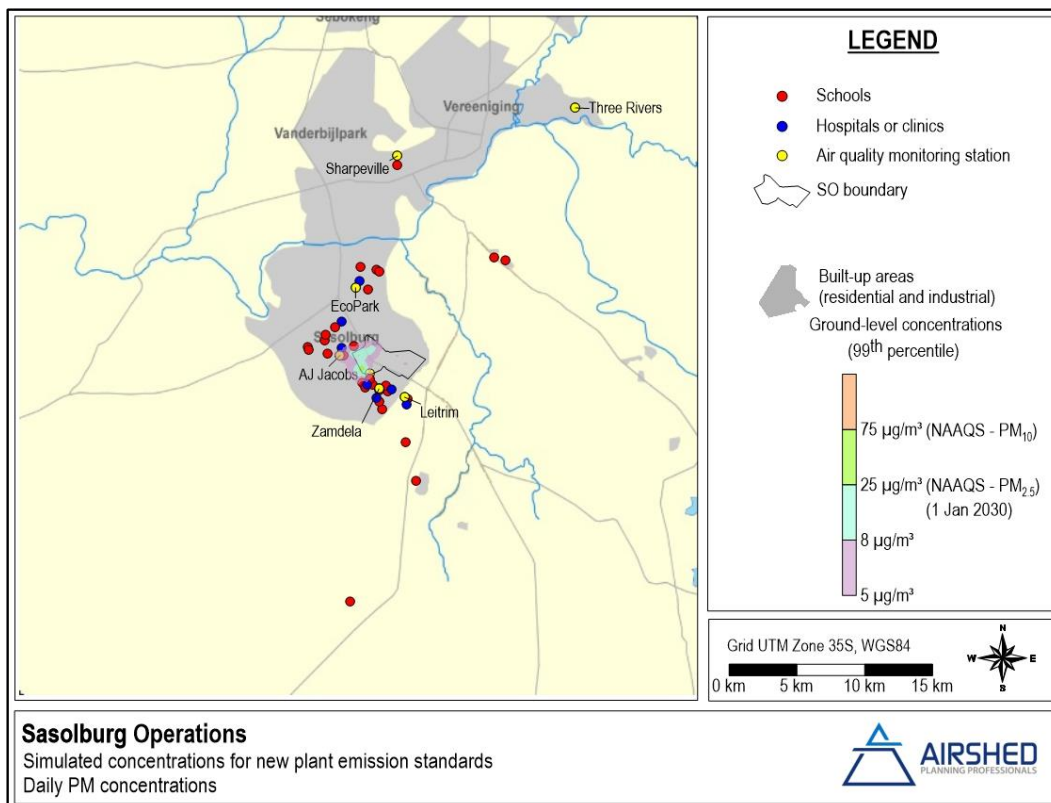Figure 5-98: Simulated annual PM concentrations as a result of baseline emissions
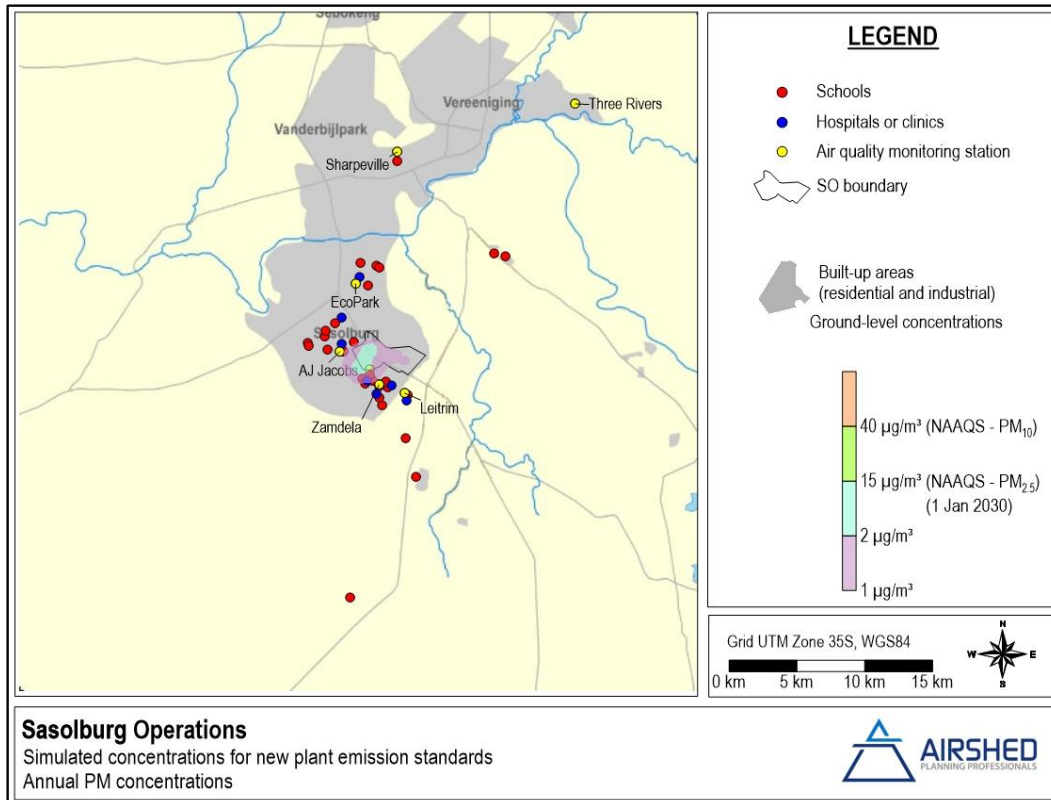
Figure 5-99: Simulated annual PM concentrations as a result of theoretical compliance with new plant emission standards
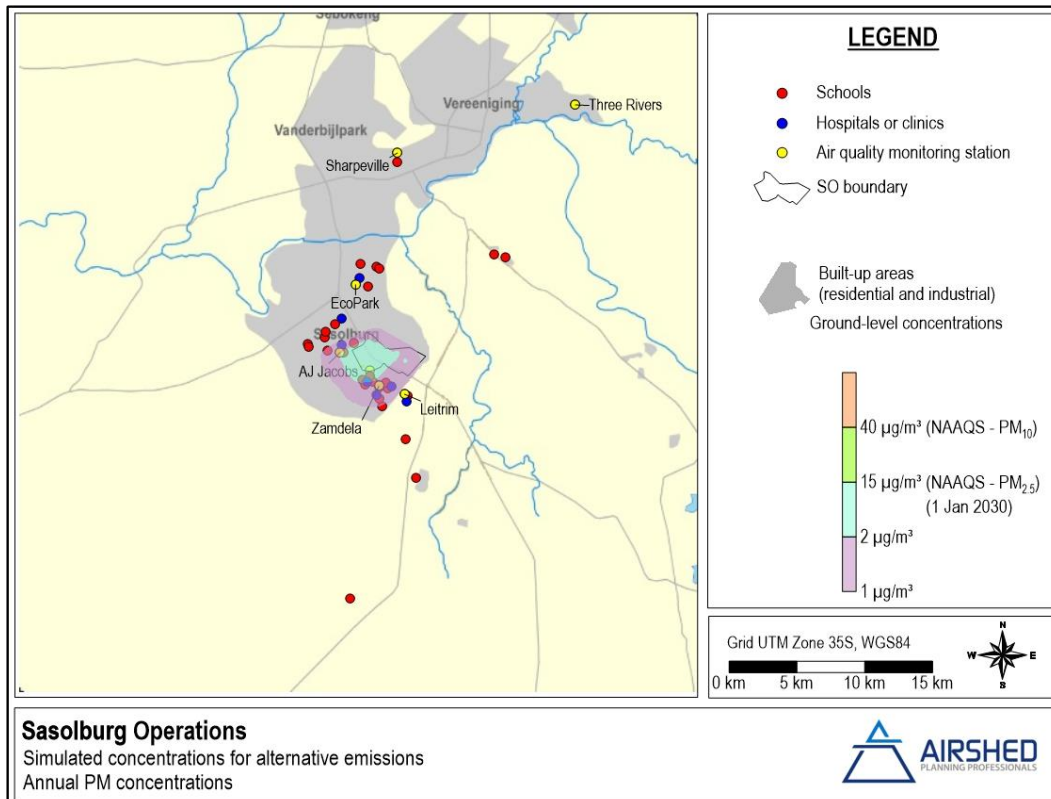
Figure 5-100: Simulated annual PM concentrations as a result of alternative emissions

5.1.8.1.4   Carbon Monoxide (CO)

Only CO sources included in the AEL, were simulated, i.e. the Subcategory 8.1 Thermal Oxidation sources (incinerators). Simulated hourly CO concentrations are in compliance with NAAQS at the AQMS (Figure 5-102) and well below the observed concentrations (Figure 5-102) and receptors (Table 5-29) for all scenarios. Theoretical compliance with the new plant emission standards will result in a reduction in ground-level concentrations by up to a maximum of 91% (Table 5-29). The large variation between the ground-level CO concentrations at the AQMS and receptors is related to the small number of sources included for this pollutant with highly variable emission rates.

Isopleth plots are presented for all averaging periods ground-level CO concentrations as a result of all emission scenarios for SO, as per the figure numbers below:

Scenario	Hourly
Baseline concentrations	Figure 5-103
New Plant standards	Figure 5-104
Alternative emissions	Figure 5-105
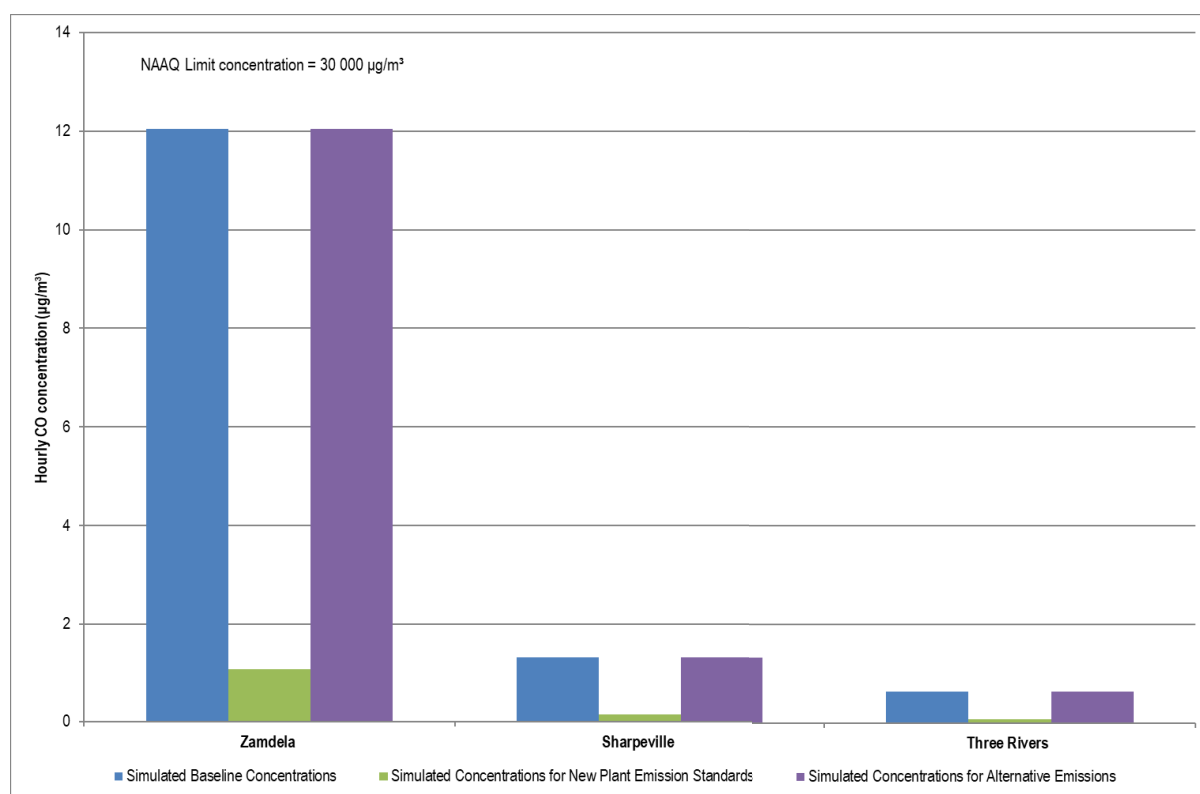
Figure 5-101: Simulated hourly CO concentrations (99th percentile) at AQMS for Sasolburg Operations
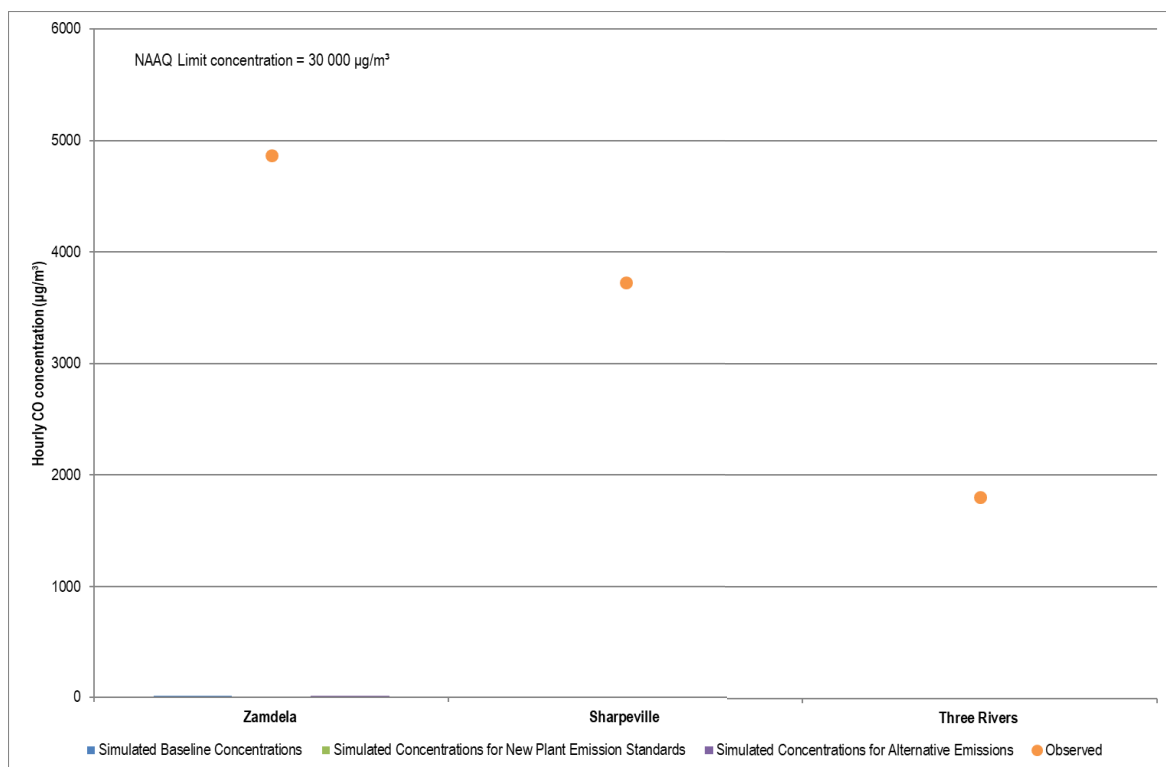
Figure 5-102: Observed hourly CO concentrations (99th percentile) at AQMS for Sasolburg Operations

Table 5-29: Simulated baseline hourly CO concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors

Receptor	Hourly CO					
	Baseline	New			Alternative	
	Concentration (µg/m³)	Concentration (µg/m³)	Relative change		Concentration (µg/m³)	Relative change
Zamdela AQMS	11.5	1.1	-90.5%		11.5	0%
Leitrim AQMS	3.8	0.7	-81.8%		3.8	0%
AJ Jacobs AQMS	17.3	1.6	-90.7%		17.3	0%
Eco Park AQMS	1.4	0.2	-89.2%		1.4	0%
Sharpeville AQMS	0.6	0.1	-88.3%		0.6	0%
Three Rivers AQMS	1.1	0.1	-88.9%		1.1	0%
Malakabeng Primary School	19.4	1.6	-91.6%		19.4	0%
Cedar Secondary School	7.2	1.0	-86.6%		7.2	0%
Bofula- Tshepe Primary School	11.8	1.1	-90.7%		11.8	0%
Clinic A Zamdela	11.4	1.1	-90.4%		11.4	0%
Zamdela Hospital Zumayear	14.4	1.3	-91.0%		14.4	0%
Iketsetseng Secondary School	11.8	1.1	-90.7%		11.8	0%
Clinic B Zamdela	5.7	1.0	-83.4%		5.7	0%
Tsatsi Primary School	18.4	1.6	-91.4%		18.4	0%
Isaac Mhlambi Primary School	6.2	0.9	-86.1%		6.2	0%
Nkopoleng Secondary School	13.2	1.2	-90.9%		13.2	0%
HTS Secondary School	11.2	1.1	-90.1%		11.2	0%
Zamdela Community Clinic	7.9	0.9	-88.8%		7.9	0%
AJ Jacobs Primary School	23.2	2.0	-91.6%		23.2	0%
Theha Setjhaba Primary School	7.1	0.8	-88.5%		7.1	0%
Sasolburg Clinic	8.0	0.9	-89.2%		8.0	0%
Credo Primary School	3.6	0.6	-82.9%		3.6	0%
Lehutso Primary School	6.3	0.8	-87.8%		6.3	0%
Harry Gwala Clinic	Creche	3.8	0.6	-84.2%		3.8	0%
Kahobotjha-Sakubusha Secondary School	7.6	0.8	-89.4%		7.6	0%
Sasolburg Provincial Hospital	2.3	0.3	-88.4%		2.3	0%
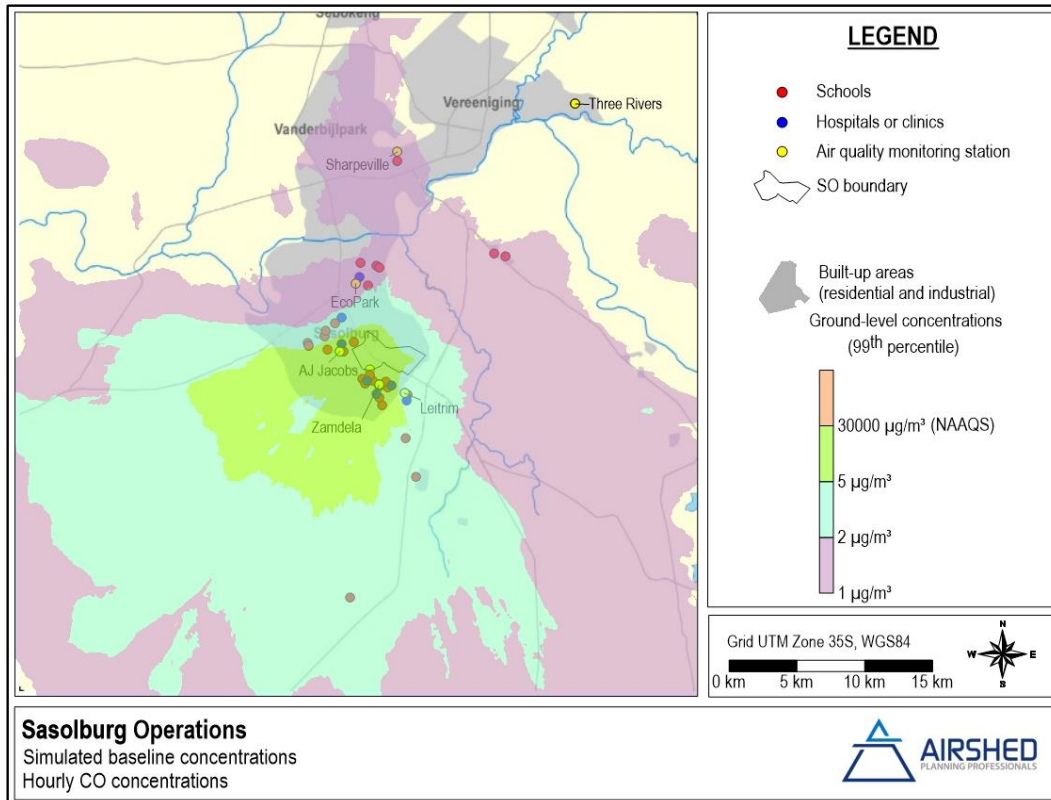
Figure 5-103: Simulated hourly CO concentrations (99th percentile) as a result of baseline emissions
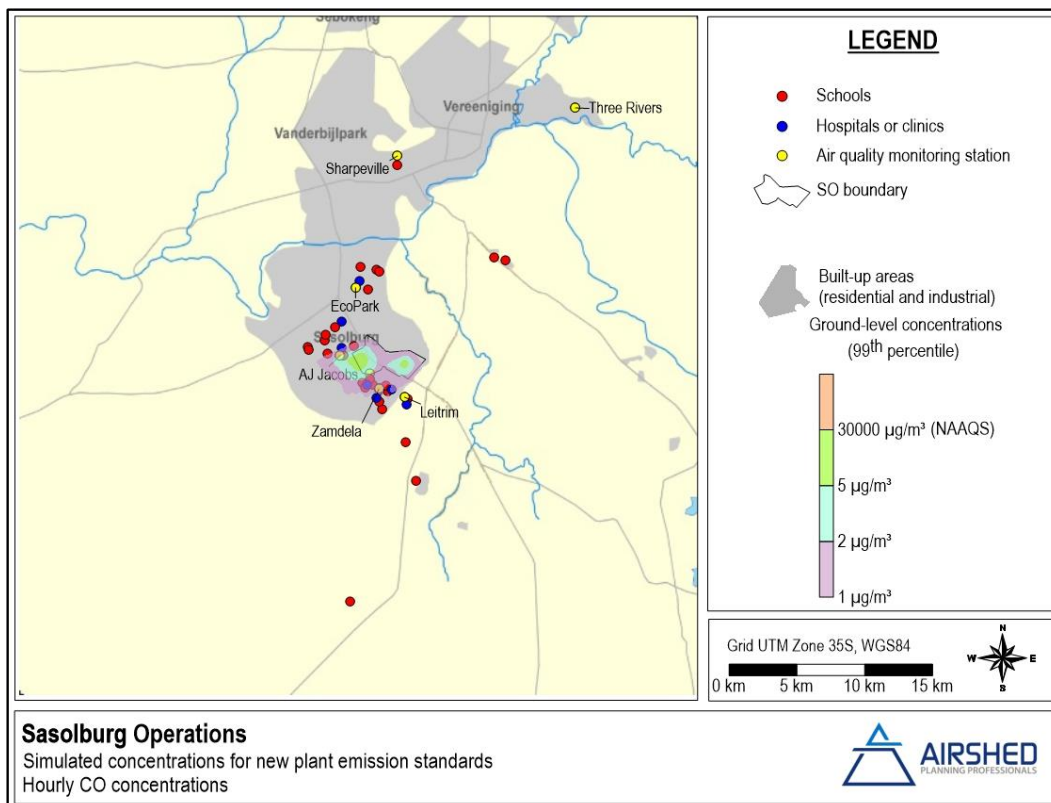
Figure 5-104: Simulated hourly CO concentrations (99th percentile) as a result of theoretical compliance with new plant emission standards
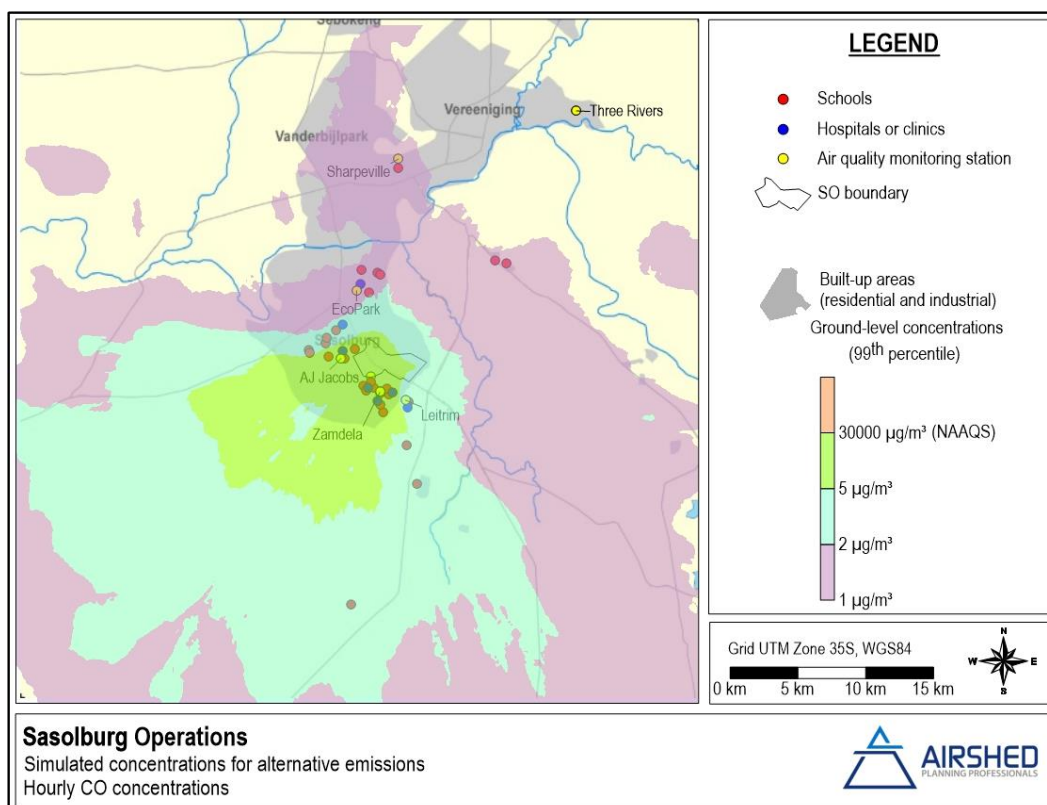
Figure 5-105: Simulated hourly CO concentrations (99th percentile) as a result of alternative emissions

5.1.8.2   Non-criteria pollutants

Ambient pollutant concentrations, either from the dispersion modelling or from direct physical measurements, are typically compared to defined standards or other thresholds to assess the health and/or environmental risk implications of the predicted or measured air quality. In South Africa, NAAQS have been set for criteria pollutants at limits deemed to uphold a permissible level of health risk and the assessment has accordingly been based on a comparison between the predicted concentrations and the NAAQS. The measured concentrations have been used to ascertain the representativeness of the modelling and to assess compliance with the NAAQS as a function of all sources of emissions.

Where NAAQS have not been set health-effect screening levels, appropriate for assessing the non-criteria pollutants emitted from SO, were identified from literature reviews and internationally recognised databases. These non-criteria pollutants for which screening levels were identified include, various emissions from the incinerators, namely lead (Pb), arsenic (As), antimony (Sb), chromium (Cr), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni), vanadium (V), mercury (Hg), cadmium (Cd), thallium (Tl), hydrogen chloride (HCl), hydrogen fluoride (HF), total organic compounds (TOC), volatile organic compounds (VOC), ammonia (NH_3) and dioxins and furans . The health-effect screening levels used are listed in Table 5-30.

Table 5-30: Most stringent health-effect screening level identified for all non-criteria pollutants assessed

Compound	Acute exposure[a] [units: µg/m³]	Chronic exposure[b] [units: µg/m³]
Lead (Pb)	[c]	[d]
Arsenic (As)	0.2 [g]	0.015 [g]
Antimony (Sb)	[c]	[d]

Compound	Acute exposure[a] [units: µg/m³]	Chronic exposure[b] [units: µg/m³]
Chromium (Cr)	[c]	0.1 [e]
Cobalt (Co)	[c]	0.1 [f]
Copper (Cu)	100 [g]	[d]
Manganese (Mn)	[c]	0.05 [e]
Nickel (Ni)	0.2 [g]	0.014 [g]
Vanadium (V)	0.8 [f]	0.1 [f]
Mercury (Hg)	0.25 [i]	0.025 [i]
Cadmium (Cd)	[c]	0.005 [j]
Thallium (Tl)	[c]	[d]
Ammonia (NH₃)	1 184 [f]	20 [g]
Hydrogen chloride (HCl)	2 100 [g]	[d]
Hydrogen fluoride (HF)	240 [g]	14 [g]
Total organic compounds (TOC)	[c]	[d]
Volatile organic compounds (VOC)	[c]	5 [h]
(a) Hourly concentrations compared with short-term / acute exposure health effect screening level		
(b) Annual concentrations compared with long-term / chronic exposure health effect screening level		
(c) No hourly health screening level		
(d) No annual health screening level		
(e) US-EPA IRIS Inhalation Reference Concentrations (µg/m³) – chronic		
(f) US ATSDR Maximum Risk Levels (MRLs) (µg/m³) - acute		
(g) Californian OEHHA (µg/m³)		
(h) NAAQS for benzene (surrogate)		
(i) TCEQ ESL (µg/m³) (November 2016)		
(j) WHO guideline (µg/m³)		

A screening exercise of non-criteria pollutants emitted from the incinerators at SO, including all non-criteria pollutants listed in Table 5-20, was undertaken to identify pollutants that would be likely to exceed the most stringent health-effect screening levels identified (Table 5-30). The non-criteria pollutants that would possibly exceed the screening level concentrations included: As, Cr, Co, Mn, Ni, and V. Further analysis used the averaged normalised fraction of sum of metals represented by each metal element. This calculation was based on at least 15 sampling runs for the three sources for which postponement is applied. It should also be noted that one of the 15 sampling runs for the Caustic Incinerator (B6993) recorded a substantially elevated Mn emission rate. This resulted in a normalised contribution of 94% of the 'sum of metals' from Mn. Excluding this outlier data point, the average contribution of Mn to the sum of metals was 52%. The use of the 94% contribution is therefore considered to be additionally conservative to Sasol's approach of emissions modelling.

The analysis of individual metal elements showed that simulated ground-level concentrations of these pollutants comply with the strictest health effect screening level concentrations across the modelling domain for all metals except Mn (Table 5-31). Potential Mn exceedances of the chronic health effect screening level occur off-site for the baseline scenario up to ~450 m from the western site boundary (Figure 5-106). Maximum concentrations are likely to occur on-site, and the plume extends over the nearby Sasol Mining and Ash dump site to the west of the facility. Concentrations at receptors are unlikely to exceed the health effect screening level. Potential public exposure to the potentially elevated Mn concentrations would be limited to individuals travelling on the public road that separates the western boundary of the SO facility from the Mining and Ash dump site.

Table 5-31: Screening of non-criteria pollutants against health risk guidelines

Metallic element	Acute exposure[a] [units: µg/m³]			Chronic exposure[b] [units: µg/m³]		
	Minimum concentration[c]	Maximum concentration[d]	Strictest health effect screening level	Minimum concentration[c]	Maximum concentration[d]	Strictest health effect screening level
Baseline Emissions						
As	0.00006	0.03	0.2 [g]	0.0000003	0.0004	0.015 [g]
Cr				0.000004	0.01	0.1 [e]
Co				0.0000001	0.0004	0.1 [f]
Mn				0.0001	0.4	0.05 [e]
Ni	0.0004	0.2	0.2 [g]	0.000002	0.006	0.014 [g]
V	0.0002	0.08	0.8 [f]	0.0000008	0.002	0.1 [f]
New Plant Standards						
As	0.00001	0.005	0.2 [g]	0.00000005	0.0001	0.015 [g]
Cr				0.00000008	0.0002	0.1 [e]
Co				0.00000002	0.00004	0.1 [f]
Mn				0.000005	0.01	0.05 [e]
Ni	0.00001	0.006	0.2 [g]	0.00000006	0.0001	0.014 [g]
V	0.000004	0.002	0.8 [f]	0.00000002	0.00006	0.1 [f]
Alternative Emissions						
As	0.00006	0.03	0.2 [g]	0.0000003	0.0004	0.015 [g]
Cr				0.000004	0.01	0.1 [e]
Co				0.0000001	0.0004	0.1 [f]
Mn				0.0001	0.4	0.05 [e]
Ni	0.0004	0.2	0.2 [g]	0.000002	0.006	0.014 [g]
V	0.0002	0.08	0.8 [f]	0.0000008	0.002	0.1 [f]

(a) hourly concentrations compared with short-term / acute exposure health effect screening level

(b) annual concentrations compared with long-term / chronic exposure health effect screening level

(c) minimum concentration simulated across the domain

(d) maximum concentration simulated across the domain

(e) US-EPA IRIS Inhalation Reference **Concentrations (µg/m³) –** chronic (exposure over a year)

(f) **US ATSDR Maximum Risk Levels (MRLs) (µg/m³)** - acute

(g) **Californian OEHHA (µg/m³)**
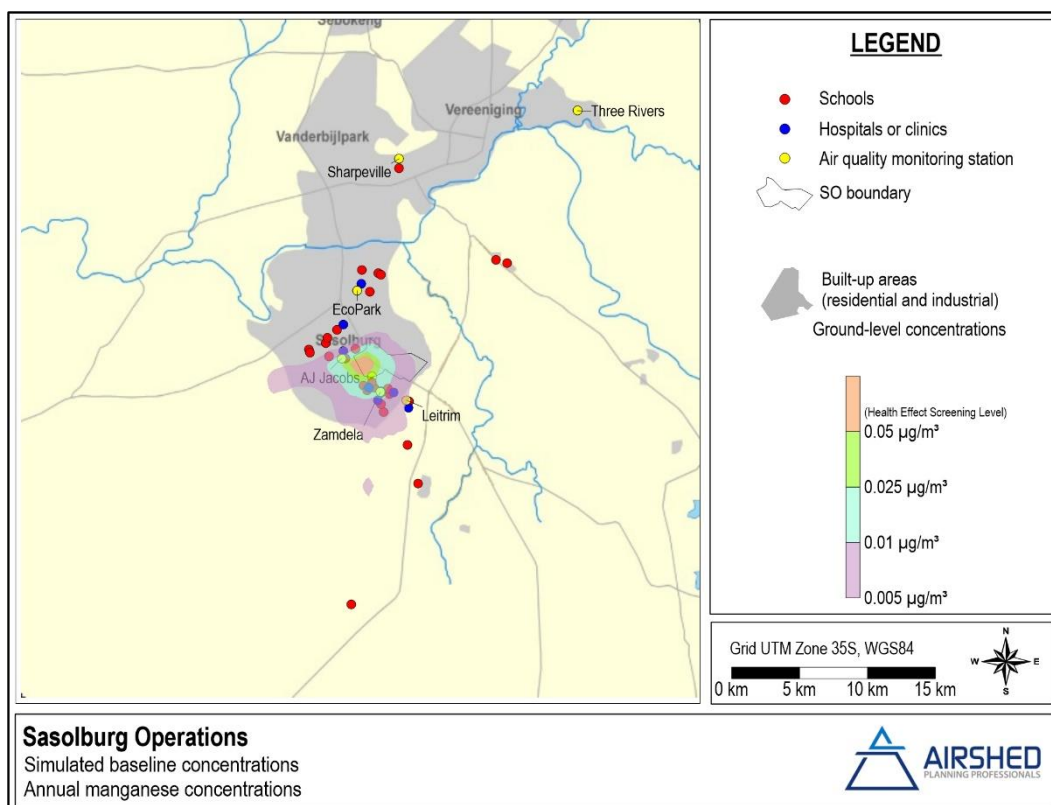
Figure 5-106: Simulated annual Mn concentrations as a result of baseline emissions

Unit risk factors (URFs) are applied in the calculation of carcinogenic risks. These factors are defined as the estimated probability of a person (60-70 kg) contracting cancer as a result of constant exposure to an ambient concentration of 1 µg/m³ over a 70-year lifetime. In the generic health risk assessment undertaken as part of the current study, maximum possible exposures (24-hours a day over a 70-year lifetime) are assumed for all areas beyond the boundary of the proposed development site. Unit risk factors were obtained from the WHO (2000) and from the US EPA IRIS database. The most stringent URFs (obtained from the WHO, IRIS and California EPA (CALEPA) databases) for compounds of interest in the current study are given in Table 5-32.

Table 5-32: Proposed unit risk factors for pollutants of interest in the current assessment

Compound	Selected Criteria $(\mu g/m^3)^{-1}$	Source
Arsenic	4.3×10^{-3}	IRIS
Benzene	2.9×10^{-5}	CALEPA
Cadmium	4.2×10^{-3}	CALEPA
Chromium (VI)	1.5×10^{-1}	CALEPA
Nickel	3.8×10^{-4}	WHO
Dioxins	33	CALEPA

The New York Department of Health have a qualitative ranking of cancer risk estimates, from very low to very high (Table 5-33).

Table 5-33: Excess Lifetime Cancer Risk (New York Department of Health)

Risk Ratio	Qualitative Descriptor
Equal to or less than one in a million	Very low
Greater than one in a million to less than one in ten thousand	Low
One in ten thousand to less than one in a thousand	Moderate
One in a thousand to less than one in ten	High
Equal to or greater than one in ten	Very high

Based on the qualitative description provided by the New York Department of Health, the cancer risk due to SO baseline and new plant standard operations is "low" to "very low".

5.1.9   Uncertainty of Modelled Results

The main steps of uncertainty management are to:
- identify and understand uncertainties;
- understand whether uncertainties matter for decisions being made at the time;
- if they do matter, decide what to do about them; and,
- recommend a way forward.

Managing uncertainties attempts to eliminate the source of technical disagreements and failure to understand them often leads to a conclusion that all uncertainties need to be eliminated before project decisions can be made. The first decision about how to manage uncertainties relates to their significance given the decision being addressed. In the current context, the different parts of the investigation were grouped into similar uncertainty regimes, namely:

- dispersion model uncertainties;
- input data uncertainties;
- the methodology of validating model results; and,
- the methodology of expressing the modelled scenarios.

A comprehensive discussion on uncertainties is provided in Appendix I.

As discussed in Section 5.1.6, the baseline predictions with the inclusion of estimated background concentrations performed well within the generally accepted (U.S. EPA 2005) **"factor of two" accuracy of dispersion models**. Unless greater general experience is gained, or some further formal validation studies are conducted, it is not possible to say how much more confidence can be given to well-executed plume and puff models.

As discussed in Appendix J, it is estimated that the ambient monitoring has an uncertainty of 5% with a 95% confidence interval and the emissions monitoring an uncertainty of 10% with a 95% confidence interval. Based on these uncertainties, it is estimated that the concentration ratios of the different emission scenarios have an uncertainty of -36% and +58%, i.e. potential under-prediction of 36% and over-prediction of 58%.

The Intergovernmental Panel on Climate Change (IPCC) produced a qualitative method for consistent communication of uncertainties in the IPCC Fifth Assessment Report. This Guidance Note has been summarised in Appendix J. On application of this guide, the results from this investigation is considered to be of "high confidence" based on a "high agreement" of the baseline predictions with observations, based on 'medium evidence'.

5.2 Analysis of Emissions' Impact on the Environment

5.2.1 Critical Levels for Vegetation

The impact of SO emissions on surrounding vegetation was assessed by comparing the simulated annual SO_2 and NO_2 concentrations for each of the emission scenarios against the critical levels for vegetation as defined by the United Nations Economic Commission for Europe (UNECE) Convention on Long Range Trans-boundary Air Pollution Limits (CLRTAP, 2015) (Table 5-34).

Table 5-34: Critical levels for SO_2 and NO_2 by vegetation type (CLRTAP, 2015)

Pollutant	Vegetation type	Critical Level ($\mu g/m^3$)	Time Period[a]
SO_2	Cyanobacterial lichens	10	Annual average
	Forest ecosystems (including understorey vegetation)	20	Annual average and Half-year mean (winter)
	(Semi-)natural vegetation	20	Annual average and Half-year mean (winter)
	Agricultural crops	30	Annual average and Half-year mean (winter)
NO_2	All	30	Annual average and Half-year mean (winter)
		75	Daily average
Notes: (a) For the purposes of mapping of critical levels and exceedances CLRTAP recommend using only the annual average, due to increased reliability of mapped and simulated data for the longer time period. It is also noted that long-term effects of NO_X are considered to be more significant than short-term effects (CLRTAP, 2015).			

The simulated off-site annual concentrations of SO_2 may exceed the critical levels for lichen (SO_2) for all emission scenarios (Figure 5-107 to Figure 5-109). However, off-site NO_2 concentrations are likely to be below the critical levels for all vegetation types (Figure 5-110 to Figure 5-112)

Figure 5-107: Annual SO₂ concentrations as a result of baseline emissions compared with CLRTAP critical levels
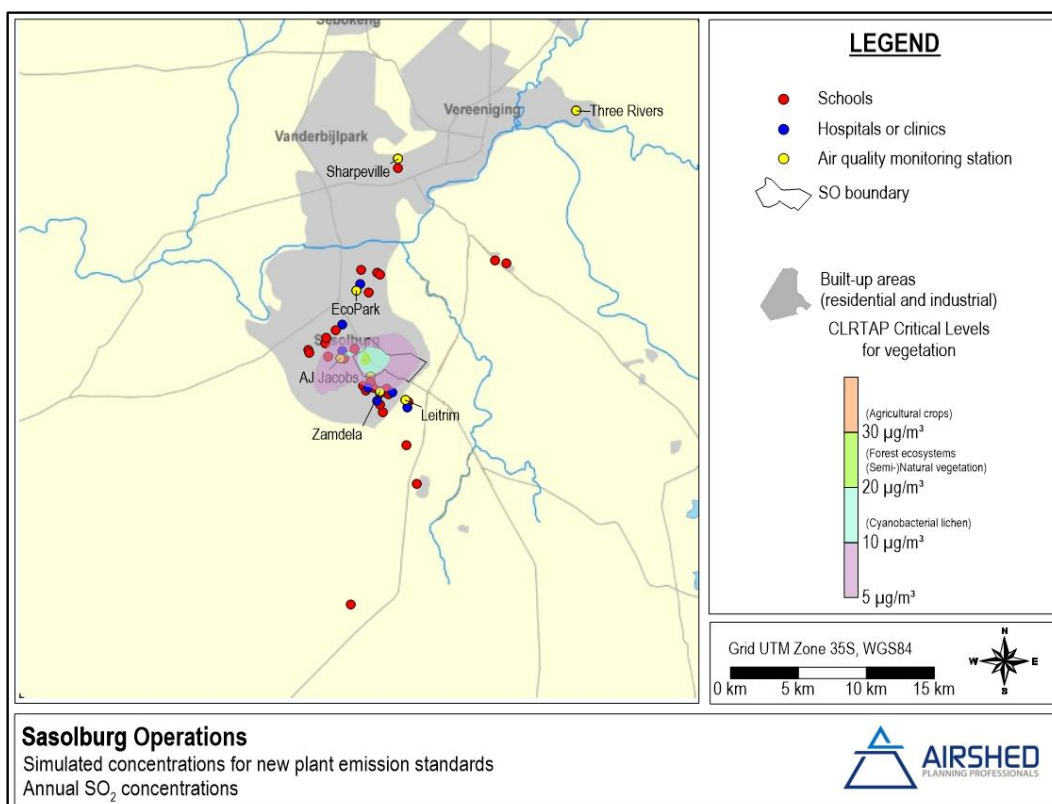
Figure 5-108: Annual SO₂ concentrations as a result of theoretical compliance with new plant emission standards compared with CLRTAP critical levels
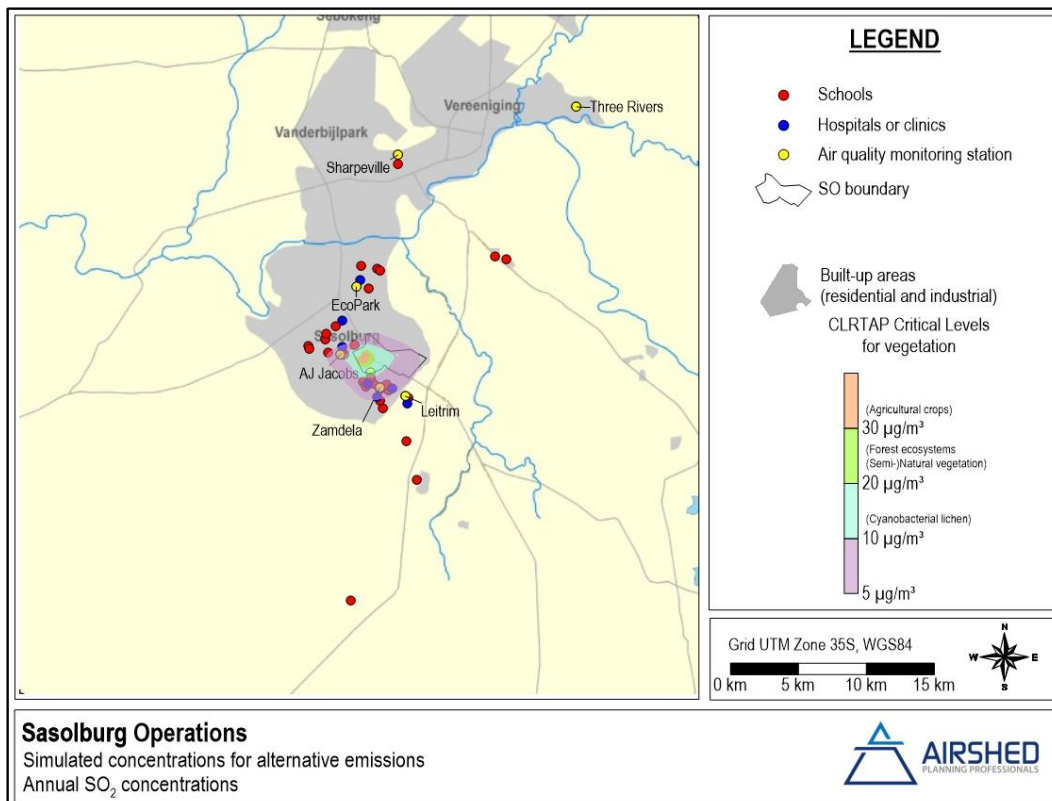
Figure 5-109: Annual SO₂ concentrations as a result of alternative emissions compared with CLRTAP critical levels
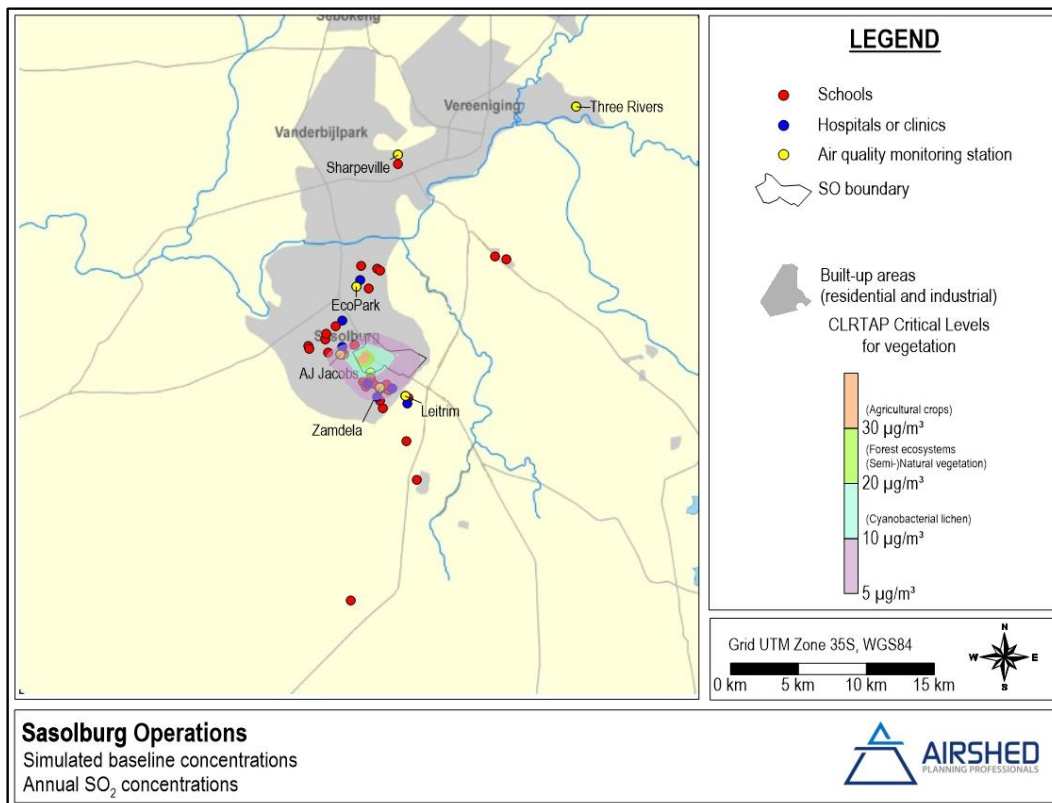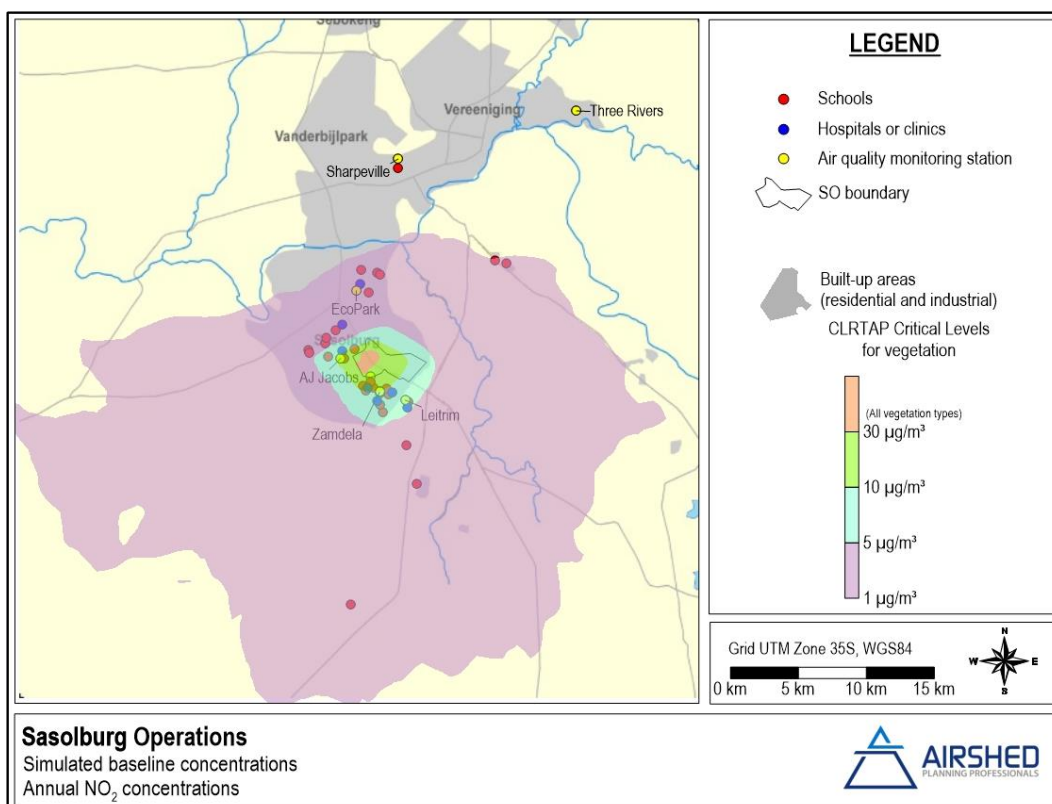

Figure 5-110: Annual NO₂ concentrations as a result of baseline emissions compared with CLRTAP critical levels
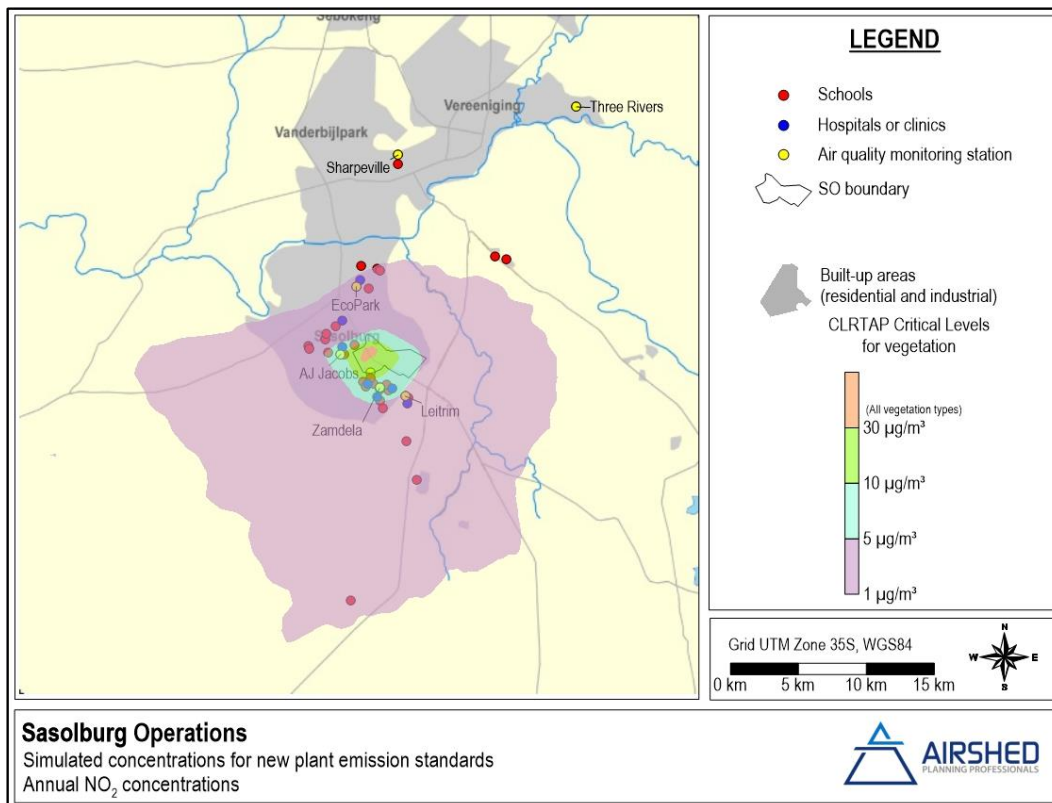
Figure 5-111: Annual NO₂ concentrations as a result of theoretical compliance with new plant emission standards compared with CLRTAP critical levels
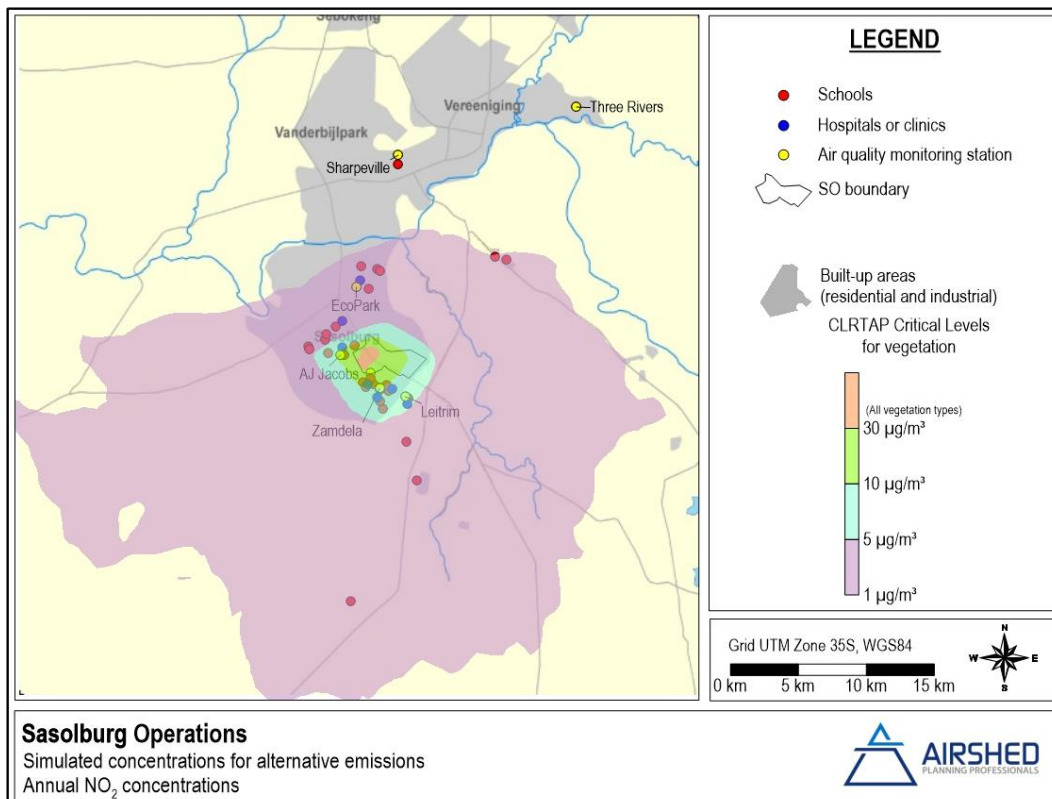
Figure 5-112: Annual NO₂ concentrations as a result of alternative emissions compared with CLRTAP critical levels

5.2.2   Dustfall

Dustfall deposition rates were estimated as a result of particulate emissions from the SO point sources. The simulated PM concentrations (Section 5.1.8.1.3) were converted to deposition rates by assuming a settling velocity of 6.43×10^{-3} m/s (based on a 10 **μ**m particle with a density of 2.1 g/m³). Estimated dustfall rates for the simulation scenarios ranged between 0.10 and 39.79 mg/m2.day, where the theoretical compliance with new plant standards would likely result in the lowest dustfall rates (Table 5-35). No exceedances of the NDCR residential standard were simulated off-site. Isopleth plots are presented for dustfall deposition rates for the three scenarios in Figure 5-113 to Figure 5-115. Simulated dustfall rates have been compared to the acceptable dustfall rate applicable to residential areas as defined by the NDCR (Table 5-3).

Table 5-35: Summary of dustfall deposition rates as a result of operations at SO

Criteria	Daily dustfall rate (mg/m².day)		
	Simulated Baseline Concentrations	Simulated Concentrations for New Plant Emission Standards	Simulated Concentrations for Alternative Emissions
Min	0.15	0.10	0.15
Max	39.79	37.30	39.79
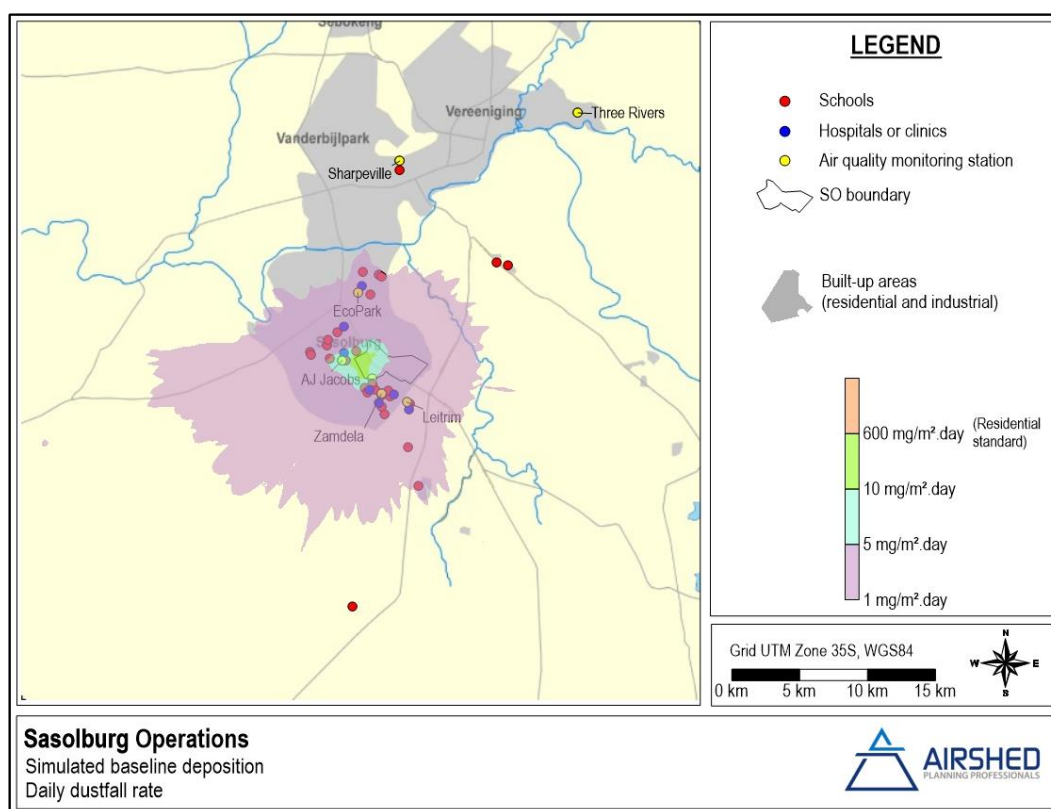
Figure 5-113: Simulated daily dustfall as a result of baseline emissions
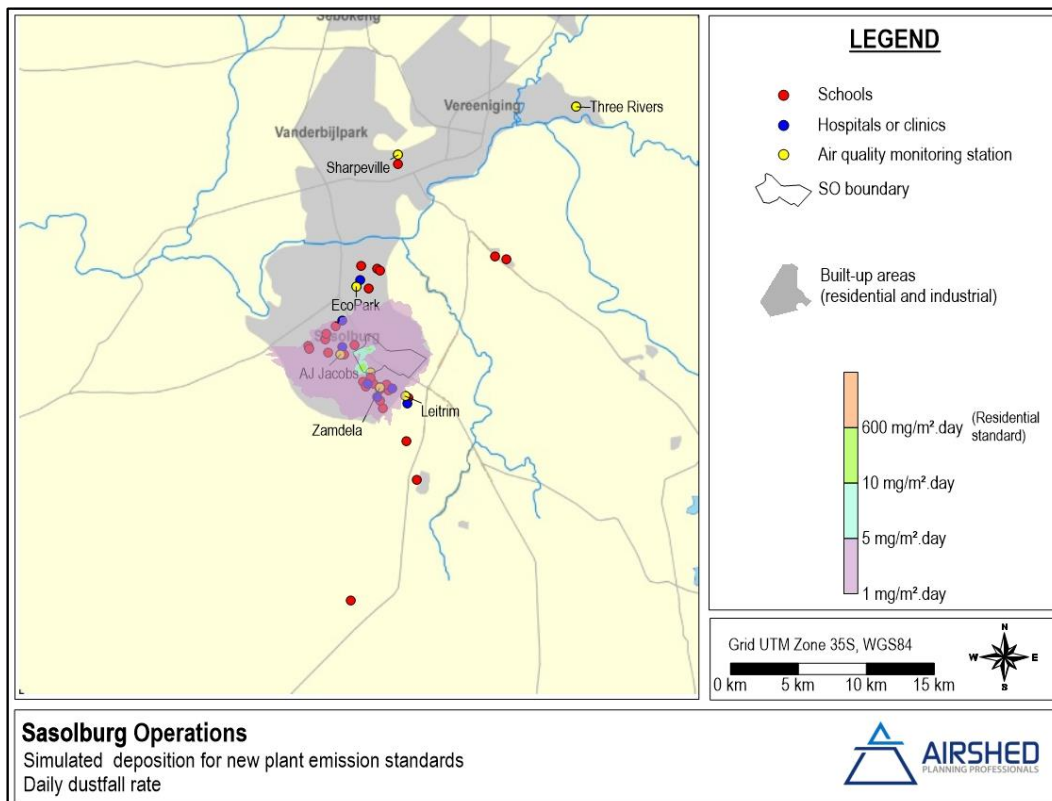
Figure 5-114: Simulated daily dustfall as a result of theoretical compliance with new plant standards
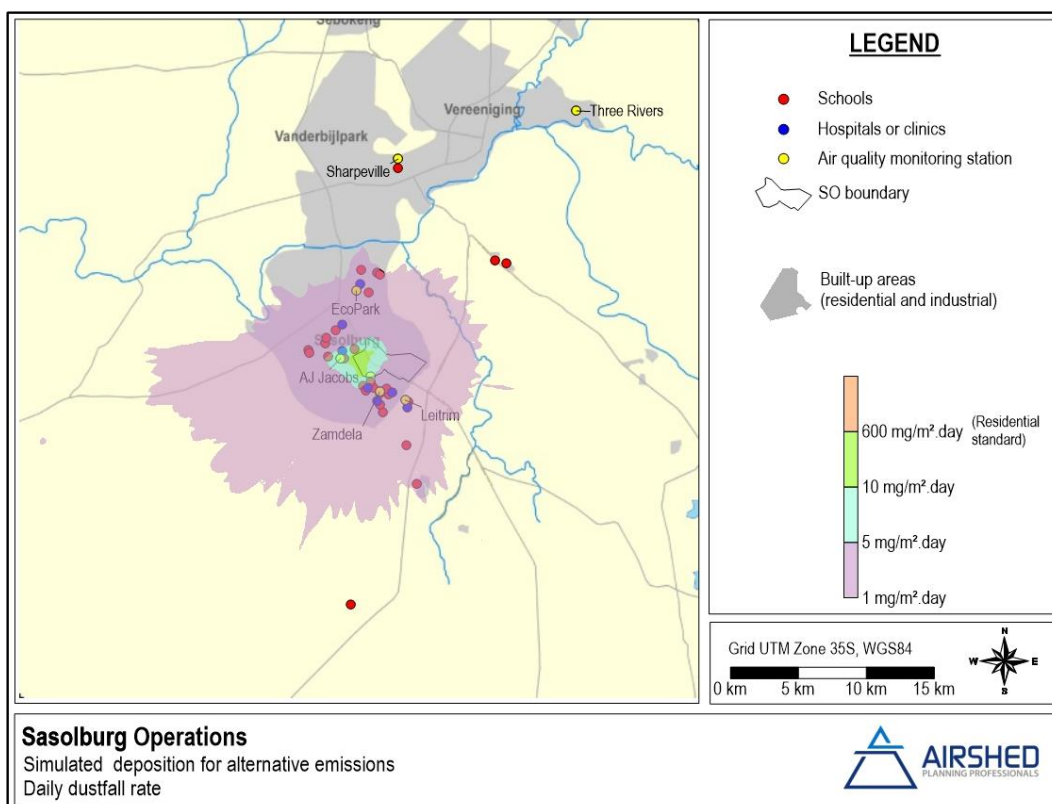
Figure 5-115: Simulated daily dustfall as a result of alternative emissions

5.2.3   Corrosion

5.2.3.1   Factors Affecting Corrosion

The most important corrosion stimulators are water (humidity) and air pollutants, such as SO_2, NH_3, and acids such as HCl and formic acid (HCOOH), as well as aerosols and particles containing chlorides (Cl^-), nitrates (NO^{3-}), and sulfates (SO_4^{2-}). The presence of a moisture film on the surface allows these pollutants to dissolve and dissociate into its respective positive and negative ions, and therefore constitutes the electrolyte for corrosion to take place. The thickness of this aqueous layer depends on the relative humidity and surface properties, and is typically a few to a few tens of nanometres (nm) at room temperature (Phipps and Rice 1979).

Dry deposition near emission sources in urban and industrial areas consists largely of the adsorption of criteria pollutants such as SO_2 and NO_X on surfaces, with the deposited amount proportional to the content in air. The deposition rate is high at elevated humidity, especially on some metals; e.g., steel and zinc (Sydberger and Vannerberg, 1972). Corrosion due to SO_2 exposure is perhaps the most significant. Although NO_X may also contribute to corrosion of metals, it is considerably less significant. Like SO_2, this pollutant is mainly emitted from combustion processes such as boilers, power stations, motor vehicle exhausts, etc. It is predominantly emitted as nitrogen oxide (NO) and oxidised in the atmosphere to nitrogen dioxide (NO_2). This oxidation process is a relatively fast process, but further oxidation of NO_2 to nitric acid (HNO_3), i.e. the form conducive for corrosion, occurs at a slow rate and therefore exposure is normally at comparatively low concentrations.

Very little work has been reported on the effect of HCl on the degradation of materials in the environment. This is probably because HCl, which is present outdoors in markedly reduced concentrations when compared with SO_2, has not been considered to contribute to significant degradation of materials. The first major study of atmospheric degradation of metals by HCl was carried out by Feitnecht (1952) who exposed zinc, iron and copper to HCl vapours at varying humidity's between 50% and 95%. Feitnecht found that HCl reacted with metals only when a critical relative humidity was exceeded, which he linked to the vapour pressure of a saturated solution of the metal chloride formed during corrosion. He regards the mechanism as electrochemical, with the oxide-film as cathodes and small areas of metal exposed at breaks as anodes; the interaction between the hydroxide ions (OH^- ions), formed by the cathodic reduction of oxygen, and the metal ions, formed by the anodic reaction, leads to hydroxide or basic chloride. Barton and Bartonova (1969) carried out an extensive investigation of the corrosive effect of HCl gas at concentrations between 7 and 10 ppm on zinc, mild steel, and copper at temperatures between 20°C and 50°C and at **relative humidity's of 70% and 95%. Two distinct stages were seen in the** behaviour:

- Stage 1 was characterized by a non-**linear increase in mass loss with time; termed the "indication period for** steady-**state corrosion".**
- **Stage 2, after about 16 days' exposu**re, showed steady-state corrosion with a linear increase in mass-loss with time.

The primary corrosion products found on iron were FeO(OH), Fe_3O_4 and $FeCl_2$, whilst those found on zinc were 4Zn (OH)$_2$. $ZnCl_2$, Zn (OH)$_2$ and ZnO. The amount of chloride in the corrosion product tended to decrease slowly with time. After the steady state corrosion stage had been reached, the composition of the corrosion product remained unchanged.

Barton and Bartonova (1969) measured the corrosion rate at different temperatures in the steady state region. For zinc, the corrosion rate decreased as the temperature increased; for iron, the corrosion rate increased with temperatures up to 40°C, but decreased at 50°C. The rate of the reactions did not appear to depend on the diffusion of HCl to the surface since the corrosion rate was similar in flowing and stationery atmospheres. The implication is that the corrosion rate is dependent on

chemical reaction rate. The kinetics of corrosion is controlled by the transfer of HCl to the corrosion product atmosphere interface, its adsorption and the subsequent production of soluble $ZnCl_2$. The corrosion rate also depends on the hydroxide / chloride ratio in the corrosion product as the hydroxides are more protective than the chlorides.

No literature could be obtained on the combined corrosive effects of gaseous SO_2 and HCl pollutant. Furthermore, no dose-response relationships between hydrochloric acid concentrating or deposition rates and corrosion rates could be obtained. Most literature on chloride exposures discusses the corrosion rates associated with marine environments. Whilst the chemical reactions may be similar, it is not clear whether an assumption of equivalence may be made between hydrochloric acid and sodium chloride. Whilst both are donors of chloride ions, the former would also reduce the pH of the moisture layer on the metal surface. Given these limitations, and in an attempt to provide an indication of the corrosion potential that the proposed facility may have on the surrounding environment, it was decided to make reference to the International Standard Organisation (ISO) corrosion classification which considers SO_2 and chloride deposition rates to establish the rate of corrosion of a number of different metal types.

5.2.3.2   International Standard Organisation

The ISO provides a classification scheme that can directly be used for technical and economic analyses of corrosion damage due to atmospheric SO_2 and chlorides, and for the rational choice of protection measures. As such, the corrosivity of the atmosphere is divided into five categories (C1 to C5), ranging from very low to very high corrosivity. These corrosivity categories are estimated using a combination of the meteorological parameters, sulfate deposition and airborne salinity (chloride ion). These are discussed below.

5.2.3.2.1   Time of Wetness

Relative humidity, rain, dew, and temperature are determinants of the so-called *time of wetness* (TOW), defined (ISO 9223) as the fraction of time with relative humidity in excess of 80%, at temperatures above freezing (>0°C). The TOW of a corroding surface is a key parameter, directly determining the duration of the electrochemical corrosion processes. This is a complex variable, since all the means of formation and evaporation of the surface electrolyte solution must be considered. The TOW refers to the period of time during which the atmospheric conditions are favourable for the formation of a surface layer of moisture on a metal or alloy. As pointed in the previous section, this moisture film is extremely important from the point of view of the chemical mechanisms of the corrosion process.

Meteorological data from the Eco Park and Leitrim AQMS were used to calculate the TOW. The average TOW is 16% and 18% per year at Eco Park and Leitrim respectively. According to the ISO 9233 classification (Table 5-36), the TOW class represented by these weather conditions is T3.

Table 5-36: ISO 9223 Classification of the Time of Wetness

Category	Time of Wetness	Example of Occurrence	Comment
	Hours per Year	Percentage	
T1	T≤10	T≤0.1	Indoor
T2	10<T≤250	0.1<T≤3	Indoor without climate control
T3	**250<T≤2500**	**3<T≤30**	Outdoor atmospheres in dry, cold climates and part of temperate climates
T4	2 500<T≤5 500	30<T≤60	Outdoor atmospheres in all climates except for dry and cold climates
T5	5 500<T	60<T	Tropical outdoor or surf

5.2.3.2.2   Atmospheric pollutants

As indicated by the ISO standard, corrosion due to atmospheric pollution is dominated by sulfur dioxide (urban environments) and chlorides (marine environments). This is also evident from open literature where the focus of atmospheric corrosion of metals has predominantly been described through the impact of these two pollutants.

Sulfur Dioxide

Sulfate ions are formed in the surface moisture layer by the oxidation of sulfur dioxide and their formation is considered to be the main corrosion accelerating effect from sulfur dioxide. Sulfur dioxide may be expressed either in terms of a deposition rate or an airborne concentration. The method of determining the deposition rate in this instance followed the ISO 9223 Method, where the corrosion potential due to SO_2 is classified according to the long-term (annual) deposition rate or air concentration of SO_2, as summarised in
Table 5-37. Any concentration of SO_2 within category P_0 is considered to be the background concentration and is insignificant from the point of view of corrosive attack. Pollution by SO_2 within category P3 is considered extreme and is typical of operational microclimates beyond the scope of the International Standard. The ground-level SO_2 concentrations, as a result of emissions from SO, fall into the P2 category for the baseline and alternative emissions scenarios, and P1 for the theoretical compliance with new plant emission standards (Table 5-38).

Table 5-37: ISO 9223 classification of pollution by sulfur-containing substances represented by SO_2

Category	Concentration of SO_2	Deposition Rate of SO_2
	$\mu g/m^3$	$mg/(m^2.day)$
P0	$P_c \leq 12$	$P_d \leq 10$
P1	$12 < P_c \leq 40$	$10 < P_d \leq 35$
P2	$40 < P_c \leq 90$	$35 < P_d \leq 80$
P3	$90 < P_c \leq 250$	$80 < P_d \leq 200$

Table 5-38: ISO 9223 classification of pollution by sulfur-containing substances represented by SO_2 as a result of SO

Criterion	Scenario		
	Baseline	New Plant Emission Standards	Alternative Emissions
Maximum annual SO_2 concentration ($\mu g/m^3$)	59.47	36.34	59.47
ISO corrosivity category for SO_2	P2	P1	P2

Airborne Chloride

The ISO 9223 classification of pollution by chloride containing substances is provided in Table 5-39. Chloride deposition rates were estimated based HCl emissions from SO sources (Table 5-40). Although maritime chloride contributions are likely to be insignificant, other industrial sources in the vicinity may also contribute to the HCl deposition load however the contribution is unknown.

Table 5-39: ISO 9223 classification of pollution by airborne chloride containing substances

Category	Deposition Rate of Chloride ($mg/m^2.day$)
S0	$S \leq 3$
S1	$3 < S \leq 60$
S2	$60 < S \leq 300$

Category	Deposition Rate of Chloride (mg/m².day)
S3	**300 < S ≤** 1500

Table 5-40: ISO 9223 classification of pollution by airborne chloride containing substances for SO

Criterion	Scenario		
	Baseline	New Plant Emission Standards	Alternative Emissions
Chloride deposition (mg/m².day)	0.05		
ISO corrosivity category for Cl	S0		

5.2.3.2.3   Corrosivity Potential

Having calculated the TOW, the classification of pollution by sulfate and chloride containing substances, the corrosivity category (C1 to C5) for individual metals can be estimated according to ISO 9223, as shown in Table 5-41, and specific corrosivity categories associated with SO are summarised for the four scenarios in Table 5-42. Once the corrosivity category has been determined, the corrosion rate for carbon and weathered steel, zinc, copper and aluminium can be estimated using the rates given in Table 5-43.

Table 5-41: Estimated corrosivity categories of the atmosphere

Unalloyed carbon steel															
	T1			T2			T3			T4			T5		
	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3
P_0-P_1	1	1	1/2	1	2	3/4	2/3	3/4	4	3	4	5	3/4	5	5
P_2	1	1	1/2	1/2	2/3	3/4	3/4	3/4	4/5	4	4	5	4/5	5	5
P_3	1/2	1/2	2	2	3	4	4	4/	5	5	5	5	5	5	5
Zinc and copper															
	T1			T2			T3			T4			T5		
	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3
P_0-P_1	1	1	1	1	1/2	3	3	3	3/4	3	4	5	3/4	5	5
P_2	1	1	1/2	1/2	2	3	3	3/4	4	3/4	4	5	4/5	5	5
P_3	1	1/2	2	2	3	3/4	3	3/4	4	4/5	5	5	5	5	5
Aluminium															
	T1			T2			T3			T4			T5		
	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3
P_0-P_1	1	2	2	1	2/3	4	3	3/4	4	3	3/4	5	4	5	5
P_2	1	2	2/3	1/2	3/4	4	3	4	4/5	3/4	4	5	4/5	5	5
P_3	1	2/3	3	3/4	4	4	3/4	4/5	5	4/5	5	5	5	5	5

Note: Corrosivity is expressed as the numerical part of the corrosivity category code (for example: 1 instead of C1).

Table 5-42: Estimated corrosivity categories of the atmosphere associated with SO

Metal type	Scenario		
	Baseline	New Plant Emission Standards	Alternative Emissions
Unalloyed carbon steel	C3/4	C2/3	C3/4
Zinc and copper	C3	C3	C3
Aluminium	C3	C3	C3

Table 5-43: Average and steady state corrosion rates for Different Metals and Corrosivity Categories

Metal	Average corrosion rate (r_{av}) during the first 10 years for the following corrosivity categories (µm/annum)				
	C1	C2	C3	C4	C5
Carbon steel	$r_{av} \leq 0.5$	$0.5 < r_{av} \leq 5$	$5 < r_{av} \leq 12$	$12 < r_{av} \leq 30$	$30 < r_{av} \leq 100$
Weathering steel	$r_{av} \leq 0.1$	$0.1 < r_{av} \leq 2$	$2 < r_{av} \leq 8$	$8 < r_{av} \leq 15$	$15 < r_{av} \leq 80$
Zinc	$r_{av} \leq 0.1$	$0.1 < r_{av} \leq 0.5$	$0.5 < r_{av} \leq 2$	$2 < r_{av} \leq 4$	$4 < r_{av} \leq 10$
Copper	$r_{av} \leq 0.01$	$0.01 < r_{av} \leq 0.1$	$0.1 < r_{av} \leq 1.5$	$1.5 < r_{av} \leq 3$	$3 < r_{av} \leq 5$
Aluminium	$r_{av} \approx 0.01$	$r_{av} \leq 0.025$	$0.01 < r_{av} \leq 0.1$	(5)	(5)

Metal	Steady state corrosion rate (r_{lin}) for the following corrosivity categories (µm/annum)				
	C1	C2	C3	C4	C5
Carbon steel	$r_{av} \leq 0.1$	$0.1 < r_{av} \leq 1.5$	$1.5 < r_{av} \leq 8$	$8 < r_{av} \leq 20$	$20 < r_{av} \leq 90$
Weathering steel	$r_{av} \leq 0.1$	$0.1 < r_{av} \leq 1$	$1 < r_{av} \leq 5$	$5 < r_{av} \leq 10$	$10 < r_{av} \leq 80$
Zinc	$r_{av} \leq 0.05$	$0.1 < r_{av} \leq 0.5$	$0.5 < r_{av} \leq 2$	$2 < r_{av} \leq 4$	$4 < r_{av} \leq 10$
Copper	$r_{av} \leq 0.01$	$0.01 < r_{av} \leq 0.1$	$0.1 < r_{av} \leq 1$	$1 < r_{av} \leq 3$	$3 < r_{av} \leq 5$
Aluminium	negligible	$0.01 < r_{av} \leq 0.02$	$0.02 < r_{av} \leq 0.2$	(5)	(5)

Notes

1) The corrosion rate of carbon steel is not constant during the first 10 years.

2) The corrosion rate of weathering steel is strongly dependent on the combination of various influencing factors (alternation between wet and dry periods). In atmospheres with sulfur dioxide (SO2) pollution, a more protective rust layer is formed. Rain protected surfaces in marine atmospheres heavily polluted with chlorides may have much higher corrosion rates than freely exposed surfaces.

3) Applies also to the copper-zinc, copper-tin and similar alloys with a copper content of at least 60 %.

4) The rates shown are based on commercially pure aluminium (purity> 99.5%) which, like most aluminium alloys, corrodes in the atmosphere at a rate that decreases with time. However, these rates are based on average mass loss results while the corrosion attack is usually manifested as pitting. Consequently, the rates shown do not represent rates of penetration. Penetration rates for pitting also decrease with exposure time. Commercially pure aluminium, aluminium alloys containing magnesium, manganese and/or silicon as the major alloying elements, and Alclad products generally have better corrosion resistance than aluminium alloys containing significant quantities of copper, zinc and/or iron. Alloys with significant quantities of magnesium, zinc, copper and/or iron may also be subject to other forms of localized corrosion such as stress corrosion cracking, exfoliation and intergranular attack.

5) In atmospheres defined by corrosivity categories C4 and C5, a marked increase in corrosion rate may be expected and local corrosion effects become important. For these two corrosivity categories, the data concerning general corrosion may be misleading.

5.2.3.3   ISOCORRAG Atmospheric Corrosion Model

The ISOCORRAG equation was developed to predict the annual corrosion rate resulting from atmospheric corrosion for several metals. The equation was created by the multiple linear regressions of corrosion data from several sites around the globe. With ISOCORRAG, the annual corrosion rate is expressed as (Knotkova et al., 1995):

$$K = a + b_1[SO_2] + b_2[Cl^-] + b_3[TOW]$$

Equation 2

Where the constants a, b_1, b_2, and b_3, differ according to the type of metal, shape of the specimen, and exposure conditions. Table 5-44 is a summary of constants for flat metal specimens. The deposition of SO2 is expressed as an equivalent concentration, i.e. µg/m³; the deposition of chloride pollutants [Cl-] is expressed in in mg/m².day, and time of wetness [TOW] in hours per year.

Table 5-44: ISOCORRAG regression model constants (Knotkova et al., 1995)

Metal	Regression Constants for ISOCORRAG model			
	a	b_1	b_2	b_3
Steel	1.3269	0.4313	0.1384	0.0057
Zinc	0.2098	0.0232	0.0059	0.00027

Metal	Regression Constants for ISOCORRAG model			
	a	b_1	b_2	b_3
Copper	0.9556	0.0065	0.00393	0.0000538
Aluminium	0.0069	0.00638	0.000558	0.0000650

Using simulated concentrations of SO_2 as a result of SO operations and wet deposition rates of chloride (HCl emissions and simulated concentrations) (as in Section 5.1.8.2) the rate of corrosion (K) was calculated (using Equation 2) across the dispersion modelling domain. TOW from Section 5.2.3.2.1 was used. A summary of the findings is presented in Table 5-45. There is some agreement between the two methods for corrosion rate estimation for aluminium, however corrosion rates calculated using the ISOCORRAG method are in higher than corrosion rates presented for the ISO method for steel, zinc and copper (Table 5-43 compared with Table 5-45).

Table 5-45: Corrosion rate of metals associated with SO calculated according to the ISOCORRAG method

Scenario	Criteria	Corrosion rate (K) [µm/annum]			
		Steel	Zinc	Copper	Aluminium
Time of wetness at Eco Park AQMS [1377 hours]					
Simulated Baseline Concentrations	Min	9.20	32.16	1.03	0.10
	Max	34.83	33.54	1.42	0.48
Simulated Concentrations for New Plant Emission Standards	Min	9.20	32.16	1.03	0.10
	Max	24.85	33.00	1.27	0.33
Simulated Concentrations for Alternative Emissions	Min	9.20	32.16	1.03	0.10
	Max	34.83	33.54	1.42	0.48
Time of wetness at Leitrim AQMS [1559 hours]					
Simulated Baseline Concentrations	Min	10.24	36.39	1.04	0.11
	Max	35.87	37.77	1.43	0.49
Simulated Concentrations for New Plant Emission Standards	Min	10.24	36.39	1.04	0.11
	Max	25.89	37.23	1.28	0.34
Simulated Concentrations for Alternative Emissions	Min	10.24	36.39	1.04	0.11
	Max	35.87	37.77	1.43	0.49

5.2.4 Sulfur and Nitrogen Deposition Impacts

Understanding the impact of deposition of atmospheric sulfur (S) and nitrogen (N) on South African ecosystems has been on-going since the late 1980's (Tyson *et al.* 1988), with much of the earlier work focussing on the circulation over the sub-continent (Tyson *et al.* 1996). More recent research has focussed on quantifying S and N deposition (Galpin and Turner 1999, Zunckel *et al.* 1996, Scorgie and Kornelius 2009, Josipovic *et al.* 2010) and the subsequent impacts on ecosystems (Fey and Guy 1993, Van Tienhoven *et al.* 1995, Reid 2007, Bird 2011, Josipovic *et al.* 2011).

These studies estimating deposition of S and or N compounds to ecosystems present ranges of deposition rates where the differences are related to the distance from major industrial sources: (the method of estimation - field work and/or calculation based on deposition velocities or dispersion modelling). As an indication, total S deposition over the industrialised Highveld of South Africa was modelled to range between 8 and 35 kg/ha/year with background levels of approximately 1 kg/ha/year (Scorgie and Kornelius 2009). In contrast, using ambient SO_2 concentrations and an inferential deposition model to calculate S deposition, Zunckel *et al.*(1996) estimated total S deposition of 13.9 kg/ha/year as maximum deposition rate on the Highveld. Estimates of nitrogen deposition range between 6.7 kg/ha/year (Collett *et al.* 2010) and 15 kg/ha/year (Scorgie and Kornelius 2009). Considering total acidic input from atmospheric sources, Josipovic and colleagues (2011) calculated a range of deposition rates between 15.8 and 23.2 kg/ha/year. All estimates are within the range of deposition rates for S and

N as for some of the industrialised regions of Europe and North America (compared in Scorgie and Kornelius 2009, and Bird 2011) raising concern that the acidic loading of sulfur and nitrogen on the ecosystems of the Highveld **– South Africa's most heavily industrialised region –** could have implications for ecosystem functioning. Impacts in the vicinity of SO, and the Free State more generally, are likely to be at the low end of the range of deposition values, being upwind of the major industrial complex of the Highveld and affected mainly by sub-continental recirculation.

Establishing clear cause-effect relationships in complex ecosystem studies can be difficult, especially where the extent of visible damage is large and local emissions are low (Matzner and Murach 1995). Reasons include: time lags between stressor (high concentration of atmospheric pollutants) and visible symptomatic response of biota; interaction of natural factors (e.g. climate, soil and pests) and human activities (such as management, site history and air pollution); local ecosystem uniqueness and difficulty of extrapolating to larger scales; or, symptomatic responses that are not unique to the cause (e.g. defoliation) (Matzner and Murach 1995). The synergistic effect of pollutant cocktails can also add complexity to identifying causative pollutants (Emberson 2003).

Mobilisation of active forms of S and N into the atmosphere, and later as deposition onto ecosystems, can result in acidification of soils and freshwater systems, soil nutrient depletion, fertilization of naturally (usually nitrogen) limited systems and increased availability of metal ions (e.g. Al) disrupting ecosystem functioning (Rodhe *et al.* 1995) and changing plant and/or freshwater species diversity (Stevens *et al.* 2004). Many of these impacts occur over a decade or longer where attributing source contributions can be complex within a regional setting. Sasol have, however, supported the long-term deposition quantification studies in South African under the DEBITS (Deposition of Biogeochemically Important Trace Species) programme, as part of the International Global Atmospheric Chemistry Project. Three DEBITS sites are maintained within South Africa, one located near Amersfoort, on the Mpumalanga Highveld, downwind from major industrial sources, including SO. Investigating the impact of deposition on the Free State and Mpumalanga grasslands downwind of SO operations was beyond the time-frame of the accompanying postponement application especially since long-term impact studies are not yet available for South Africa.

6 COMPLAINTS

Year	Nature of complaints	Actions taken to investigate complaints	Causes of complaints identified	Measures taken to avoid reoccurrences in **instances where the plant's operations** were found to be the cause
FY15/16	A total of 6 external Sasolburg Operations related complaints were **received during SO's 2015/2016 financial year. The mentioned** incidents varied from minor to moderate incidents. 4 odour complaints related to acrylate and gaseous odours 2 visual smoke complaints, one related to planned fire break burning and another of windblown dust	Sasol operates a complaint line where any environmental complaint can be registered. The environmental standby will investigate the complaint and ensure that the necessary steps are taken to reduce and manage the impact and to reduce the time of the incident. Subsequent to an investigation, corrective action measures are implemented	Process related upsets including shut downs; Fire break burning; Elevated wind speeds under drought conditions entraining dust	Root cause investigations, followed by the implementation of corrective and preventative measures where possible.
FY16/17	A total of 15 external Sasolburg Operations related complaints were **received during SO's 2016/2017 financial year. The mentioned** incidents were all classified as minor incidents. 10 odour, 1 noise, 2 smoke and 2 excessive emission related complaints were received during the financial year	Sasol operates a complaint line where any environmental complaint can be registered. The environmental standby will investigate the complaint and ensure that the necessary steps are taken to reduce and manage the impact and to reduce the time of the incident. Subsequent to an investigation, corrective action measures are implemented	Process related upsets including start-ups and shut downs;	Root cause investigations, followed by the implementation of corrective and preventative measures where possible.

7   CURRENT OR PLANNED AIR QUALITY MANAGEMENT INTERVENTIONS

An overview of approved air quality management improvement interventions, currently implemented and scheduled over the next 5 to 10 years, is detailed in the accompanying Motivation Report.

8   COMPLIANCE AND ENFORCEMENT ACTIONS

No final directives or compliance notices have been issued to SO in the last five years.

9   ADDITIONAL INFORMATION

Beyond the requirements stipulated in the AIR Regulations and Dispersion Modelling Regulations, the following additional information is considered useful for better understanding the impacts of Sasol's activities and the implications of the requested postponements on ambient air quality. A brief description of each of these analyses is provided below, and referenced to where in the applications the information may be found.

a)   Polar plots

Polar plots have been provided in Section 5.1.6.1 to visually demonstrate directional contribution as well as the dependence of concentrations on wind speed, in much the same way as a pollution rose does. The polar plots identify major contributing emissions sources impacting on a monitoring station and the direction of the impact. These polar plots do not replace isopleth plots, but rather provide additional information on the measured air quality in the region of the facility.

b)   Peer review of dispersion model

To provide increased certainty to both the DEA and the public that the dispersion modelling approach of Airshed is accurate, valid and representative, Sasol decided to take an additional step to appoint an independent international expert to peer review the modelling methodology, Exponent Incorporated. Exponent Inc. is a world-renowned expert assisting the US-EPA with compliance modelling in similar instances in the United States

c)   Delta approach to assessing implications of postponements for ambient air quality

In assessing the impacts of Sasol's postponement applications on ambient air quality, a fit-for-purpose approach, as requested for by the Dispersion modelling Regulations, was taken to assess the results from the dispersion modelling, which we have referred to as the "delta approach". The delta approach is premised on recognising that the difference between the current or "before additional compliance is implemented" emission scenario (i.e. the baseline scenario) and "after additional compliance is implemented" scenario (i.e. the 2020 MES compliance scenario) relates to the change in emissions from the point sources in question.

Therefore, the delta approach focuses on demonstrating the change in predicted ambient impacts of the various compliance scenarios, to guide decision makers toward better understanding the implications of the approval of postponements on air quality, and how compliance with the new plant standards would impact on prevailing ambient air quality.

A detailed explanation of the scenarios modelled to highlight the delta changes in ambient air quality arising from retrofit of abatement technology is provided in Section 5.1.1.2. In summary, the three scenarios modelled include:
- Baseline Emissions – modelling conducted based on the current inventory and impacts;
- Minimum Emissions Standards – modelling conducted based on plants theoretically complying with New Plant Standards;
- Alternative Emission Limits – the proposed maximum emission concentrations, where applicable and different from the other three emission scenarios.

d) Estimating background ambient air pollutant concentrations

A background air concentration is normally defined as that concentration which would result from air emission sources outside the chosen modelling domain. This concentration can, for instance, be estimated by analysing observed air concentrations for those wind directions when it is blowing towards the sources included in the modelling domain. In other words, the observation point would be upwind from the sources being simulated by the dispersion modelling.

However, as used in the current investigation, background concentrations could also incorporate the contributions from air emission sources present in the modelling domain, but which were not included in the dispersion simulations. For example, air emissions from vehicle tailpipes can significantly contribute to the local ambient NO_2 concentrations. Although most of the sources of air emissions within the Sasol operations were included in the simulations, there remains some that were excluded, for instance fugitive emissions, but would add to the background concentration level.

Since these sources are not neatly located for easy analysis of upwind contributions, the procedure normally adopted to **estimate background air concentrations could not be followed. Instead, the "background' concentration was established by** comparing the predicted air concentrations with the observed air concentrations. The background concentration as used in this application therefore corresponds to the observed concentration value at a monitoring site when the simulated value at this site reached a near zero value. In other words, the observed residual air concentration was assumed to arise from other sources in the modelling domain.

With this method, the assumption is made that the model performs realistically and that the residual concentration determined this way is a good reflection of the emissions not included in the simulations. In an attempt to illustrate the model accuracy, the fractional bias was calculated for each monitoring station as described in Section 5.1.6.2 of the AIRs. This methodology has been prescribed by the US EPA (U.S. EPA 1992) as an acceptable manner to illustrate the validity of atmospheric dispersion model. Given the good model performance, as measure by the fractional bias, it is assumed that the background concentration obtained using this methodology is reasonable estimates.

e) Ambient impacts of secondary particulates arising from Sasol emissions

As detailed in Section 5.1.4.4, one of the reasons for selection of the CALPUFF modelling suite is the fact this this enabled inclusion of the impact of the chemical conversion of sulfur dioxide and nitrogen oxides to secondary particulates within the dispersion model results. Thus, the predicted PM_{10} concentrations reflected in Section 5.1.8.1.3 include direct emissions of **PM plus secondary particulates formed from Sasol's emis**sions.

10 ANNEXURE A

DECLARATION OF ACCURACY OF INFORMATION – APPLICANT

Name of Enterprise: <u>**Sasol South Africa Limited acting through its Sasolburg Operations**</u>

Declaration of accuracy of information provided:

Atmospheric Impact Report in terms of section 30 of the Act.

I, ___*R. van Zyl*___ [*duly authorised*], declare that the information provided in this atmospheric impact report is, to the best of my knowledge, in all respects factually true and correct. I am aware that the supply of false or misleading information to an air quality officer is a criminal offence in terms of section 51(1)(g) of the National Environmental Management : Air Quality Act (Act No. 39 of 2004).

Signed at ___*Sasolburg*___ on this _*10*_ day of ___*December*___ 2018

_____
SIGNATURE

___*Manager : Air Quality & GHGs.*___
CAPACITY OF SIGNATORY

11 ANNEXURE B

DECLARATION OF INDEPENDENCE - PRACTITIONER

Name of Practitioner: Reneé von Gruenewaldt

Name of Registration Body: South African Council for Natural Scientific Professions

Professional Registration No.: 400304/07

Declaration of independence and accuracy of information provided:

Atmospheric Impact Report in terms of section 30 of the Act.

I, Reneé von Gruenewaldt, declare that I am independent of the applicant. I have the necessary expertise to conduct the assessments required for the report and will perform the work relating the application in an objective manner, even if this results in views and findings that are not favourable to the applicant. I will disclose to the applicant and the air quality officer all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the air quality officer. The additional information provided in this atmospheric impact report is, to the best of my knowledge, in all respects factually true and correct. I am aware that the supply of false or misleading information to an air quality officer is a criminal offence in terms of section 51(1)(g) of this Act.

Signed at Midrand on this 11 day of December 2018

SIGNATURE

Principal Air Quality Scientist

CAPACITY OF SIGNATORY

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APPENDIX A: COMPETENCIES FOR PERFORMING AIR DISPERSION MODELLING

All modelling tasks were performed by competent personnel. Table A-1 is a summary of competency requirements. Apart from the necessary technical skills required for the calculations, personnel competency also include the correct attitude, behaviour, motive and other personal characteristic that are essential to perform the assigned job on time and with the required diligence as deemed necessary for the successful completion of the project.

The project team included a two principal engineers, with relevant experience of 34 years and 15 years and two principal scientists with 16 years and 6 years relevant experience. One of the principal scientists managed and directed the project.

One of the principal engineers conducted verification of modelling results. This function requires a thorough knowledge of the

- meteorological parameters that influence the atmospheric dispersion processes and
- atmospheric chemical transformations that some pollutants may undergo during the dispersion process.

Table A-1: Competencies for Performing Air Dispersion Modelling

Competency	Task, Knowledge and Experience
Context	Communication with field workers, technicians, laboratories, engineers and scientists and project managers during the process is important to the success of the model
	Familiar with terminology, principles and interactions
	Record keeping is important to support the accountability of the model - Understanding of data collection methods and technologies

Knowledge	Meteorology:
	• Obtain, review and interpret meteorological data
	• Understanding of meteorological impacts on pollutants
	• Ability to identify and describe soil, water, drainage and terrain conditions
	   o Understanding of their interaction
	   o Familiarity with surface roughness`
	• Ability to identify good and bad data points/sets
	• Understanding of how to deal with incomplete/missing meteorological data

	Atmospheric Dispersion models • Select appropriate dispersion model • Prepare and execute dispersion model • Understanding of model input parameters • Interpret results of model
	Chemical and physical interactions of atmospheric pollutants • Familiarity with fate and transport of pollutants in air • Interaction of primary pollutants with other substances (natural or industrial) to form secondary pollutants
	Information relevant to the model • Identify potential pollution (emission) sources and rates • Gather physical information on sources such as location, stack height and diameter • Gather operating information on sources such as mass flow rates, stack top temperature, velocity or volumetric flow rate • Calculate emission rates based on collected information • Identify land use (urban/rural) • Identify land cover/terrain characteristics • Identify the receptor grid/site
	Legislation, regulations and guidelines in regards to National Environment Management: Air Quality Act (Act No 39 of 2004), including • Minimum Emissions Standards (Section 21 of Act) • National Ambient Air Quality Standards • Regulations Regarding Air Dispersion Modelling • Atmospheric Impact Report (AIR)
Abilities	Ability to read and understand map information
	Ability to prepare reports and documents as necessary

Competency	Task, Knowledge and Experience
	Ability to review reports to ensure accuracy, clarity and completeness
	Communication skills
	Team skills

APPENDIX B: COMPARISON OF STUDY APPROACH WITH THE REGULATIONS PRESCRIBING THE FORMAT OF THE ATMOSPHERIC IMPACT REPORT AND THE REGULATIONS REGARDING AIR DISPERSION MODELLING (GAZETTE NO 37804 PUBLISHED 11 JULY 2014)

The Regulations prescribing the format of the Atmospheric Impact Report (AIR) (Government Gazette No 36094; published 11 October 2013) were referenced for the air dispersion modelling approach used in this study. Table B-1 compares the AIR Regulations with the approach used in Section 5.

The promulgated Regulations regarding Air Dispersion Modelling (Gazette No. 37804, vol. 589; 11 July 2014) were consulted to ensure that the dispersion modelling process used in this assessment was in agreement with the regulations. Table B-2 compares the Air Dispersion Modelling Regulations with the approach used in Section 5. The only updates applied, following stakeholder comment, was to the receptors to include schools and clinics, as indicated on the isopleth plots in Section 5.1.8.

Table B-1: Comparison of Regulations for the AIR with study approach

Chapter	Name	AIR regulations requirement	Status in AIR
1	Enterprise details	• Enterprise Details • Location and Extent of the Plant • Atmospheric Emission Licence and other Authorisations	Enterprise details included. Location of plant included. APPA permit numbers included.
2	Nature of process	• Listed Activities • Process Description • Unit Processes	All detail included in the regulated format
3	Technical Information	• Raw Materials Used and Production Rates • Appliances and Abatement Equipment Control Technology	All raw materials information that is not confidential and proprietary information. Sensitive information will be made available to the Licensing Authorities upon request (Section 3.1 and 3.2).

4	Atmospheric Emissions	• Point Source Emissions
		  • Point Source Parameters
		  • Point Source Maximum Emission Rates during Normal Operating Conditions
		  • Point Source Maximum Emission Rates during Start-up, Maintenance and/or Shut-down
		• Fugitive Emissions
		• Emergency Incidents
			There is no information available regarding the maximum rates, because these are not measured, and are impractical to measure; therefore only emissions rates during normal operating conditions are available. Information regarding fugitive sources has not been included, as the modelling only considers the sources included in the AEL.
			
			Information regarding emergency incidents was not included as the applications deal with normal operating conditions.

5	Impact of enterprise on receiving environment		
5.1	Analysis of emissions impact on human health	Must conduct dispersion modelling, must be done in accordance with Regulations; must use NAAQS	Completed as set out by the Regulations.
5.2	Analysis of emissions impact on environment	Must be undertaken at discretion of Air Quality Officer.	Literature review and analysis, where possible, included in AIR.
6	Complaints	Details on complaints received for last two years	Included
7	Current or planned air quality management interventions	Interventions currently being implemented and scheduled and approved for next 5 years.	Information on air quality interventions are included in detail in the motivation reports
8	Compliance and enforcement history	Must set out all air quality compliance and enforcement actions undertaken against the enterprise in the last 5 years. Includes directives, compliance notices, interdicts, prosecution, fines	Included

Chapter	Name	AIR regulations requirement	Status in AIR
9	Additional information		Included polar plots as an additional visualisation means of ambient air quality as monitored. Independent peer review of dispersion modelling methodology by international expert consultant.

Table B-2: Comparison of Regulations regarding the Air Dispersion Modelling with study approach

AIR Regulations	Compliance with Regulations	Comment

Levels of assessment
 	
• Level 1: where worst-case air quality impacts are assessed using simpler screening models
• Level 2: for assessment of air quality impacts as part of license application or amendment processes, where impacts are the greatest within a few kilometres downwind (less than 50km)
• Level 3: requires more sophisticated dispersion models (and corresponding input data, resources and model operator expertise) in situations:
  – where a detailed understanding of air quality impacts, in time and space, is required;
  – where it is important to account for causality effects, calms, non-linear plume trajectories, spatial variations in turbulent mixing, multiple source types, and chemical transformations;
  – when conducting permitting and/or environmental assessment process for large industrial developments that have considerable social, economic and environmental consequences;
  – when evaluating air quality management approaches involving multi-source, multi-sector contributions from permitted and non-permitted sources in an airshed; or,
  – when assessing contaminants resulting from non-linear processes (e.g. deposition, ground-level ozone (O_3), particulate formation, visibility)
	Level 3 assessment using CALPUFF	This Lagrangian Gaussian Puff model is well suited to simulate low or calm wind speed conditions. Alternative regulatory models such as the US EPA AERMOD model treats all plumes as straight-line trajectories, which under calm wind conditions grossly over-estimates the plume travel distance.
		
		CALPUFF is able to perform chemical transformations. In this study the conversion of NO to NO_2 and the secondary formation of particulate matter were concerns.

Model Input Source characterisation	Yes	Source characterisation provided in Section 5.1.7.
Emission rates: For new or modified existing sources the maximum allowed amount, volume, emission rates and concentration of pollutants that may be discharged to the atmosphere should be used	Yes	Emission rates used for each scenario are provided in Section 5.1.7.
Meteorological data Full meteorological conditions are recommended for regulatory applications.	Yes	WRF modelled meteorology (including upper air) corrected with on-site observed meteorology (surface meteorology) (Sections 5.1.4.6 and 5.1.5).
Data period	Yes	3 years (2015 to 2017)
Geographical Information Topography and land-use		Required for CALMET 3D meteorological file preparation (Section 5.1.4.6.2)

AIR Regulations	Compliance with Regulations	Comment
Domain and co-ordinate system	Yes	• Dispersion modelling domain: 57 x 57 km • UTM co-ordinate system (WGS84) (Section 5.1.4.6.4)
General Modelling Considerations		
Ambient Background Concentrations, including estimating background concentrations in multi-source areas	Yes	Section 5.1.5.4, Section 5.1.6, and Appendix G
NAAQS analyses for new or modified sources: impact of source modification in terms of ground-level concentrations should be assessed within the context of the background concentrations and the	Yes	Model predicted, 99th percentile ground-level concentrations compared against current observed concentrations and assessed for contribution to ambient concentrations. Used as an indication of how modifications to the plant will impact ambient concentrations. (Section 5.1.8)
Land-use classification	Yes	Section 5.1.4.2 and Section 5.1.4.6.2
Surface roughness	Yes	Computed from Land-use categories in the CALMET pre-processing step (Section 5.1.4.6.2).
Albedo	Yes	Computed from Land-use categories in the CALMET pre-processing step (Section 5.1.4.6.2).
Temporal and spatial resolution		
Receptors and spatial resolutions	Yes	Sections 5.1.8 and 5.1.4.6.4
Building downwash	Yes	Section 5.1.4.6.5
Chemical transformations	Yes	Sections 5.1.4.3, Section 5.1.4.4 and Appendix E and Appendix F.
General Reporting Requirements		
Model accuracy and uncertainty	Yes	Section 5.1.6, Section 5.1.9, Appendix I and Appendix J
Plan of study	Yes	Section 5.1.1.1
Air Dispersion Modelling Study Reporting Requirements	Yes	As per the Regulations Prescribing the Format of the Atmospheric Impact Report, Government Gazette No. 36904, Notice Number 747 of 2013 (11 October 2013) and as per the Regulations Regarding Air Dispersion Modelling (Government Gazette No. 37804 Notice R533, 11 July 2014).
Plotted dispersion contours	Yes	Section 5.1.8

APPENDIX C: RAW MATERIALS, ABATEMENT EQUIPMENT, ATMOSPHERIC EMISSIONS AND MEASURED DUSTFALL AT SASOL'S SASOLBURG OPERATIONS

C1: Raw Materials

Table C-1: Raw materials used at SO

Raw Material Type	Maximum Permitted Consumption Rate (Quantity)	Units (quantity/period)
Sasolburg Operations		
ATR		
Natural Gas		kNm^3/a
Rectisol		
Gas mixture (CO, H$_2$, CO$_2$, CH$_4$)	1 576 800	kNm^3/a
Thermal oxidation		
Spent Caustic	30 660	tonnes/year
Organic Solvents	13 140	tonnes/year
High Sulphur Pitch	21 900	tonnes/year
Limestone	26 280	tonnes/year
Organic waste water	17 520	tonnes/year
Off- specification waxes	720	tonnes/year
Sasol spent catalyst	2 448	tonnes/year
Polyethylene wax	960	tonnes/year
Other solid waste	1 800	tonnes/year
High organic waste	4 800	tonnes/year
Pitch/ tar waste slop oils	1 800	tonnes/year
Fuel gas	8 760	kNm^3/a
Steam Stations		
Water (Steam station 1)	6 132	kt/a
Water (Steam station 2)	9 070	kt/a
Coal (Steam station 1)	2 148	kt/a
Coal (Steam station 2)	2 000	kt/a
Ammonia		
Gas mixture (CO, H$_2$, CO$_2$, CH$_4$)		Nm^3/h
Nitrogen		Nm^3/h
Steam		tonnes/hour
Prillian		
Ammonia nitrate solution (88%)		tonnes/day
Nitric Acid/Ammonium Nitrate		
Ammonia		tonnes/day
SGEPP		
Natural gas	276 000 000	kg/a
SCCM		
Alumina		tonnes/year
Tetra Ethyl Ortho Silicate		tonnes/year
Wax		tonnes/year
Hydrogen		kNm^3/year
Ethanol		tonnes/year
Ammonia		tonnes/year
Fuel Gas		tonnes/year
Electrical Power		MVA
Nitrogen		kNm^3/year
Cobalt Solution		tonnes/year
Platinum		tonnes/year
N=Base, Cresol, Paraffin, TNPE and Phenosolvan		
IP sensitive information		
Solvents – All plants		
Hydrogen	1046	Nm^3/h
Acetone	18	m^3/h
Catalyst	15000	l/a

Raw Material Type	Maximum Permitted Consumption Rate (Quantity)	Units (quantity/period)
Solvents – MIBK 1 and 2		
Crude methanol		m³/h
Make – up water		l/h
Solvents – Methanol		
Crude methanol		m³/h
Make – up water		l/h
Solvents – Methanol TG		
Crude methanol E1102		m³/h
Solvents – E1204		
Sabutol feed		m³/h
Solvents - Butanol		
Propylene		tonnes/hour
Synthesis gas		Nm³/h
99 mol% Hydrogen		Nm³/h
Solvents - AAA		
Propylene		tonnes/year
Butanol		tonnes/year
Ethanol		tonnes/year
LOC		
Storage of various raw materials and products on site		
Polymers		
Poly 2		
Ethylene	Information protected. Licensing Authority can view information on site	
Additives		
1-Hexene		
Hydrogen		
Poly 3		
Ethylene		tonnes/year
Propylene		tonnes/year
Isododecain		
Organic peroxide initiators		tonnes/year
Additives (depending on market requirements)		tonnes/year
VCM and PVC		
VCM Plant		
Ethylene		tonnes/day
Chlorine		tonnes/day
Oxygen		tonnes/day
Hydrogen		tonnes/day
PVC Plant		
Vinyl Chloride monomer (VCM)		tonnes/day
Ethyl chloroformate		tonnes/day
Monomers		
C2-feed from Secunda	Information IP sensitive	
Ethane from Secunda		
Depropaniser off gas from Natref (propane + ethane)		
PPU4 bottoms from Natref (mainly propane)		
Cyanide 1		
Ammonia		tonnes/month
		Nm³/h (instantaneous)
Natural gas		GJ/month
		Nm³/h (instantaneous)
Electricity		MW/month
		kW instantaneous
Caustic		tonnes/month
		kg/h (instantaneous)
Graphite		tonnes/month
Nitrogen		kNm³/month
		Nm³/h (instantaneous)
Cyanide 2		
Ammonia		tonnes/month

Raw Material Type	Maximum Permitted Consumption Rate (Quantity)	Units (quantity/period)
		Nm^3/h (instantaneous)
Natural gas		GJ/month
		Nm^3/h (instantaneous)
Electricity		MW/month
		kW instantaneous
Caustic		tonnes/month
		kg/h (instantaneous)
Graphite		tonnes/month
Nitrogen		kNm^3/month
		Nm^3/h (instantaneous)
Chlorine		
Sodium Chloride		tonnes/year
Wax		
Sasol Wax – Production	Information IP sensitive	
Sasol Wax – Catalyst preparation		

* Raw materials not provided are due to IP or competition law sensitivities

Table C-2: All appliances and abatement equipment used on unit processes at SO

Appliance name	Appliance type/description	Appliance function/purpose
Precipitators	Electrostatic precipitators	Reduce particulate emissions
Bag filters	Bag house	Reduce particulate emissions
Venturi Scrubber	Venturi Scrubber	Reduce particulate and SO_2 emissions
SCR	Selective catalytic reduction unit	Reduce NOx emissions
Flares	Flare	Convert organic gasses into CO_2 and H_2O
Scrubbers	Wet scrubbers	Reduce particulate emissions
Filters	Reverse pulse cartridge filters	Reduce particulate emissions
VCU	Vapour combustion units	Converting fugitive emissions from columns, tanks and loading operations into CO_2 and H_2O
Cyclones	Cyclones	Reduce particulate emissions

C2: Point Source Emissions

Table C-3: Point source parameters

Point Source Code	Source Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Height of Release Above Ground (m)	Height Above Nearby Building (m)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temperature (°C)	Actual Gas Volumetric Flow (m³/hr)	Actual Gas Exit Velocity (m/s)	Emissions Hours	Type of Emissions (Continuous / Batch)
					Sasolburg Operations						
					ATR						
I3	Fired Heaters ATR A	-26.82631	27.84055	65	-	3.32	190	794 710	25.5	24 Hours	Continuous
I4	Fired Heaters ATR B	-26.82668	27.84077	65	-	3.32	190	769 778	24.7	24 Hours	Continuous
					Steam Stations						
I23	SS1 Boiler 4	-26.82217	27.84073	75	n/a	2.5	160	235 030	13.3	24 Hours	Continuous
I24	SS1 Boiler 5&6	-26.82235	27.84037	75	n/a	2.5	160	458 751	26.0	24 Hours	Continuous
I25	SS1 Boiler 7&8	-26.82248	27.84009	75	n/a	25	160	478 543	27.1	24 Hours	Continuous
I26	SS2 Boiler 1 to 7	-26.82217	27.84884	145	n/a	7.8	160	1 746 014	10.2	24 Hours	Continuous
					Thermal Oxidation						
I32	Heavy Ends B incinerator (B6990)	-26.82549	27.84035	40	n/a	1.5	570	63 617	3.9	24 Hours	Continuous
I33	High sulfur pitch incinerator (B6930)	-26.82537	27.84022	40	n/a	1.53	171	139 958	26.2	24 Hours	Continuous
I34	Spent caustic incinerator (B6993)	-26.82553	27.84043	40	n/a	1.2	83	50 894	12.9	24 Hours	Continuous
					PRILLAN / Ammonium nitrate						
I5	J 4062 A Dust scrubber	-26.82900	27.84100	22	n/a	1	29	106 311	37.6	24 Hours	Batch
I6	J 4062 B Dust scrubber	-26.82900	27.84100	22	n/a	1	28	92 372	32.67	24 Hours	Batch
I7	J4063 A	-26.82900	27.84100	85	n/a	1.5	21	89 700	14.1	24 Hours	Batch
I8	J4063 B	-26.82900	27.84100	85	n/a	1.5	23	94 599	14.87	24 Hours	Batch
I9	J4063 C	-26.82900	27.84100	85	n/a	1.5	23	66 607	10.47	24 Hours	Batch

Point Source Code	Source Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Height of Release Above Ground (m)	Height Above Nearby Building (m)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temperature (°C)	Actual Gas Volumetric Flow (m³/hr)	Actual Gas Exit Velocity (m/s)	Emissions Hours	Type of Emissions (Continuous / Batch)
					Nitric Acid Plant						
I53	Effluent stack	-26.82524	27.86023	75	n/a	1.5	215	39 634	6.23	24 Hours	Continuous
					N-Base, Cresol, TNPE and Phenosolvan						
I12	Fuel gas furnace	-26.83023	-26.83023	40	None in vicinity	0.11	99	164	4.8	24h/d	Continues
I13	Phenol plant	-26.82387	-26.82387	30	None in vicinity	0.2	29	26	0.23	24h/d	Continues
I14	SOx scrubber on N-base units	-26.83000	-26.83000	12	None in vicinity	0.11	300	1 687	49.3	24h/d	Continues
	Merisol Flare	-26.831706	27.845865	67	None in vicinity	1.2	Not available	2 000 m3/hr	4.8	adhoc	adhoc
					AAA						
I1	ST6010	-26.82300	27.86800	20	n/a	0.95	790	16 586	6.4	24 hours	Continuous
I2	ST1040	-26.82328	27.86682	25	n/a	1.5	123	70 615	12.63	24 hours	Continuous
					Solvents						
	E 501 Bottoms knockout	-26.776	27.84419	Ties in to B 1102 – 10 m	Ties in to B 1102	Ties in to B 1102	Ties in to B 1102	Ties in to B 1102	Ties in to B 1102	24 hours	Continuous
	F501 + F 502 vent	-26.77617	27.84472	15	None in vicinity	0.16	35	50.7	0.7	24 hours	Continuous
	F 505 vent	-26.77618	27.84471	15	None in vicinity	0.1	176	57.1	2.02	24 hours	Continuous
	E1204	-26.77589	27.84469	15	None in vicinity	0.1	24	12.4	0.44	24 hours	Continuous
	B 1102	-26.7759	27.8447	10	None in vicinity	0.4	59	452.4	1	24 hours	Continuous
	F1133 A+B	-26.77588	27.84468	15	None in vicinity	0.1	27	36.8	1.3	24 hours	Continuous
					LOC						
	VCU UNIT	-26.82794	27.84175	12		2.4	152	68401	4.2	24 hours	Intermittently when loading occurs

Point Source Code	Source Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Height of Release Above Ground (m)	Height Above Nearby Building (m)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temperature (°C)	Actual Gas Volumetric Flow (m³/hr)	Actual Gas Exit Velocity (m/s)	Emissions Hours	Type of Emissions (Continuous / Batch)
						Poly 2 (LLDPE) and Poly 3 (LDPE) plant					
	Poly 2 Flare	-26.83327	27.87093	±52	None in the vicinity	TBM	Flame	7173	Above flashback velocity	24 hours	Continuous
	Poly 3 Flare	-26.83271	27.87146	52	None in the vicinity	0.6	Flame	Designed for max relief load of 120t/h	Above flashback velocity	24 hours	Continuous
	Poly 3 Emergency Vent Separator (EVS)			8	None in the vicinity	0.8	Used only during emergency situations			24 hours	Continuous
						Monomers					
I10	Steam cracker furnaces, B002A/B	-26.83199	27.84400	20	None in the vicinity	1.8	417	54 049	5.9	24 hours	Continuous
I11	Steam cracker furnaces, B003	-26.83190	27.84395	26	None in the vicinity	1.2 x 2	200	34 608	8.5	24 hours	Continuous
	Elevated Flare (B101)	-26.83351	27.84492	65	None in the vicinity	0.914	176 (op)	Non continuous Flow		24 hours	Continuous
	Tank Flare (B180)	-26.83408	27.84626	30	None in the vicinity			Non continuous Flow		24 hours	Continuous
	Ground Flare (B009)	-26.83342	27.84558	24.39	None in the vicinity	19.278	100 (20 – 200)	12.1	0.0065	24 hours	Continuous
	Mea Regen Off Gas	-26.832	27.84386	35	None in the vicinity	0.1016	40	0.098	0.003	24 hours	Continuous
						Vinyl Chloride Monomer (VCM) Plant					
	VCM incinerator	-26.82999	27.87300	30	None in the vicinity	0.36	134	9527	22.7	24 hours	Continuous
	VCM Cracker	-26.82999	27.87300	40	None in the vicinity	1.71	390	26457	3.2	24 hours	Continuous
	VCM Safety Scrubber – not continuous flow	-26.82833	27.87253	26.6	None in the vicinity	0.7	96	18500	13.5	24 hours	Continuous
	VCM Cold Flare – not continuous flow	-26.82858	27.87306	50	None in the vicinity	0.81	136	77200	42	24 hours	Continuous

Point Source Code	Source Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Height of Release Above Ground (m)	Height Above Nearby Building (m)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temperature (°C)	Actual Gas Volumetric Flow (m³/hr)	Actual Gas Exit Velocity (m/s)	Emissions Hours	Type of Emissions (Continuous / Batch)
					Poly Vinyl Chloride (PVC) Plant						
	PVC Reaction Stack North	-26.82758	27.87408	24	n/a	0.6	30	7700	7.6	24 hours	Continuous
	PVC Reaction Stack South	-26.82717	27.87353	24	n/a	0.6	30	7700	7.6	24 hours	Continuous
	PVC Slurry Stock Tank Stack	-26.82717	27.87442	35	n/a	1.2	45	60000	15	24 hours	Continuous
	PVC VCM Recovery Stack	-26.828	27.87408	24	n/a	0.05	-40	19	3	24 hours	Continuous
	PVC Multigrade Vent Stack	-26.82758	27.87408	6	n/a	0.05	100	89	12.6	24 hours	Continuous
I29	PVC Drier Stack North	-26.82787	27.87330	35	n/a	1.8	63	131 917	14.4	24 hours	Continuous
I30	PVC Dryer Stack South	-26.82791	27.87336	35	n/a	1.8	55	141 352	15.4	24 hours	Continuous
					Chlorine plant						
I31	HCl burner stacks	-26.82546	27.84039	15	n/a	0.16	30	120	2.8	24 hours	Continuous
	Chlorine hypo stacks	-26.82361	27.87406	40	n/a	0.25	23	60	2.2	24 hours	Continuous
					Cyanide plant						
	Cyanide stacks	-26.82361	27.86672			0.2	35	Cannot be quantified due to hydrogen and the associated fire risk		24 hours	Continuous
					Sasol Wax						
I15	Oven B 4701	-26.83078	27.84631	26	None in the vicinity	1	409	18 378	6.5	24 hours	Continuous

Point Source Code	Source Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Height of Release Above Ground (m)	Height Above Nearby Building (m)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temperature (°C)	Actual Gas Volumetric Flow (m³/hr)	Actual Gas Exit Velocity (m/s)	Emissions Hours	Type of Emissions (Continuous / Batch)
I16	Oven B 4702	-26.83079	27.84625	26	None in the vicinity	1	320	18 661	6.6	24 hours	Continuous
I17	Oven B 4801	-26.83081	27.84639	26	None in the vicinity	1.25	165	23 856	5.4	24 hours	Continuous
I18	Oven B 4802	-26.83076	27.84648	26	None in the vicinity	1.25	285	30 925	7	24 hours	Continuous
I19	Oven L 4234 Catalyst washout	-26.83109	27.84242	45	None in the vicinity	0.5	61	9 613	13.6	24 hours	Continuous
	Oven B 2801	-26.82617	27.84292	20	None in the vicinity	0.7	188	3 930	2.8	24 hours	Continuous
	Oven B 1521	-26.82578	27.84256	20	None in the vicinity	0.77	285	4 670	2.8	24 hours	Continuous
Wax catalyst preparation											
I20	Catalyst preparation Salt plant	-26.83108	27.84210	15	None in the vicinity	0.2	36	1312	11.6	24 hours	Continuous
I21	Catalyst preparation SBR	-26.83131	27.84264	15	More or less midway between the ground and the roof	0.5	58	6 030	8.53	24 hours	Continuous
I22	Catalyst preparation FBR	-26.83109	27.84244	15	On top of the roof	0.61	61	15 879	15.6	24 hours	Continuous
	Nitric acid plant / Calciner stack	-26.831254	27.842644	40m	± 3 m	1	40	4 000	5.7	24 hours	Continuous
Sasol Gas Engine Power Plant											
I35	Bay 1 (stack 1 - 6) - Engine 1	-26.81964	27.84770	27	n/a	1.2	301	114 613	28.2	24 hours	Continuous
I36	Bay 1 (stack 1 - 6) - Engine 2	-26.81964	27.84770	27	n/a	1.2	346	107284	26.4	24 hours	Continuous
I37	Bay 1 (stack 1 - 6) - Engine 3	-26.81964	27.84770	27	n/a	1.2	341	144 946	35.6	24 hours	Continuous
I38	Bay 1 (stack 1 - 6) - Engine 4	-26.81964	27.84770	27	n/a	1.2	345	134 970	33.2	24 hours	Continuous

Point Source Code	Source Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Height of Release Above Ground (m)	Height Above Nearby Building (m)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temperature (°C)	Actual Gas Volumetric Flow (m³/hr)	Actual Gas Exit Velocity (m/s)	Emissions Hours	Type of Emissions (Continuous / Batch)
I39	Bay 1 (stack 1 - 6) - Engine 5	-26.81964	27.84770	27	n/a	1.2	325	116 445	28.6	24 hours	Continuous
I40	Bay 1 (stack 1 - 6) - Engine 6	-26.81964	27.84770	27	n/a	1.2	338	135 581	33.3	24 hours	Continuous
I41	Bay 2 (stack 7-12) - Engine 7	-26.81936	27.84820	27	n/a	1.2	339	125 606	30.9	24 hours	Continuous
I42	Bay 2 (stack 7-12) - Engine 8	-26.81936	27.84820	27	n/a	1.2	356	135 581	33.3	24 hours	Continuous
I43	Bay 2 (stack 7-12) - Engine 9	-26.81936	27.84820	27	n/a	1.2	339	122 145	30.0	24 hours	Continuous
I44	Bay 2 (stack 7-12) - Engine 10	-26.81936	27.84820	27	n/a	1.2	342	131 713	32.4	24 hours	Continuous
I45	Bay 2 (stack 7-12) - Engine 11	-26.81936	27.84820	27	n/a	1.2	345	140 060	34.4	24 hours	Continuous
I46	Bay 2 (stack 7-12) - Engine 12	-26.81936	27.84820	27	n/a	1.2	331	118 277	29.1	24 hours	Continuous
I47	Bay 3 (stack 13-18) - Engine 13	-26.81918	27.84860	27	n/a	1.2	335	114 409	28.1	24 hours	Continuous
I48	Bay 3 (stack 13-18) - Engine 14	-26.81918	27.84860	27	n/a	1.2	351	137 820	33.9	24 hours	Continuous
I49	Bay 3 (stack 13-18) - Engine 15	-26.81918	27.84860	27	n/a	1.2	343	127 642	31.4	24 hours	Continuous
I50	Bay 3 (stack 13-18) - Engine 16	-26.81918	27.84860	27	n/a	1.2	342	134 156	33.0	24 hours	Continuous
I51	Bay 3 (stack 13-18) - Engine 17	-26.81918	27.84860	27	n/a	1.2	353	132 935	32.7	24 hours	Continuous
I52	Bay 3 (stack 13-18) - Engine 18	-26.81918	27.84860	27	n/a	1.2	346	100 810	24.8	24 hours	Continuous
Pilot plant Group Technology											
	Pilot Plant Flare	-26.8221	27.8447	39	3.5	0.15-0.2	200	2160	~70	24 Hours	Intermittently related to start-up, shut down and upset

Point Source Code	Source Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Height of Release Above Ground (m)	Height Above Nearby Building (m)	Diameter at Stack Tip / Vent Exit (m)	Actual Gas Exit Temperature (°C)	Actual Gas Volumetric Flow (m³/hr)	Actual Gas Exit Velocity (m/s)	Emissions Hours	Type of Emissions (Continuous / Batch)
											conditions

Table C-4: Point source emission rates during normal operating conditions

Point Source Code	Pollutant Name	Maximum Release Rate (mg/Nm³)[a]	Average Period	Duration of Emissions
SO				
ATR A	Particulates	120	Hourly	Continuous
	NO_x	1700	Hourly	Continuous
	SO_2	1700	Hourly	Continuous
ATR B	Particulates	120	Hourly	Continuous
	NO_x	1700	Hourly	Continuous
	SO_2	1700	Hourly	Continuous
Boiler 4	Particulates	165	Daily	Continuous
	SO_2	2000	Hourly	Continuous
	NO_x	1450	Hourly	Continuous
Boiler 5&6	Particulates	165	Daily	Continuous
	SO_2	2000	Hourly	Continuous
	NO_x	1450	Hourly	Continuous
Boiler 7&8	Particulates	165	Daily	Continuous
	SO_2	2000	Hourly	Continuous
	NO_x	1450	Hourly	Continuous
SS2 Boiler 1-7	Particulates	100	Daily	Continuous
	SO_2	2000	Hourly	Continuous
	NO_x	1250	Hourly	Continuous
Thermal Oxidation (90 Furnace)	Particulates	Cannot be measured due to high temperature		
	CO	50	Hourly	Continuous
	NO_x expressed as NO_2	360	Hourly	Continuous
	SO_2	50	Hourly	Continuous
	HCl	10	Hourly	Continuous
	HF	1.5	Hourly	Continuous
	Pb+As+Sb+Cr+Co+Cu+Mn+Ni+V	Cannot be measured due to high temperature		
	Hg			
	Cd+Tl			
	TOC	25	Hourly	Continuous
	NH_3	10	Hourly	Continuous
	Dioxins and furans	Cannot be measured due to high temperature		
Thermal Oxidation (30 Furnace)	Particulates	50	Hourly	Continuous
	CO	75	Hourly	Continuous
	NO_x expressed as NO_2	750	Hourly	Continuous
	SO_2	1800	Hourly	Continuous
	HCl	10	Hourly	Continuous
	HF	1	Hourly	Continuous
	Pb+As+Sb+Cr+Co+Cu+Mn+Ni+V	1	Hourly	Continuous
	Hg	0.05	Hourly	Continuous
	Cd+Tl	0.05	Hourly	Continuous
	TOC	50	Hourly	Continuous
	NH_3	10	Hourly	Continuous
	Dioxins and furans	0.1 ng TEQ/Nm³	Hourly	Continuous
Thermal Oxidation	Particulates	180	Hourly	Continuous

Point Source Code	Pollutant Name	Maximum Release Rate (mg/Nm^3)[a]	Average Period	Duration of Emissions
(93 Furnace)	CO	1050	Hourly	Continuous
	NOx expressed as NO$_2$	420	Hourly	Continuous
	SO$_2$	50	Hourly	Continuous
	HCl	15	Hourly	Continuous
	HF	1.2	Hourly	Continuous
	Pb+As+Sb+Cr+Co+Cu+Mn+Ni+V	22	Hourly	Continuous
	Hg	0.05	Hourly	Continuous
	Cd+Tl	0.05	Hourly	Continuous
	TOC	10	Hourly	Continuous
	NH$_3$	10	Hourly	Continuous
	Dioxins and furans	0.1 ng TEQ/Nm^3	Hourly	Continuous
10	Particulates	50	Hourly	Batch
	NH$_3$	100	Hourly	Batch
11	Particulates	50	Hourly	Batch
	NH$_3$	100	Hourly	Batch
12	Particulates	50	Hourly	Batch
	NH$_3$	100	Hourly	Batch
13	NOx	500	Hourly	Continuous
Cobalt Catalyst plant				
1	VOCs	40	Hourly	Continuous
2	NOx	700	Hourly	Continuous
3	NOx	700	Hourly	Continuous
4	VOCs	40	Hourly	Batch
5	VOCs	40	Hourly	Batch
6	Particulates	50	Hourly	Continuous
7	NO$_X$	700	Hourly	Continuous
	VOCs	40	Hourly	Continuous
8	NO$_X$	700	Hourly	Continuous
9	NO$_X$	700	Hourly	Continuous
	VOCs	40	Hourly	Continuous
10	NO$_X$	700	Hourly	Continuous
	VOCs	40	Hourly	Continuous
11	NO$_X$	700	Hourly	Continuous
	VOCs	40	Hourly	Continuous
Merisol				
1	Particulates	120	Hourly	Continuous
	NO$_X$ expressed as NO$_2$	1700	Hourly	Continuous
	SO$_2$	1700	Hourly	Continuous
2	SO$_3$	100	Hourly	Continuous
	VOCs	40000	Hourly	Continuous
3	SO$_3$	100	Hourly	Continuous
	VOCs	40000	Hourly	Continuous
4	VOCs	40000	Hourly	Continuous
Sastech				
1	Not applicable as the point source is associated with emergency flaring.			

Point Source Code	Pollutant Name	Maximum Release Rate (mg/Nm³)[(a)]	Average Period	Duration of Emissions
Solvents				
1	VOCs	150	Hourly	Continuous
2	VOCs	150	Hourly	Continuous
3	VOCs	150	Hourly	Continuous
4	VOCs	150	Hourly	Continuous
5	VOCs	150	Hourly	Continuous
6	VOCs	150	Hourly	Continuous
7	VOCs	150	Hourly	Continuous
8	VOCs	150	Hourly	Continuous
LOC				
98	VOCs	150	Hourly	Intermittent
Polymers				
1	Particulates	120	Hourly	Continuous
	SO_2	1700	Hourly	Continuous
	NO_X expressed as NO_2	1700	Hourly	Continuous
1b	Particulates	120	Hourly	Continuous
	SO_2	1700	Hourly	Continuous
	NO_X expressed as NO_2	1700	Hourly	Continuous
1c	Methyl amine	10	Hourly	Continuous
2	Particulates	25	Hourly	Continuous
	SO_2	50	Hourly	Continuous
	NO expressed as NO_2	200	Hourly	Continuous
	HF	1	Hourly	Continuous
	CO	75	Hourly	Continuous
	HCl	30	Hourly	Continuous
	Pb+As+Sb+Cr+Co+Cu+Mn+Ni+V	0.5	Hourly	Continuous
	Hg	0.05	Hourly	Continuous
	Cd+Tl	0.5	Hourly	Continuous
	TOC	10	Hourly	Continuous
	NH_3	10	Hourly	Continuous
	Dioxins	$0.2ngTEQ/Nm^3$	Hourly	Continuous
3	Particulates	120	Hourly	Continuous
	SO_2	1700	Hourly	Continuous
	NO_X	200 ppm	Hourly	Continuous
3a	VOCs	40000	Hourly	Continuous
3b	Bursting discs – emissions will only occur during over pressure incidents			Only during emergencies
3c				Only during emergencies
3d				Only during emergencies
3e				Only during emergencies
3f				Only during emergencies
3g				Only during emergencies
3h				Only during emergencies
3i				Only during emergencies
3j				Only during emergencies
3k				Only during emergencies
3l	VCM	150 ppm (m/m)	Daily	Continuous

Point Source Code	Pollutant Name	Maximum Release Rate (mg/Nm^3)[a]	Average Period	Duration of Emissions
3m	VCM	150 ppm (m/m)	Daily	Continuous
3n	VCM	25 ppm (m/m)	Daily	Continuous
3o	VOCs	40000	Hourly	Continuous
3p	VOCs	40000	Hourly	Continuous
4	Particulates	21 mg/Am^3	Hourly	Continuous
5	Particulates	21 mg/Am^3	Hourly	Continuous
6	Cl_2	5	Hourly	Continuous
6	HCl	10	Hourly	Continuous
7	Cl_2	50	Hourly	Continuous
8	HCN	50 ppm	Hourly	Continuous
Wax				
1, 2, 3, 4, 5, 6, 7, 12, 13	Particulates	120	Hourly	Continuous
1, 2, 3, 4, 5, 6, 7, 12, 13	NO_X	1700	Hourly	Continuous
1, 2, 3, 4, 5, 6, 7, 12, 13	SO_2	1700	Hourly	Continuous
8, 9, 10	Particulate Matter	50	Hourly	Continuous
8, 9, 10	NO_X	2000	Hourly	Continuous
8, 9, 10	SO_2	1700	Hourly	Continuous
11	NO_X	3.5 t/month	Daily	Continuous

(a) units mg/Nm^3 unless otherwise stated

C3: Fugitive emissions – dustfall monitoring
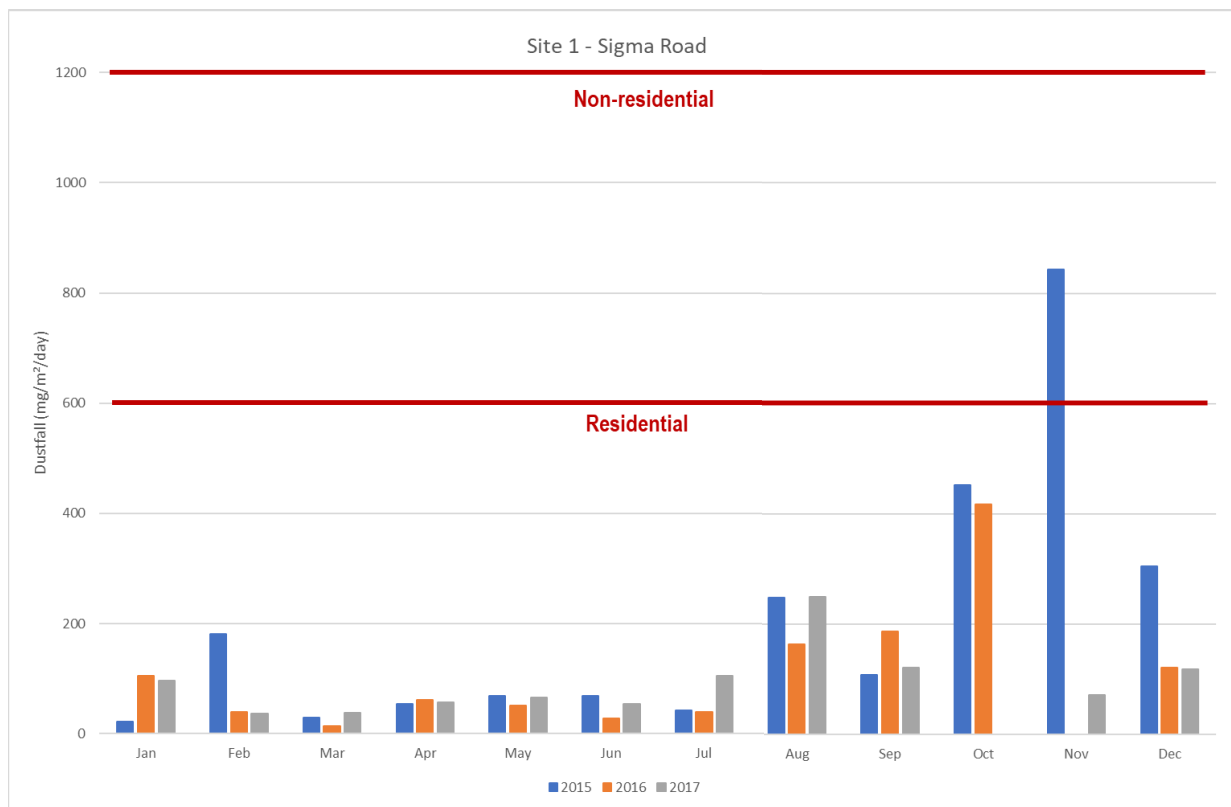
Figure C-1: Dustfall rates at Site 1 (Sigma road) between 2015 and 2017

Figure C-2: Dustfall rates at Site 2 (Anthrum road) between 2015 and 2017
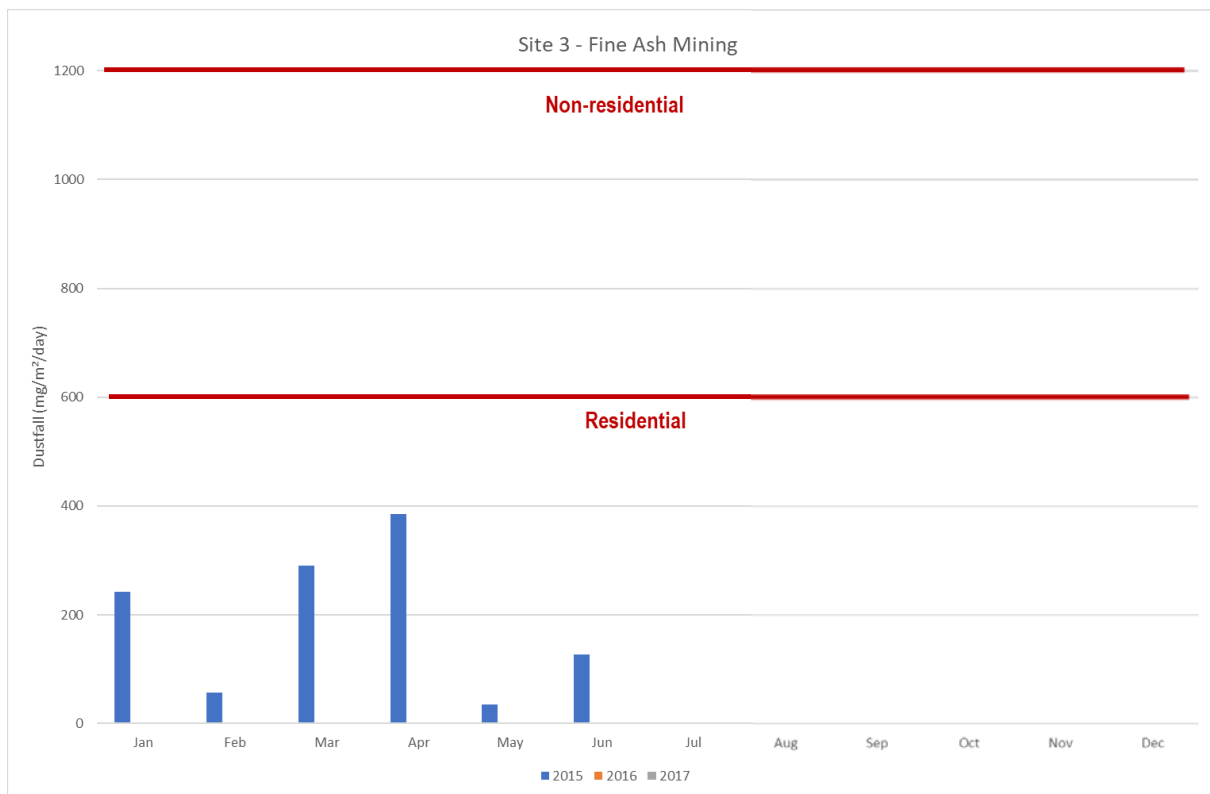
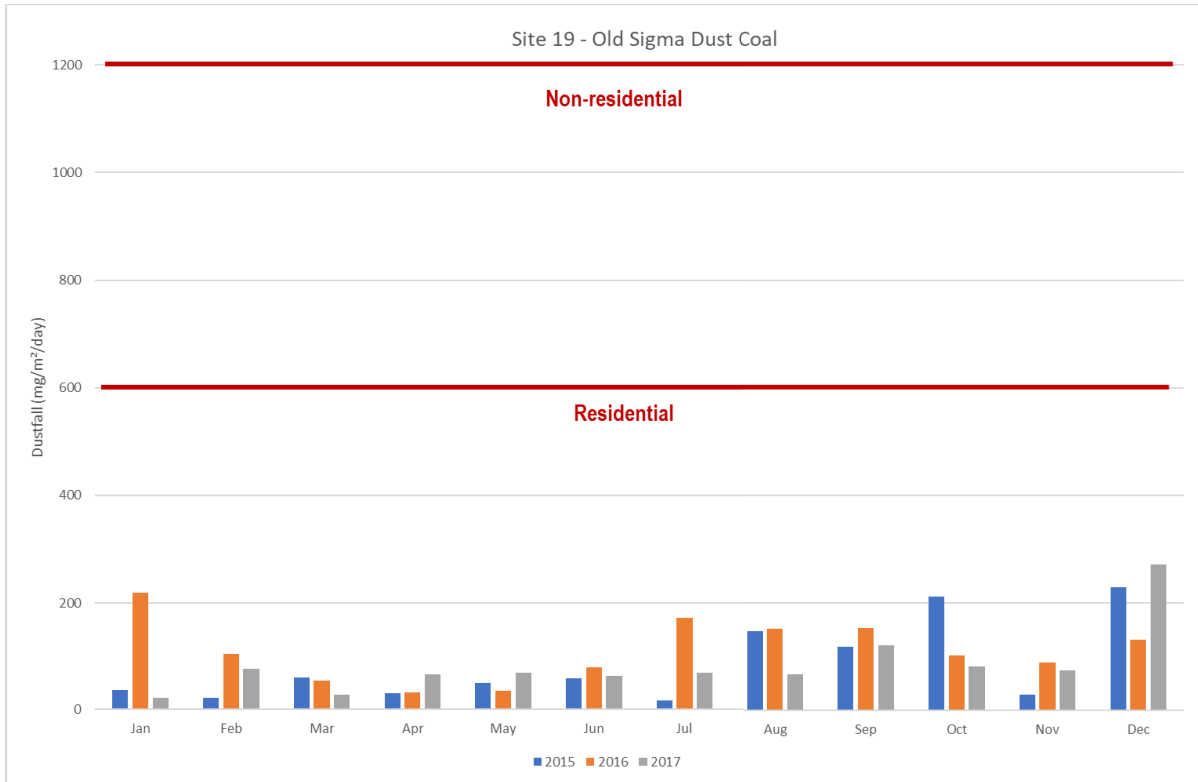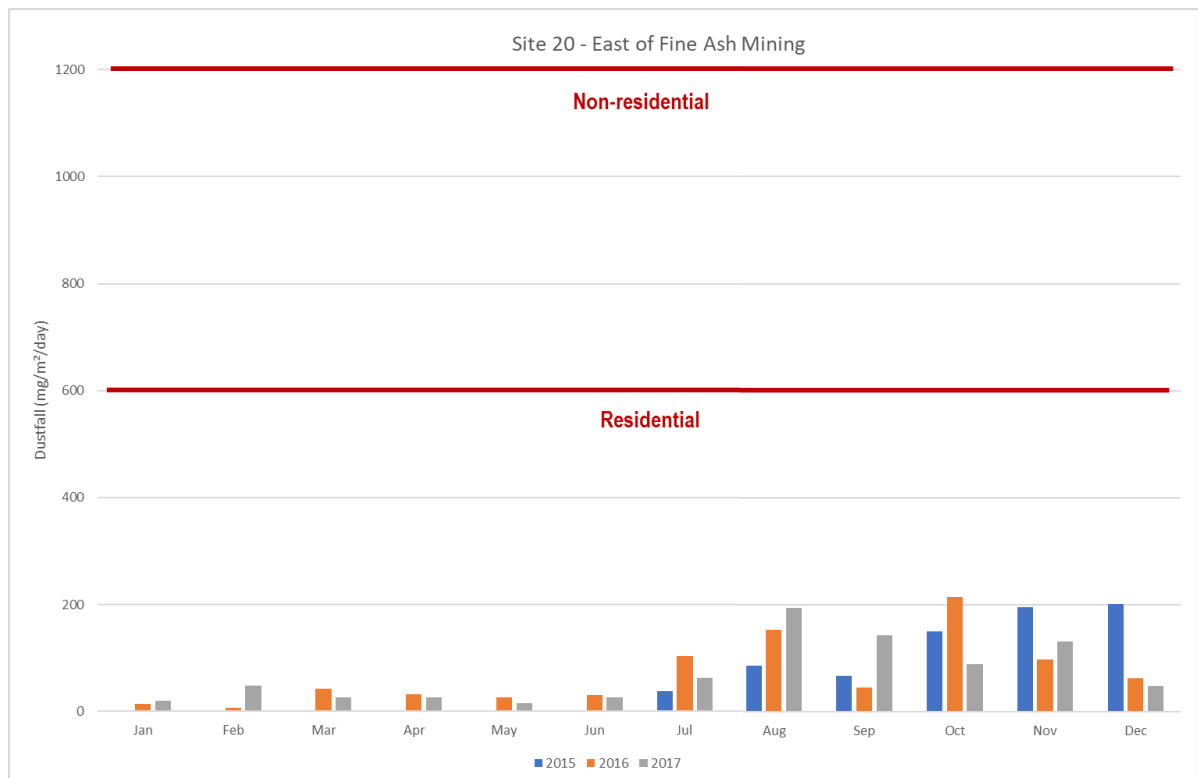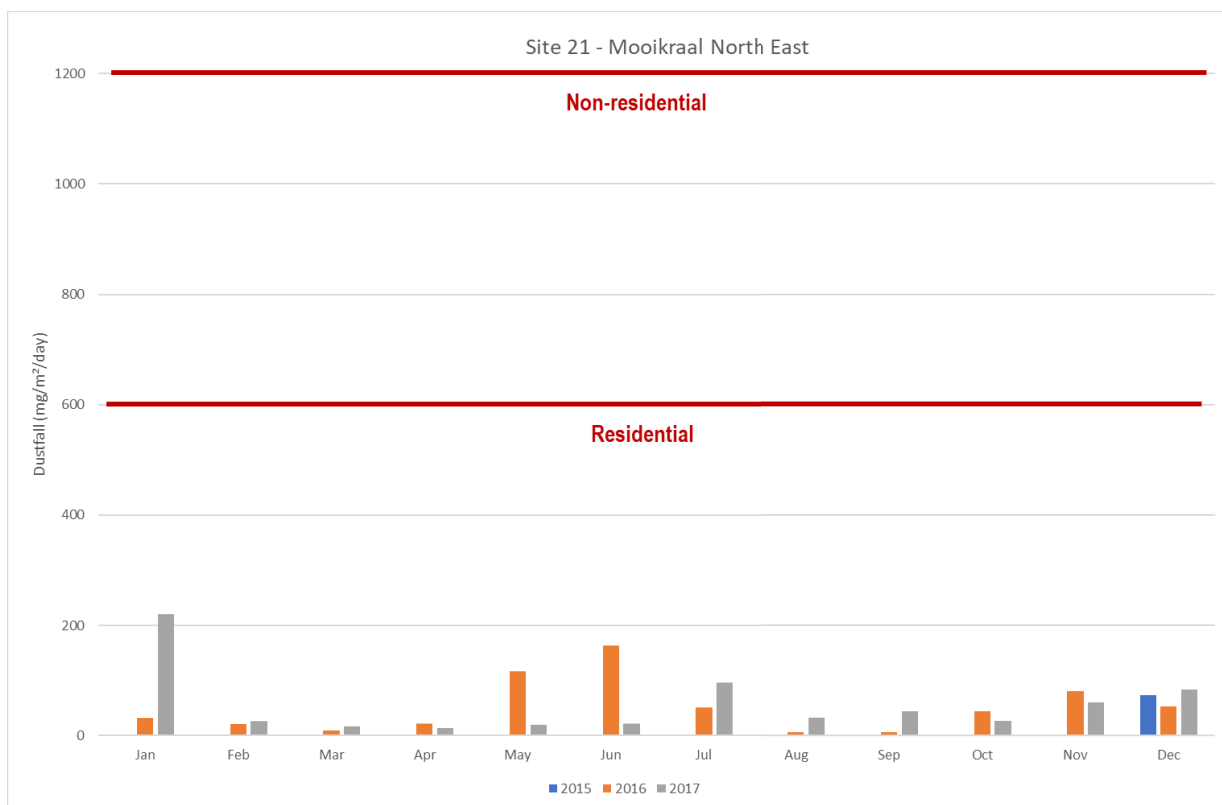Figure C-3: Dustfall rates at Site 3 (Fine Ash Mining) between 2015 and 2017

Figure C-4: Dustfall rates at Site 4 (West Gate) between 2015 and 2017

Figure C-5: Dustfall rates at Site 5 (Substation) between 2015 and 2017
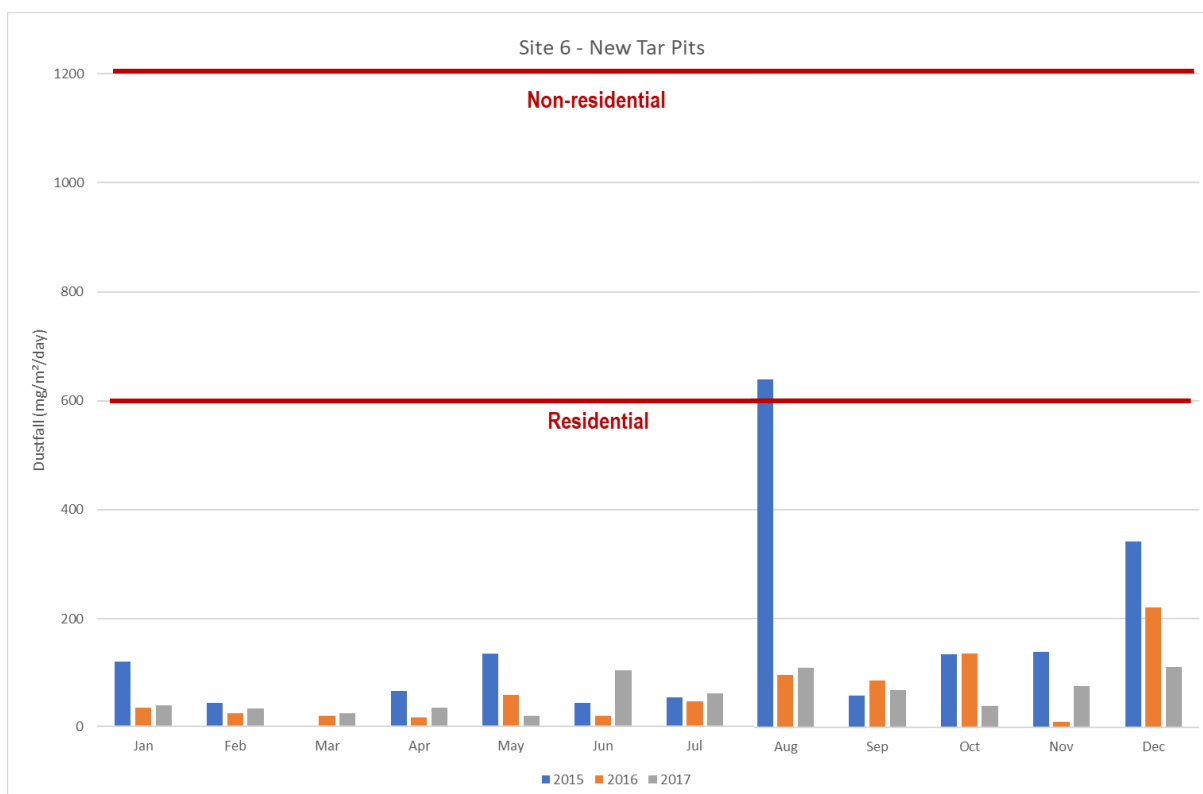
Figure C-6: Dustfall rates at Site 6 (New Tar Pits) between 2015 and 2017
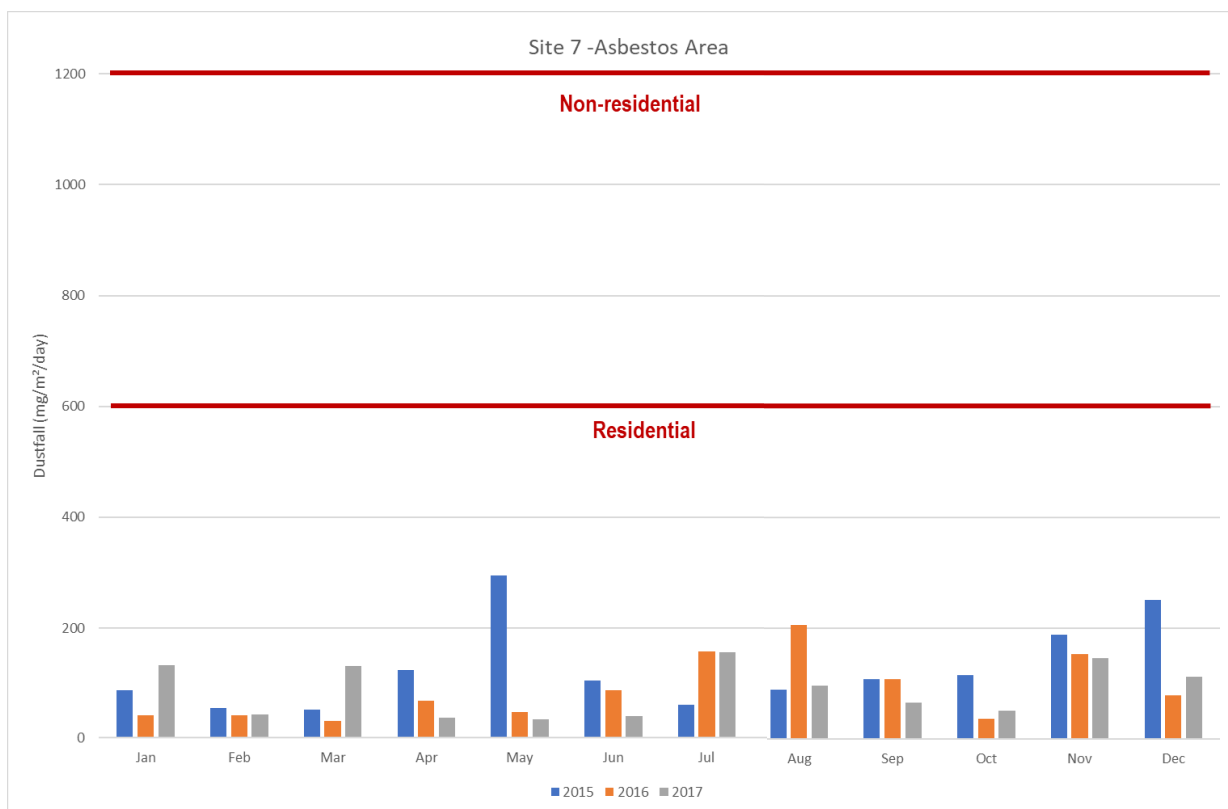
Figure C-7: Dustfall rates at Site 7 (Asbestos area) between 2015 and 2017
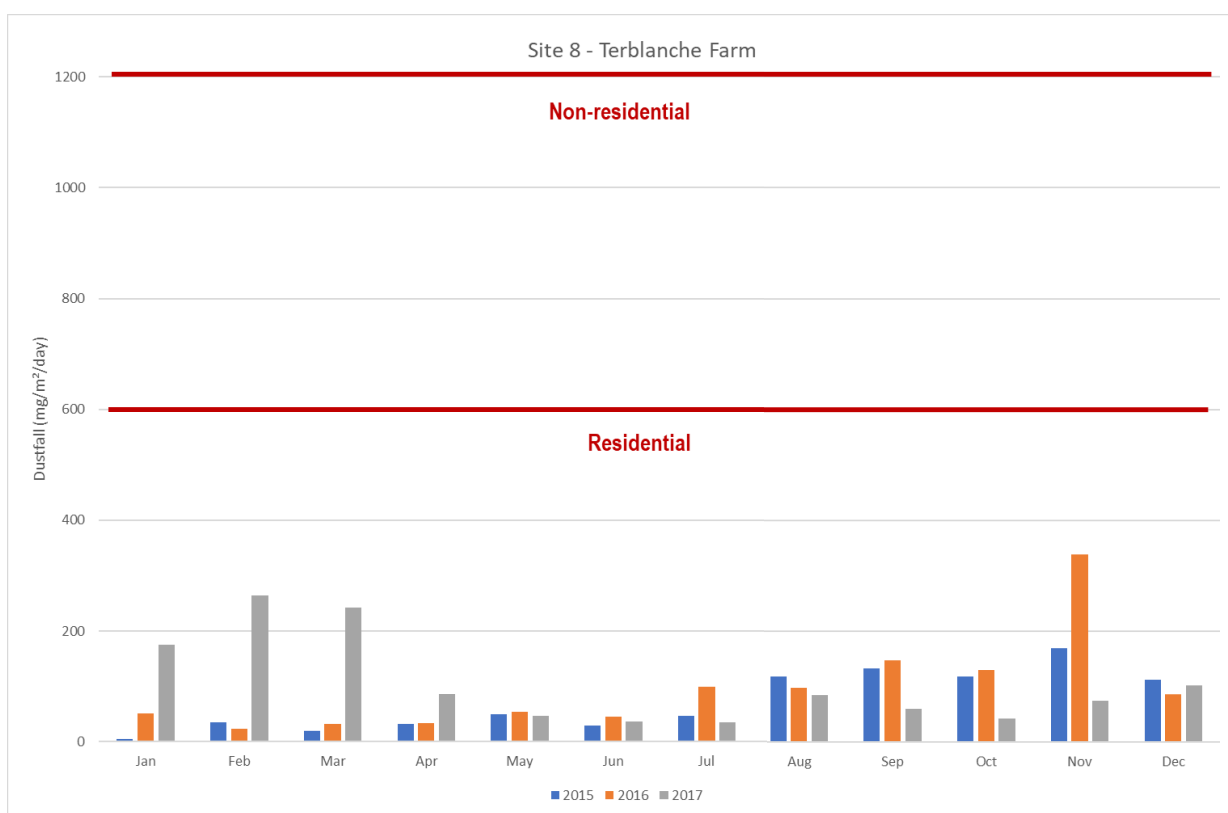
Figure C-8: Dustfall rates at Site 8 (Terblanche farm) between 2015 and 2017

Figure C-9: Dustfall rates at Site 9 (Sewage farm) between 2015 and 2017
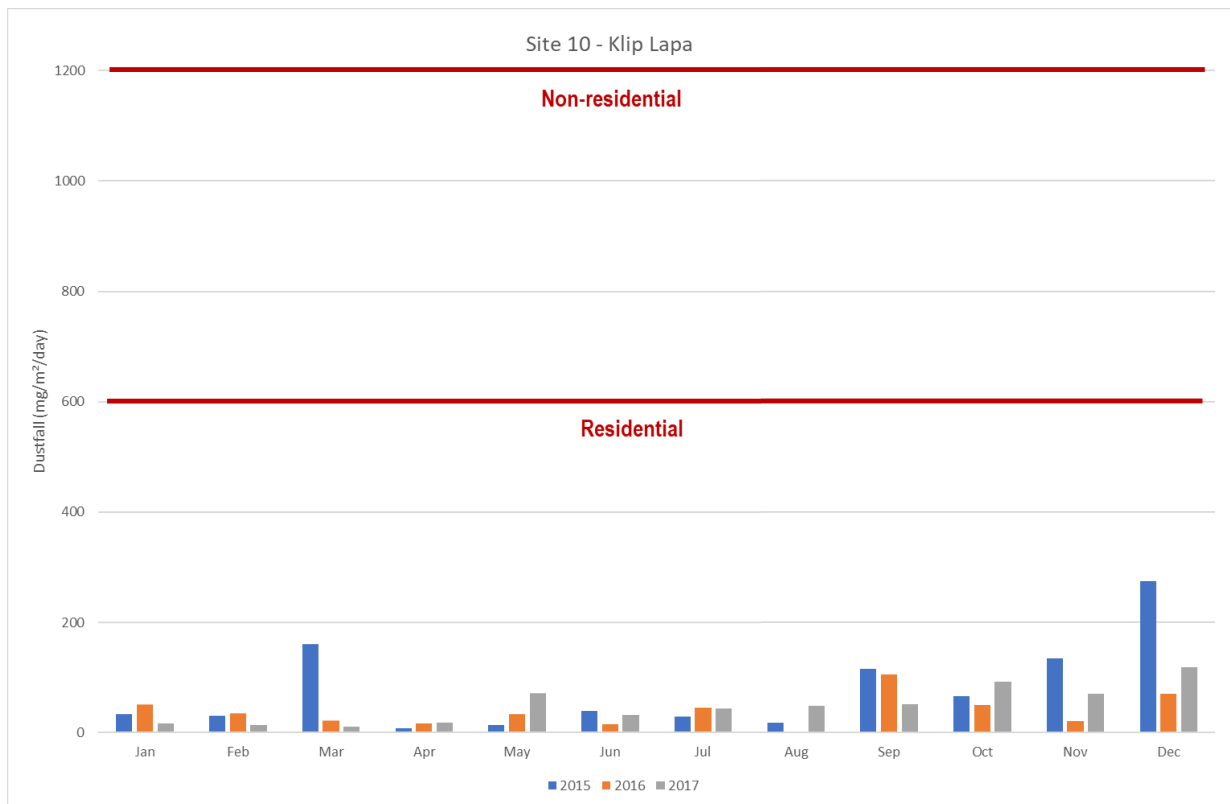
Figure C-10: Dustfall rates at Site 10 (Klip Lapa) between 2015 and 2017

Figure C-11: Dustfall rates at Site 11 (#5 Fine Ash) between 2015 and 2017

Figure C-12: Dustfall rates at Site 12 (Emergency dam) between 2015 and 2017
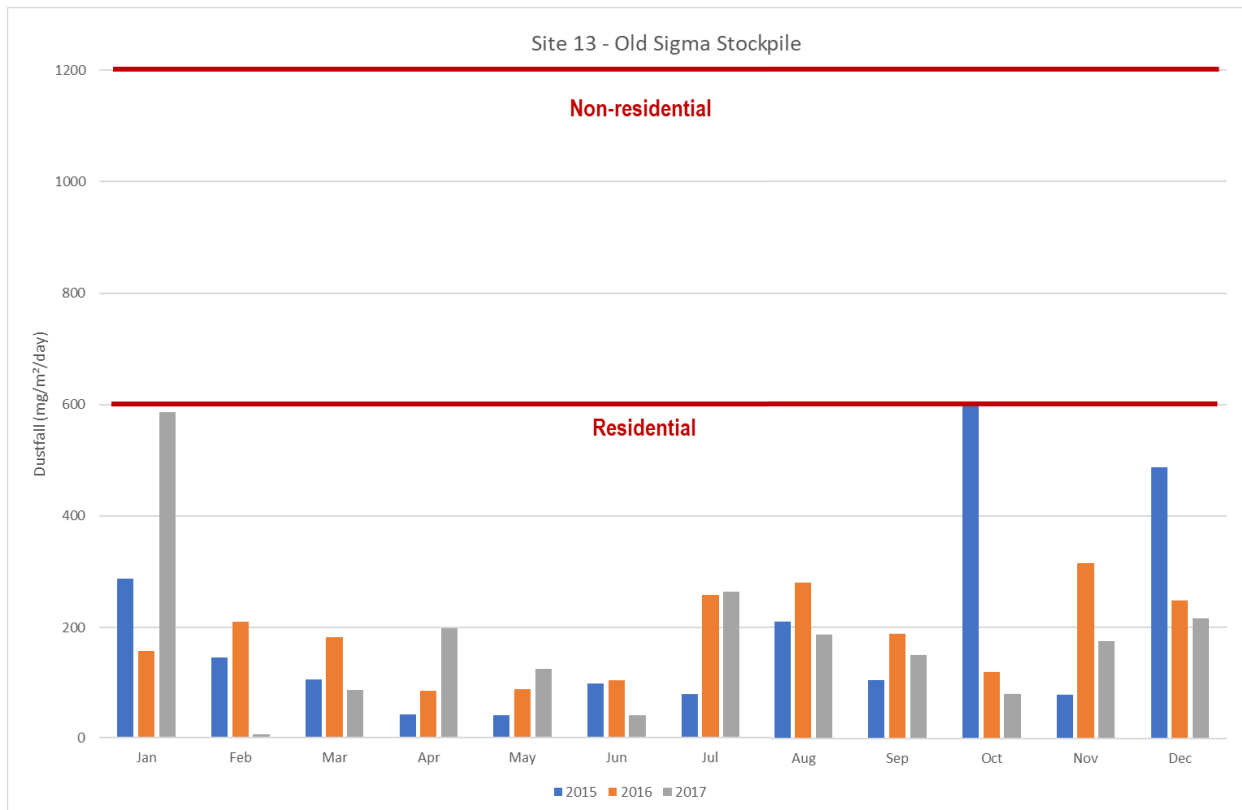
Figure C-13: Dustfall rates at Site 13 (Old Sigma Stockpile) between 2015 and 2017
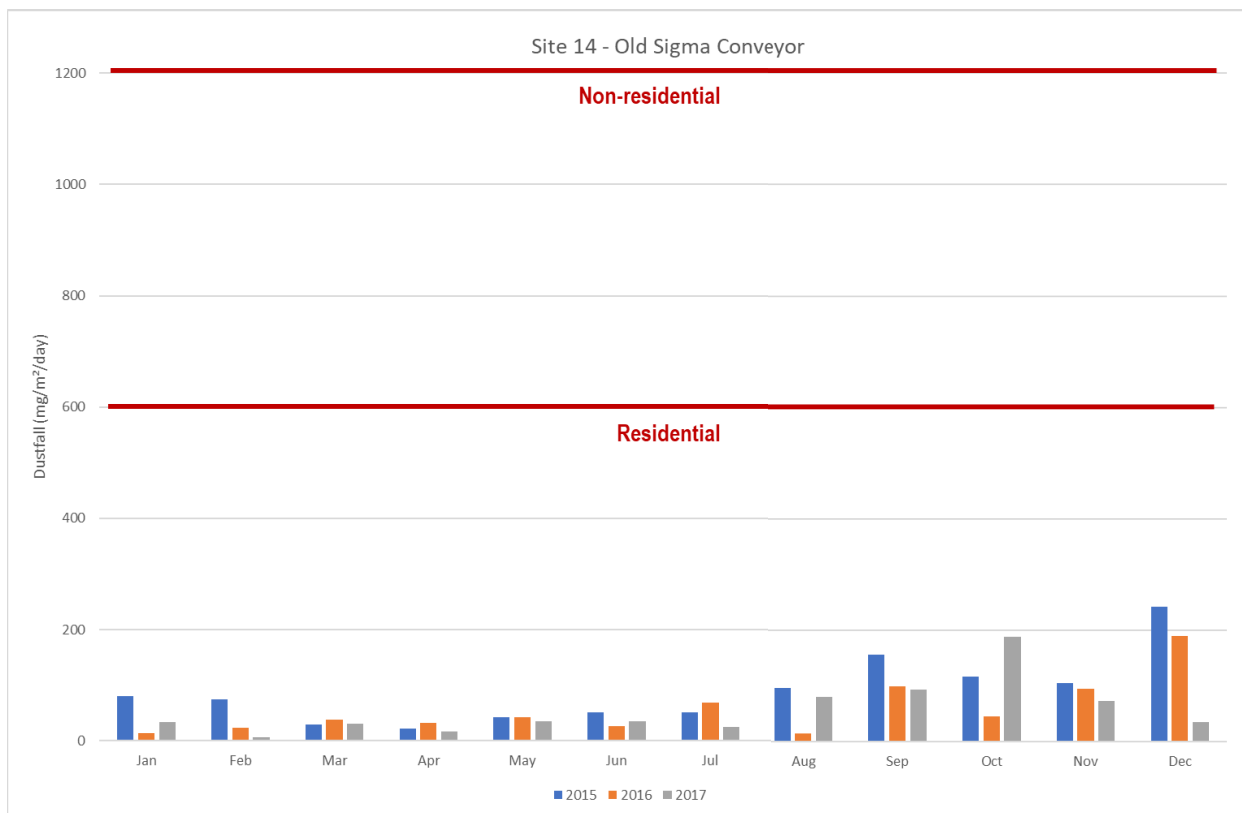
Figure C-14: Dustfall rates at Site 14 (Old Sigma Conveyor) between 2015 and 2017
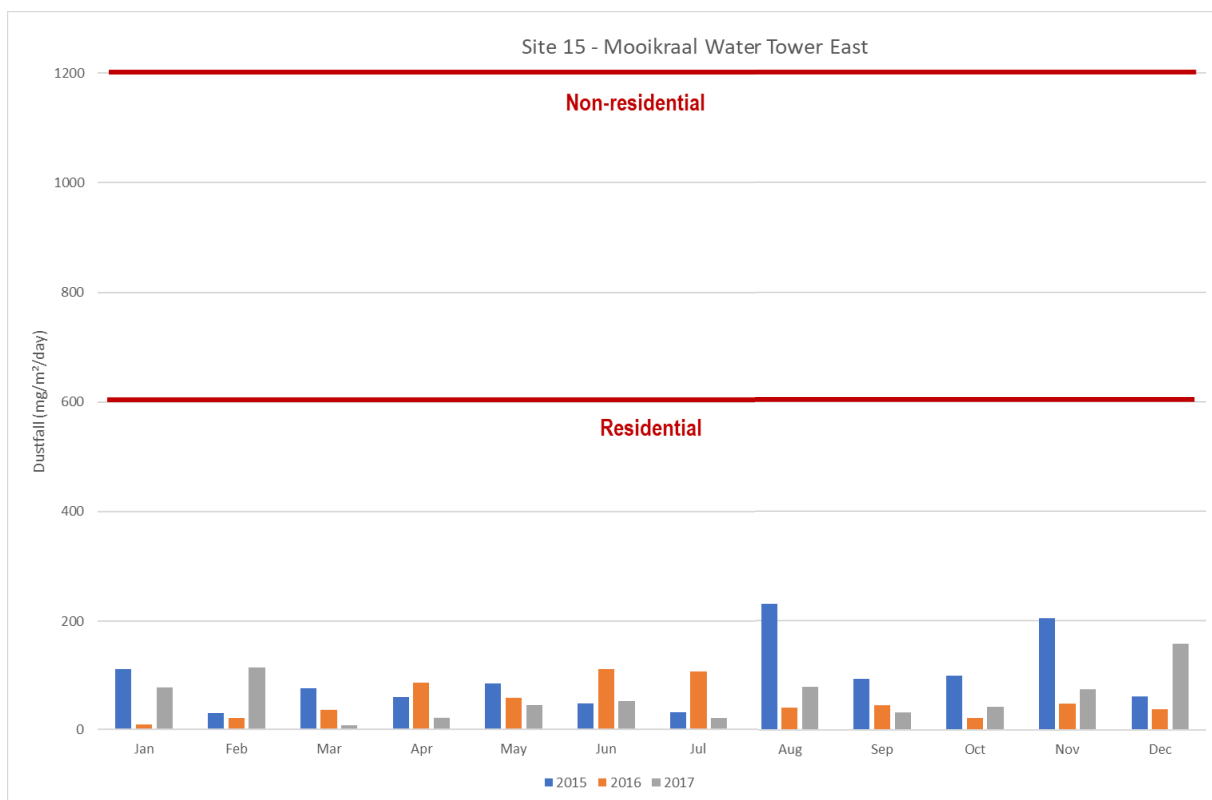
Figure C-15: Dustfall rates at Site 15 (Mooiwater Water Tower East) between 2015 and 2017

Figure C-16: Dustfall rates at Site 16 (Mooiwater Silo East) between 2015 and 2017
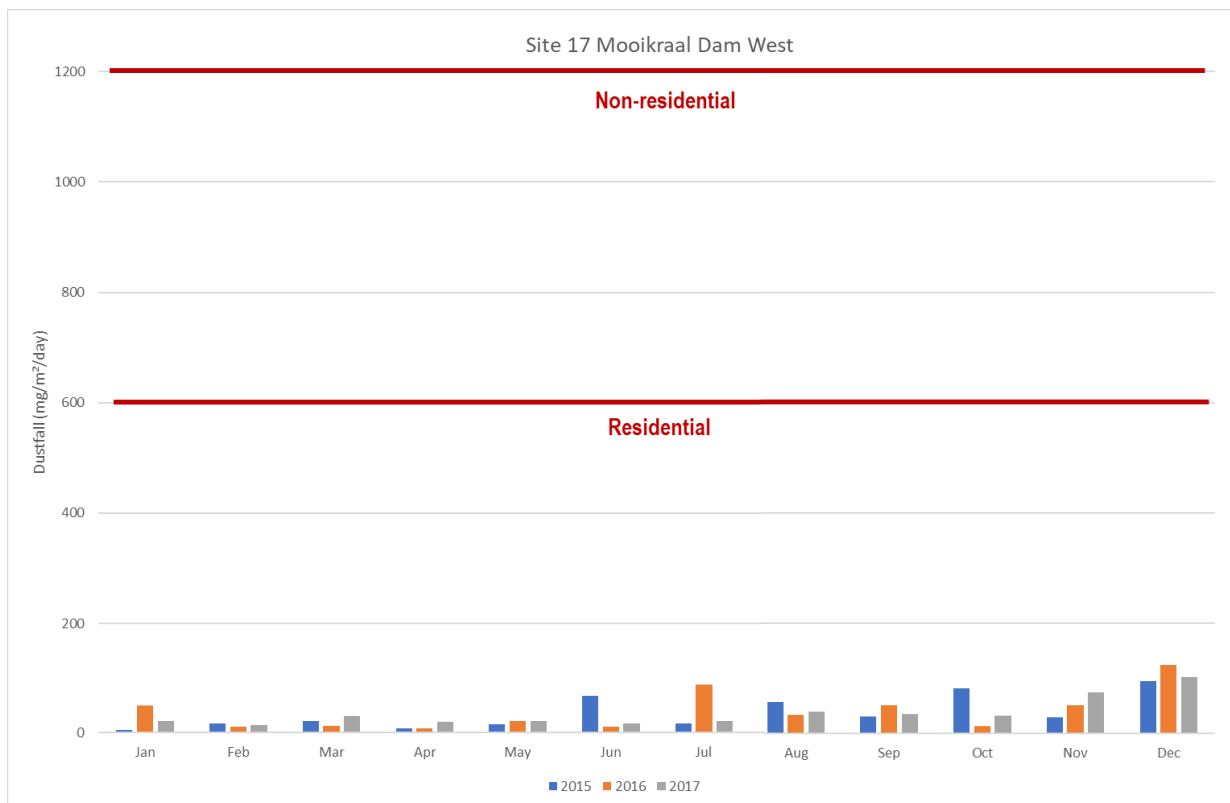
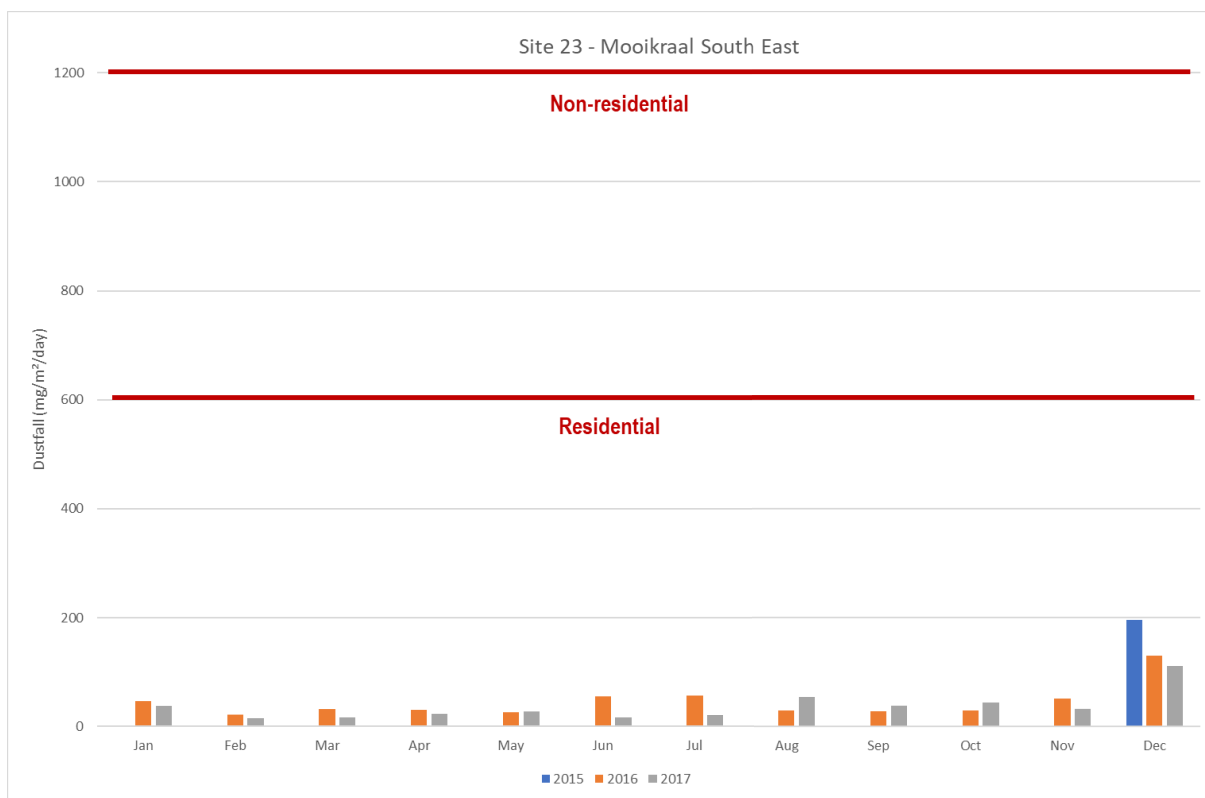Figure C-17 Dustfall rates at Site 17 (Mooiwater Dam West) between 2015 and 2017
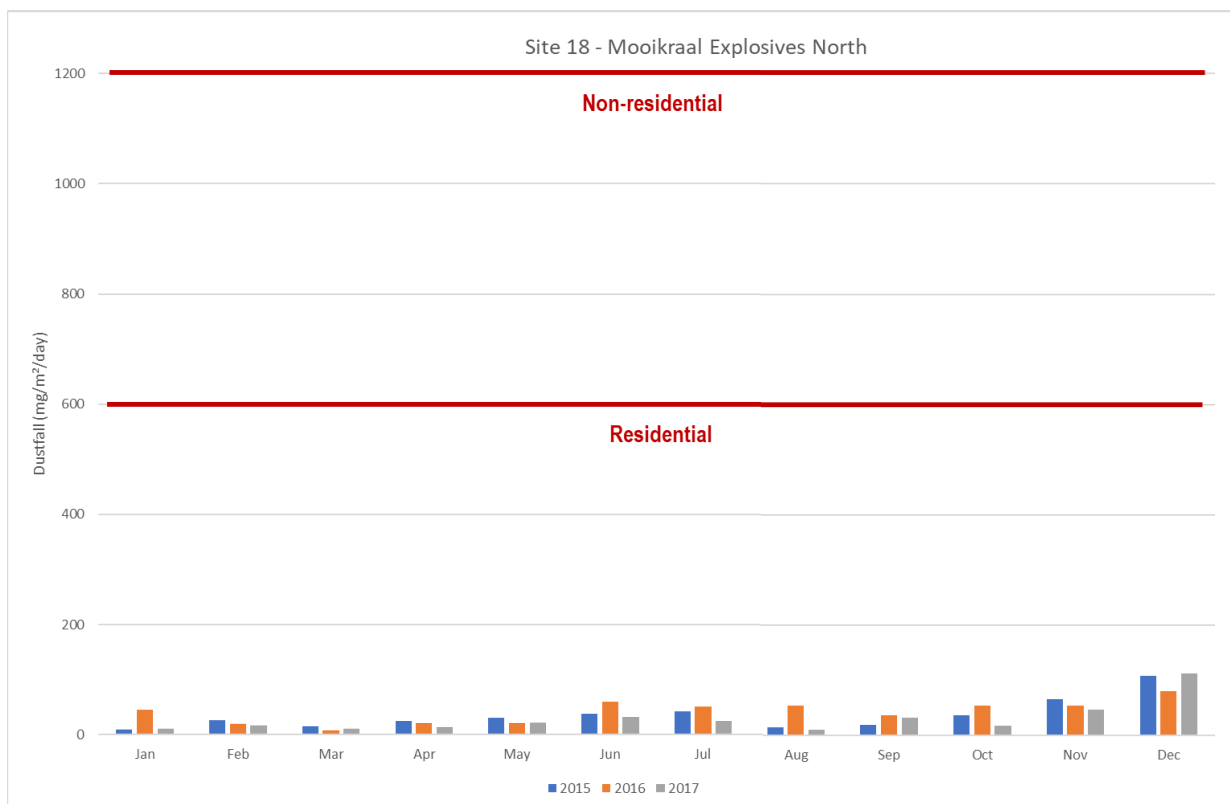
Figure C-18: Dustfall rates at Site 18 (Mooiwater Explosives North) between 2015 and 2017

Figure C-19: Dustfall rates at Site 19 (Old Sigma Dust Coal) between 2015 and 2017

Figure C-20: Dustfall rates at Site 20 (East of Fine Ash Mining) between 2015 and 2017

Figure C-21: Dustfall rates at Site 21 (Mooikraal North East) between 2015 and 2017
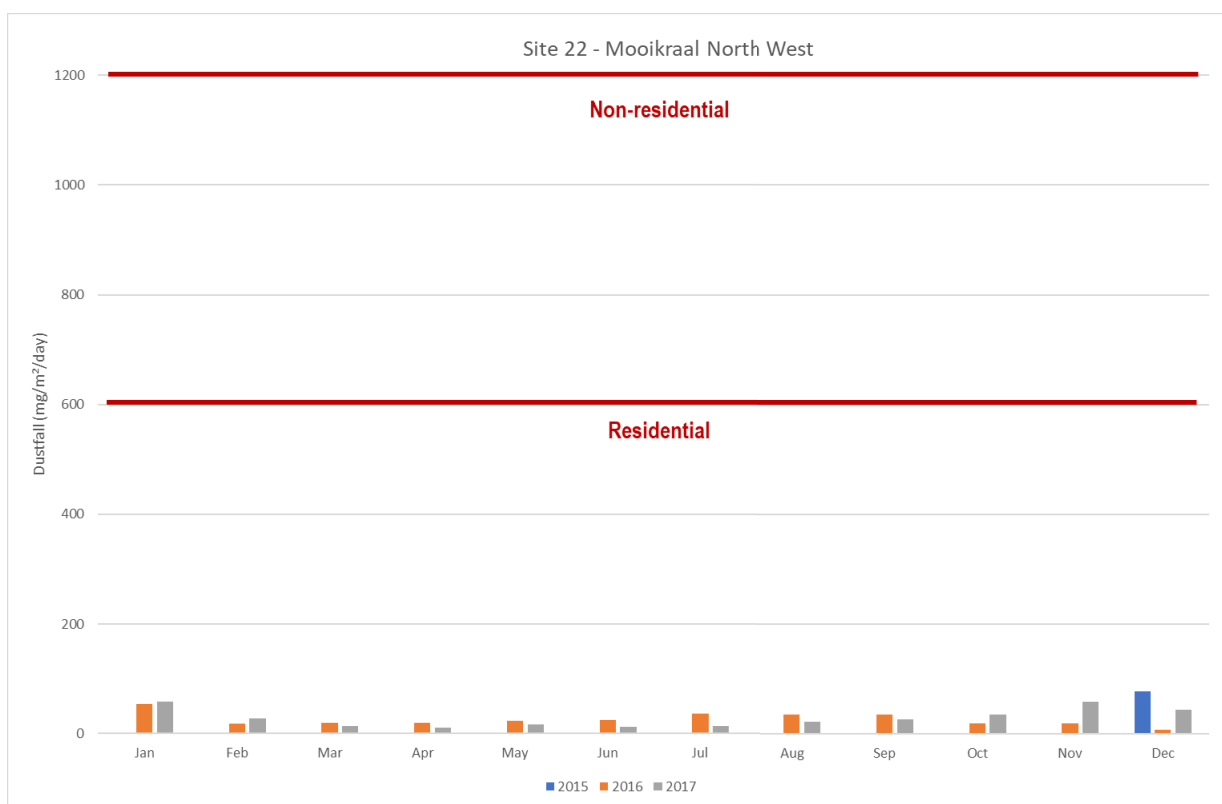
Figure C-22: Dustfall rates at Site 22 (Mooikraal North West) between 2015 and 2017

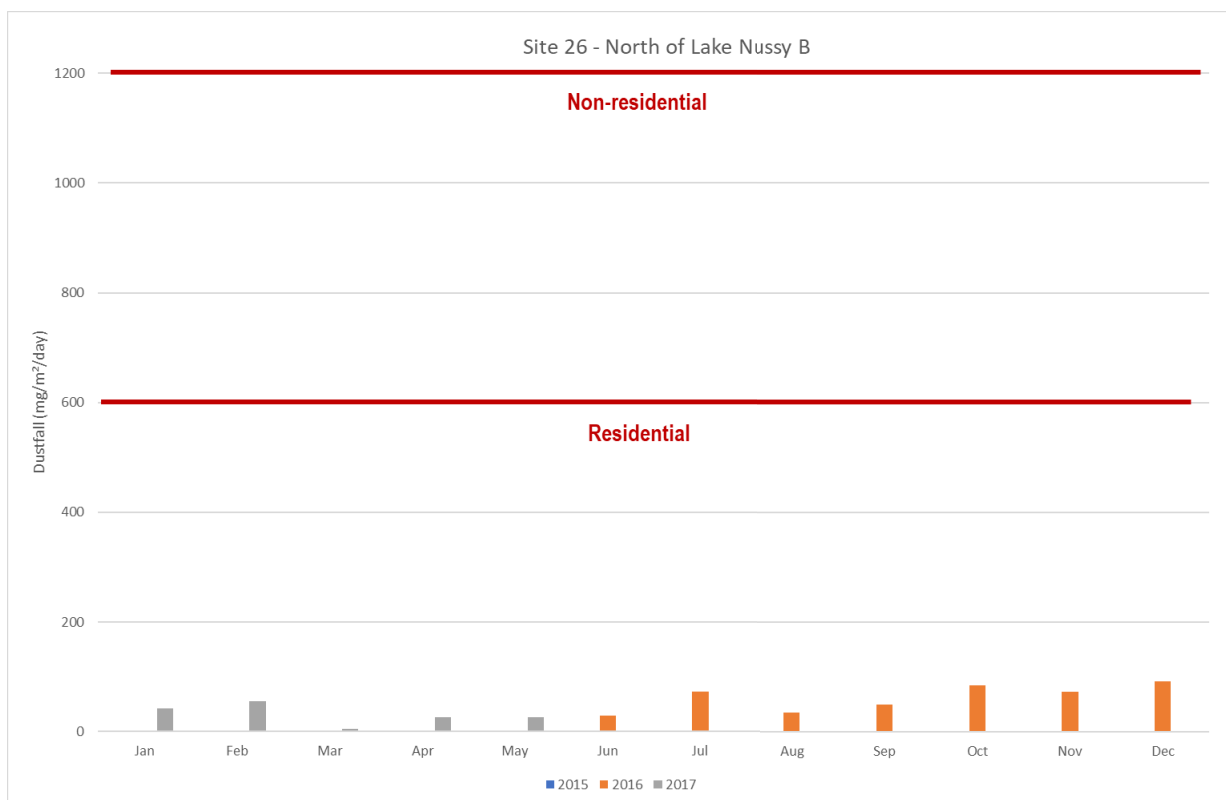Figure C-23: Dustfall rates at Site 23 (Mooikraal South East) between 2015 and 2017
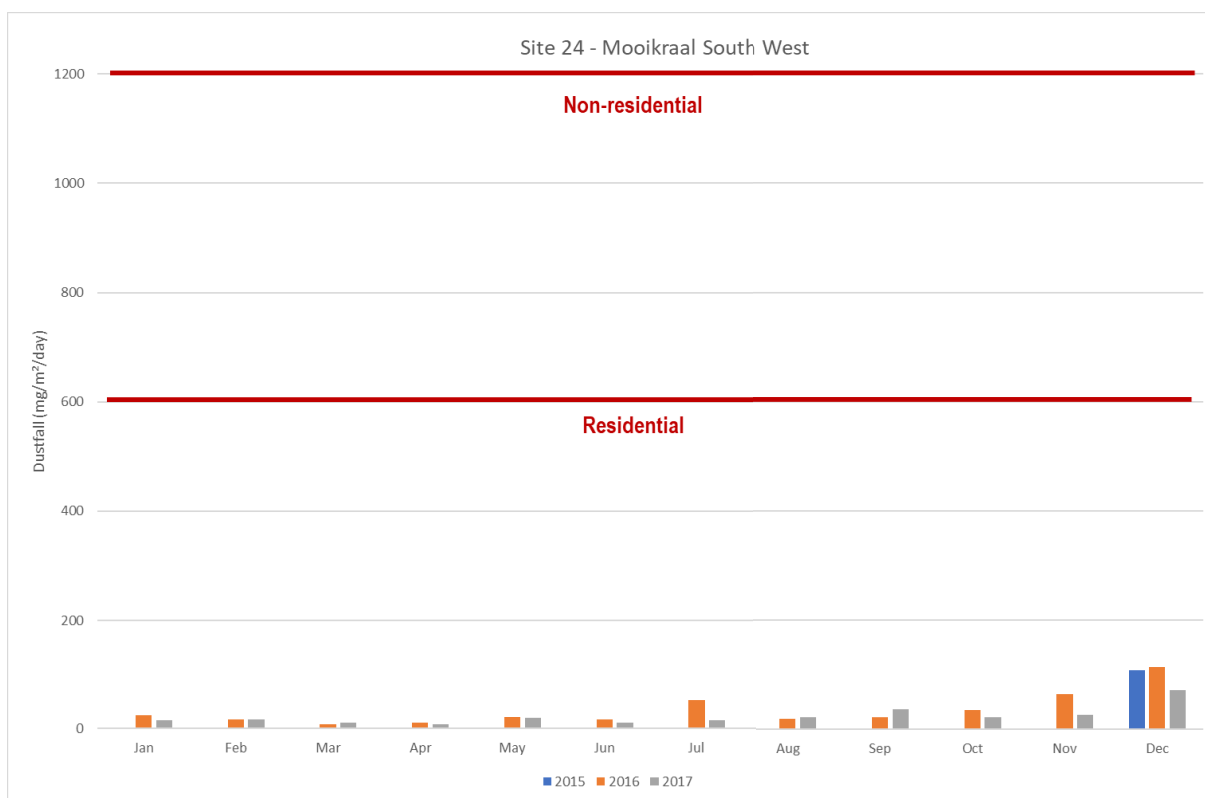
Figure C-24: Dustfall rates at Site 24 (Mooikraal South West) between 2015 and 2017

Figure C-25: Dustfall rates at Site 25 (Wonder Water A) between 2015 and 2017

Figure C-26: Dustfall rates at Site 26 (North of Lake Nussy B) between 2015 and 2017
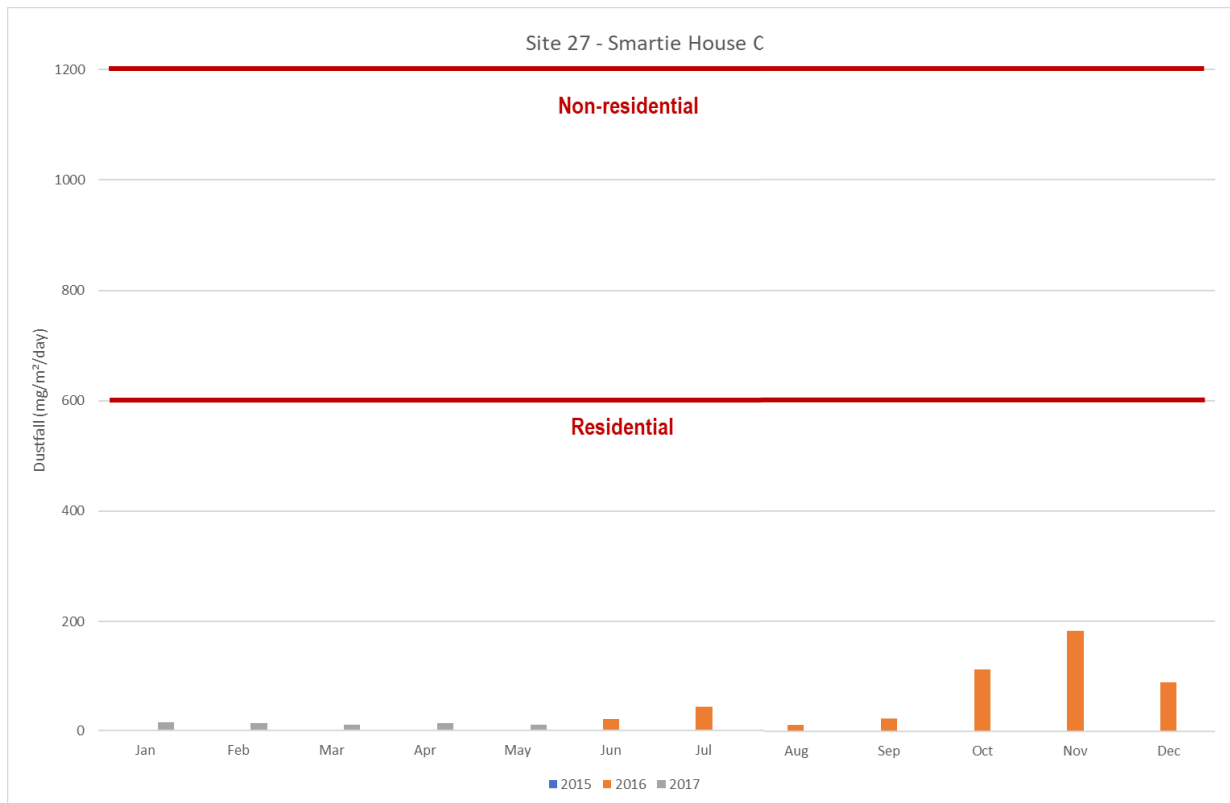
Figure C-27: Dustfall rates at Site 27 (Smartie House C) between 2015 and 2017
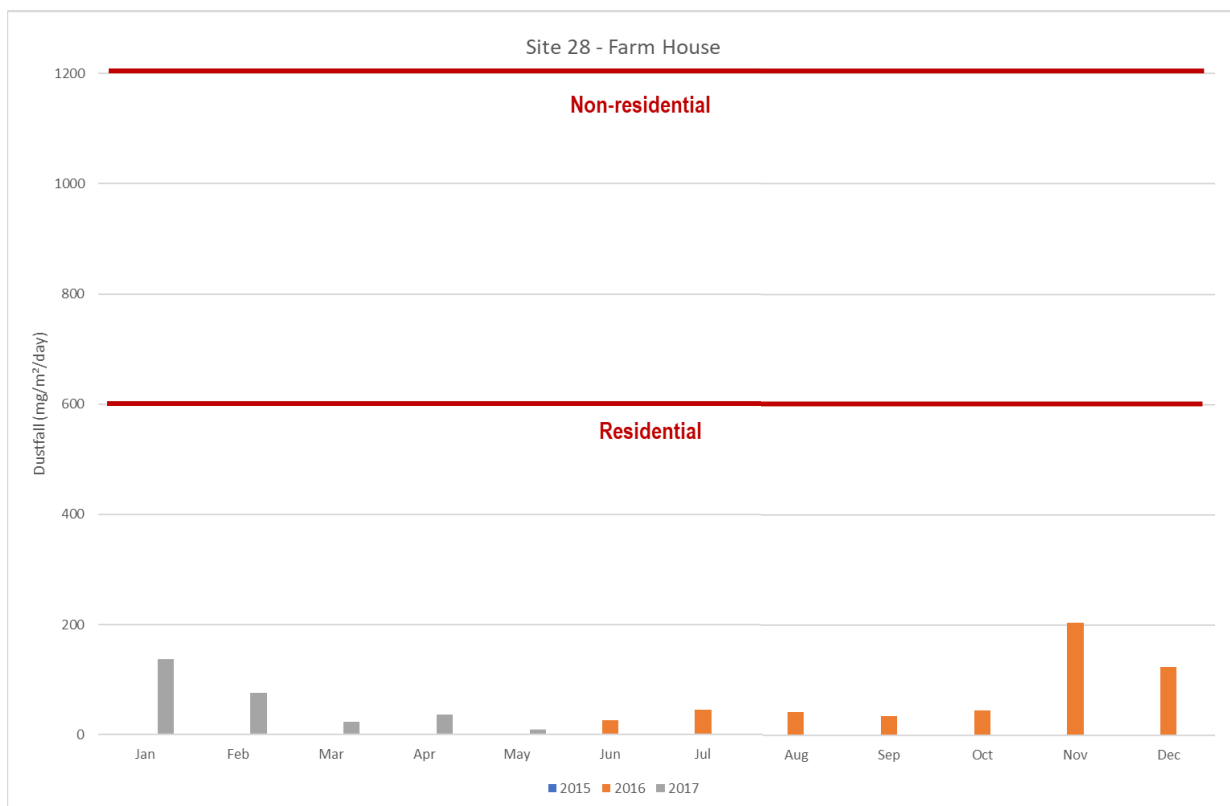

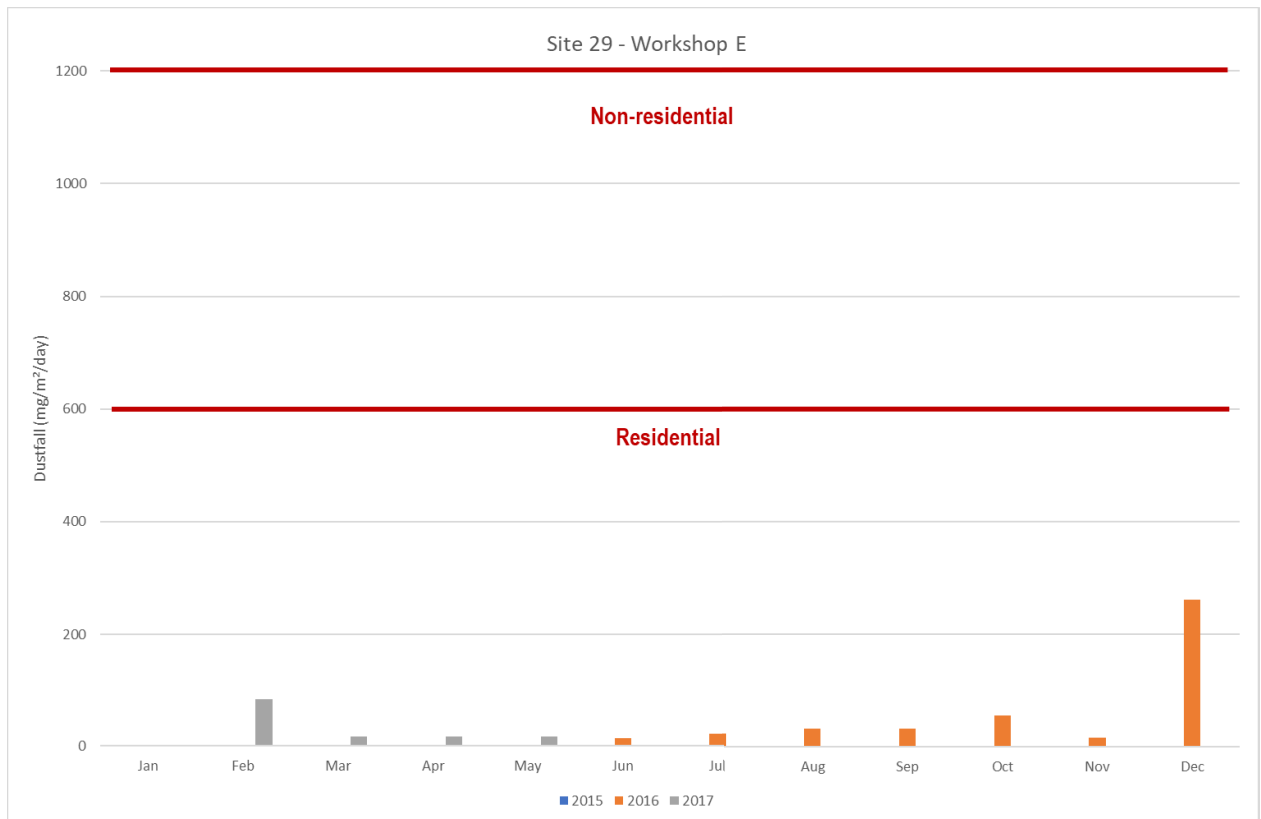Figure C-28: Dustfall rates at Site 28 (Farm House) between 2015 and 2017

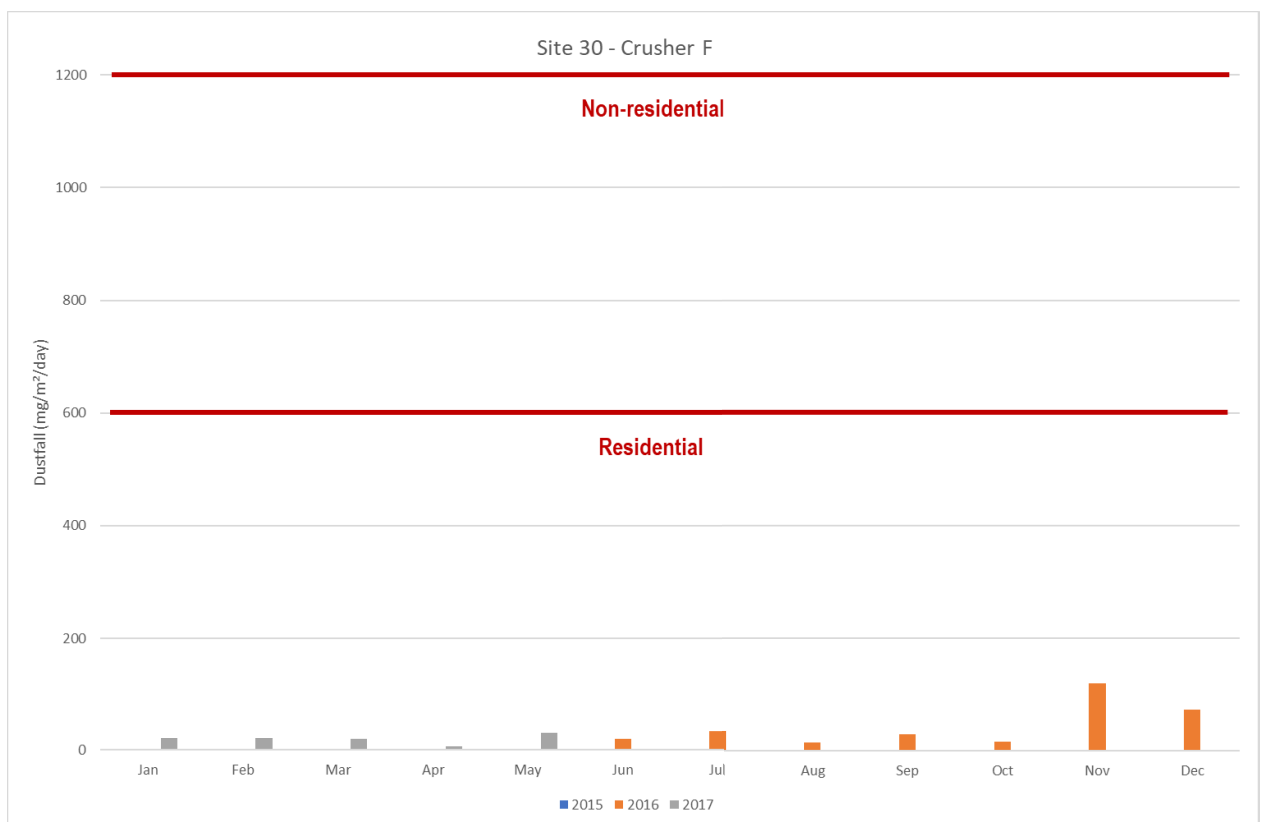Figure C-29: Dustfall rates at Site 29 (Workshop E) between 2015 and 2017

Figure C-30: Dustfall rates at Site 30 (Crusher F) between 2015 and 2017
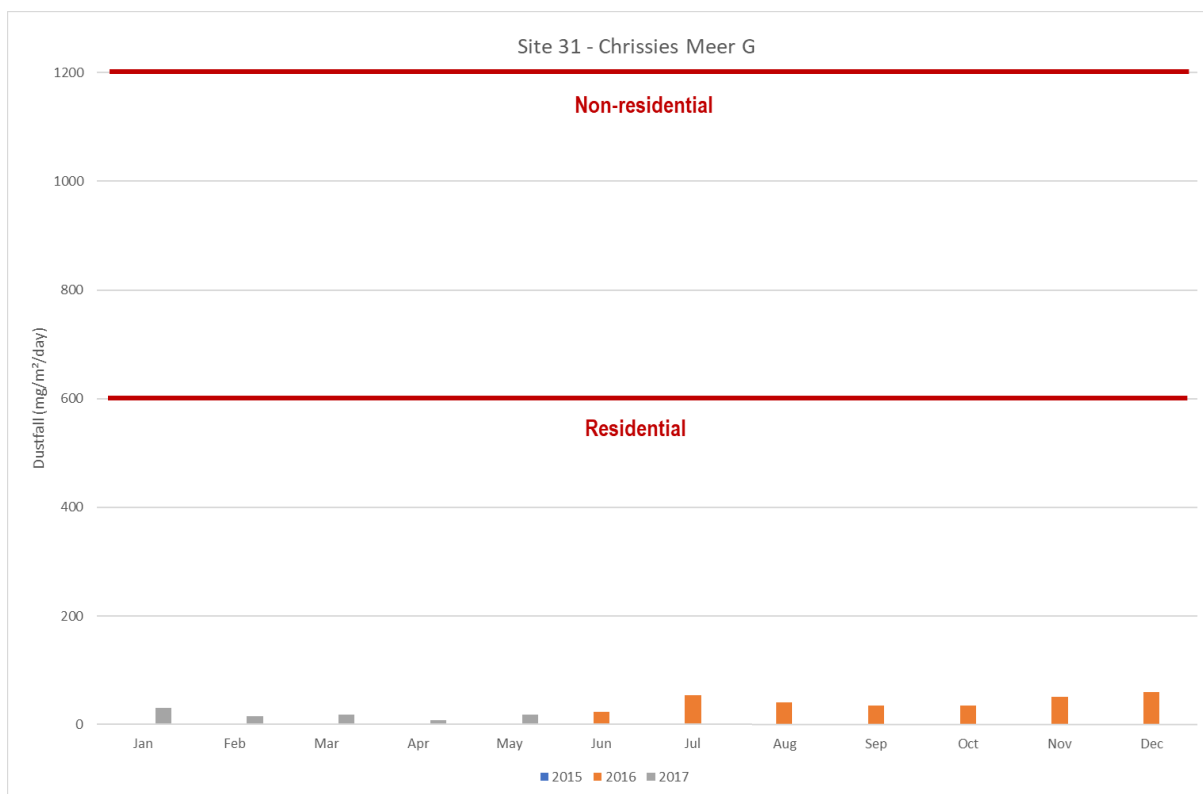
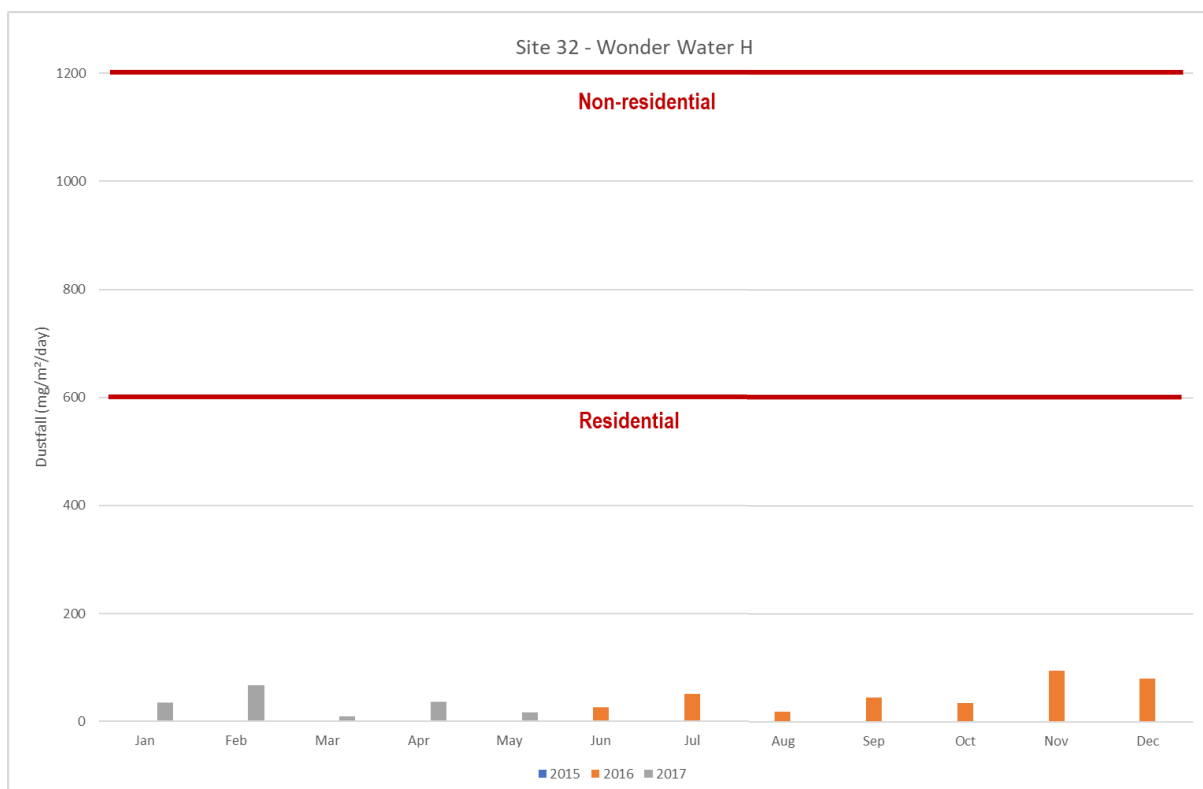Figure C-31: Dustfall rates at Site 31 (Chrissies Meer G) between 2015 and 2017

Figure C-32: Dustfall rates at Site 32 (Wonder Water H) between 2015 and 2017

APPENDIX D: CALMET MODEL CONTROL OPTIONS

The CALMET run type selected for this assessment has been highlighted in blue in Table D-1 below.

Table D-1: CALMET model control options

Run Type	Description of Run Type	Ease of Use and Representativeness	Data availability	Advantages	Disadvantages
No Observations	•Prognostic model data, such as WRF to drive CALMET. •No surface or upper air observations input at all.	•Relatively simple to implement in model •Representative of regional meteorological conditions	WRF data (Lakes Environmental) for 2015, 2016 and 2017 at 4km resolution for 200km by 200km study area (Secunda + Sasolburg)	•Simple to implement •Full spatial and temporal variability •No overwater data required •Cloud cover has spatial distribution •Eliminates need for complicated 7 user-input site-specific variables •Ideal as screening run as gives very good estimate	Resolution of prognostic data may potentially be too coarse to be representative of local conditions
Partial Observations	•Prognostic model data, such as WRF to drive CALMET PLUS •One or more surface stations	•More difficult to implement than only prognostic (WRF) data. •Require 7 site-specific model parameters to be specified. •Difficulty in dealing with missing data. •Potential disagreement between prognostic and surface observations. •Very representative and considered 'refined modelling'	• WRF data (Lakes Environmental) for 2015, 2016 and 2017 at 4km resolution for 200km by 200km study area (Secunda + Sasolburg) •Sasol operated surface meteorological weather stations (3 Sasolburg[3] and 3 Secunda[4])	•Full spatial and temporal variability •No overwater data required •Refined model run as using combined approach of numerical model and observations. •Ability to incorporate surface representative observation data when WRF data is too coarse to fully pick up local effects.	•Surface data, especially winds may be different to that in the WRF data file •User must include 7 site-specific variables •Data preparation and missing data
Observations Only	CALMET driven solely by surface, upper air and optional overwater and precipitation stations	•Require 7 site-specific model parameters to be specified. Difficulty in dealing with missing data. •Considered representative if sufficient observation stations and site-specific	•Sasol operated surface meteorological weather stations (3 Sasolburg and 3 Secunda) •Closest upper air monitoring station is at OR Tambo International Airport (twice-daily	Very good if upper air and surface stations are located close to the facility and if upper air data are recorded at sunrise and sunset.	•Upper air data typically 12 hourly, poor spatial and temporal resolution •Model has to interpolate between 12 hour soundings •Soundings at incorrect time of

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[3] AJ Jacobs (WS, WD, SO$_2$, NO$_2$, PM$_{10}$, PM$_{2.5}$); Leitrim (WS, WD, TEMP, AMB PRESS, RH, SO$_2$, NO$_2$, PM$_{10}$, PM$_{2.5}$) and Eco Park (WS, WD, TEMP, RH, AMB PRESS, SOL RAD, RAIN, SO$_2$, O$_3$, NO$_2$, PM$_{10}$, PM$_{2.5}$)

[4] Sasol Club (WS, WD, TEMP, NO$_2$, SO$_2$, O$_3$, PM$_{10}$, PM$_{2.5}$, CO); Bosjespruit (WS, WD, TEMP, NO$_2$, SO$_2$, H$_2$S, PM$_{10}$, PM$_{2.5}$) and Embalenhle (WS, WD, TEMP, NO$_2$, SO$_2$, PM$_{10}$, PM$_{2.5}$, Benzene)

Run Type	Description of Run Type	Ease of Use and Representativeness	Data availability	Advantages	Disadvantages
		choice of parameters by the modeller.	soundings only)		the day. **•User has to deal with missing** surface and upper air data

APPENDIX E: CALPUFF MODEL CONTROL OPTIONS

The CALPUFF run type selected for this assessment has been highlighted in blue in Table E-1 below.

Table E-1: CALPUFF model control options

Run Type	Description of Run Type	Ease of Use and Representativeness	Data availability	Advantages	Disadvantages
Sampling Function Puff	This sampling scheme employs radically symmetric Gaussian puffs and is suitable for far field.				
Sampling Function Slug	This sampling scheme uses a non-**circular puff (a "slug),** elongated in the direction of the wind during release, to eliminate the need for frequent releases of puffs. Used for near field during rapidly-varying meteorological conditions.				Takes a very long time to run.
Dispersion coefficients MDISP = 1	• Dispersion coefficients are computed from measured values of turbulence, sigma-v and sigma-w.	• **The user must provide an external** PROFILE.DAT file containing these parameters, and select a backup method out of options 2, 3 and 4 below in case of missing data.	• **This measured data is not** available in South Africa	• Very good if data is available.	• **These measured parameters** are not readily available in South Africa.
Dispersion coefficients MDISP = 2	• **Dispersion coefficients are** computed from internally-calculated sigma-v, sigma-w using micrometeorological variables (u*, w*, L, etc.).	• **This option can simulate AERMOD-**type dispersion when the user also selects the use of PDF method for dispersion in the convective boundary layer (MPDF = 1). Note that when simulating AERMOD-type dispersion, the input meteorological data must be from CALMET and cannot be ISC-type ASCII format data. The user should also be aware that under this option the	• **The data is obtained from WRF** input information.	• Based on improved theoretical work and is an improvement over Pasquill-Gifford.	• **The coefficients are derived** from other parameters.

Run Type	Description of Run Type	Ease of Use and Representativeness	Data availability	Advantages	Disadvantages
		CALPUFF model will be more sensitive to the appropriateness of the land use characterization.			
Dispersion coefficients MDISP = 3	• Pasquill-Gifford (PG) dispersion coefficients for rural areas (computed using the ISCST3 multi-segment approximation) and McElroy-Pooler (MP) coefficients in urban areas.	• The current default selection is MDISP = 3, which is ISC-type dispersion. Given the demonstrated improved characterization of dispersion provided by AERMOD, and EPA's intention to replace ISC with AERMOD, use of AERMOD-like dispersion (MDISP = 2, and MPDF = 1) is also acceptable, but likely will be of most benefit for short-range complex flow applications.		• Simple to use if you don't have detailed meteorological information. This option can be run using fairly basic meteorological data.	• Based on discreet classification scheme (not continuous function). Based on field experiments done elsewhere, may or may not be representative of Highveld area. Previous projects done using this scheme however have provided good correlation over this area.
Dispersion coefficients MDISP = 4	• Same as MDISP = 3, except PG coefficients are computed using the MESOPUFF II equations				
Dispersion coefficients MDISP = 5	• CTDM sigmas are used for stable and neutral conditions. For unstable conditions, sigmas are computed as in MDISP=3 described above.	• When selecting this option, the user must provide an external PROFILE.DAT file, and select a backup method out of options 2, 3 and 4 above in case of missing data.			
Chemical transformation RIVAD	• Pseudo-first-order chemical mechanism for SO_2, SO_4^{2-}, NO, NO_2, HNO_3, and NO_3 - (RIVAD/ARM3 method)	• RIVAD is a 6-species scheme wherein NO and NO_2 are treated separately. • In the RIVAD scheme the conversion of SO_2 to sulfates is not RH-dependent. • The conversion of NO_x to nitrates is RH-dependent.	• In order to use the RIVAD scheme, the user must divide the NO_x emissions into NO and NO_2 for each source. • Two options are specified for the ozone concentrations: (1) hourly ozone concentrations from a network of stations, or (2) a single user defined ozone value.	• In several tests conducted to date, the results have shown no significant differences between the RIVAD and MESOPUFF II options.	• User has to input the NO and NO_2 emissions which are not always known for all sources. • User has to input the ozone concentrations which are not always known. • The model is restricted to rural conditions.

Run Type	Description of Run Type	Ease of Use and Representativeness	Data availability	Advantages	Disadvantages
			• The background ammonia concentrations required for the HNO_3/NH_4NO_3 equilibrium calculation can be user-specified or a default value will be used.		
Chemical transformation MESOPUFF II	• Pseudo-first-order chemical mechanism for SO_2, SO_4^{2-}, NO_x, HNO_3, and NO_3 - (MESOPUFF II method)	• MESOPUFF II is a 5-species scheme in which all emissions of nitrogen oxides are simply input as NO_x. • In the MESOPUFF II scheme, the conversion of SO_2 to sulfates is dependent on relative humidity (RH), with an enhanced conversion rate at high RH. • The conversion of NO_x to nitrates is RH-dependent.	• The MESOPUFF II scheme assumes an immediate conversion of all NO to NO_2. • Two options are specified for the ozone concentrations: (1) hourly ozone concentrations from a network of stations, or (2) a single user defined ozone value. • The background ammonia concentrations required for the HNO_3/NH_4NO_3 equilibrium calculation can be user-specified or a default value will be used.	• In several tests conducted to date, the results have shown no significant differences between the RIVAD and MESOPUFF II options for sulfate and nitrate formation. • The model is applicable to both urban and rural conditions.	• User has to input the ozone concentrations which are not always known. • NO to NO_2 conversion.is not included. In model.
User-specified diurnal cycles of transformation rates					
No chemical conversion					

APPENDIX F: THE NO₂/NOₓ CONVERSION RATIOS FOR NO₂ FORMATION

Scire and Borissova (2011) analysed hourly monitored NO_2 and NO_x data for 2006 at 325 monitoring sites throughout USA (approximately 2.8 million data points for each species), These observations were grouped into a number of concentration bins and were used to compute bin maximums and bin average curves. Short-term (1-hr) NO_2/NO_x ratios were developed on bin-maximum data, whereas the long-term (annual average) NO_2/NOx ratios were based on bin-averaged data. The method was subsequently tested using the NO_2/NOx ratios applied to the observed NO_x at selected stations to predict NO_2, and then compared to observed NO_2 concentrations at that station. As illustrated in the examples, Figure F-1 and Figure F-2, using these empirical curves provide a reasonable estimate of the observed NO_2 can be obtained, albeit mostly more conservative. In Figure F-3, the method is compared to the assumption of 100% conversation over the short-term, which clearly illustrates the extreme conservatism, especially at elevated concentrations.

Figure F-1: Comparison of observed with predicted NO_2 concentrations (Long Island, NY) using the derived short-term NO_2/NO_x ratios (Scire and Borissova, 2011)
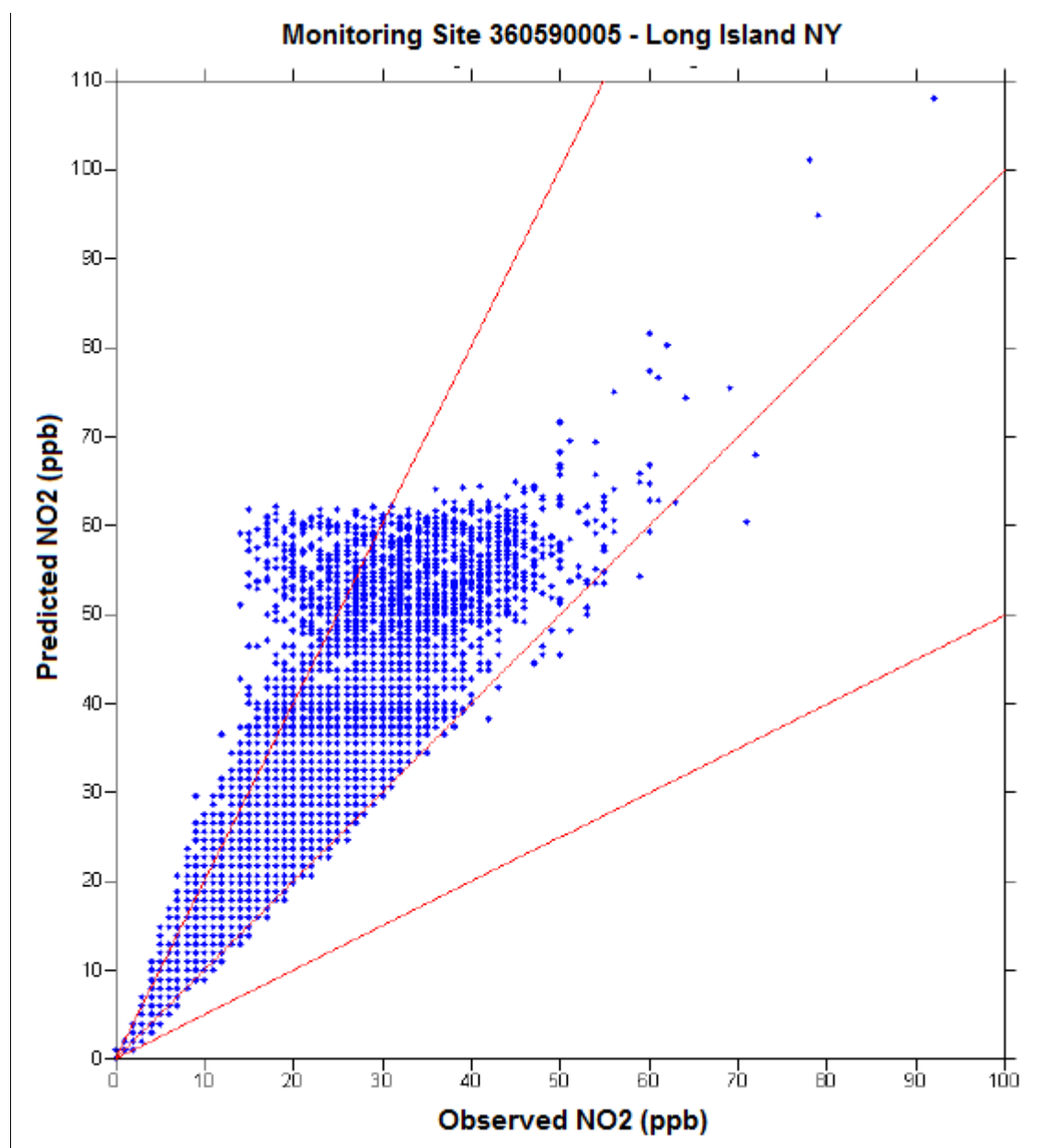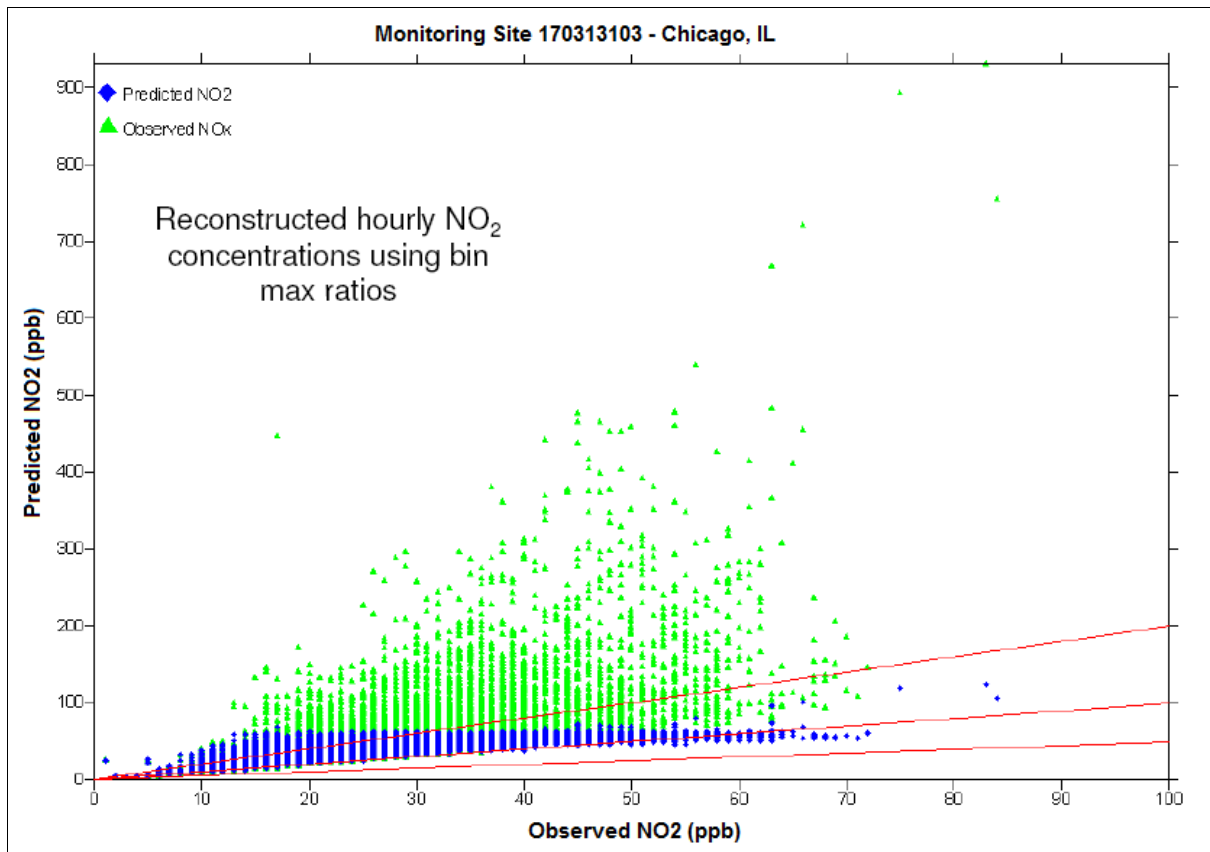
Figure F-2: Comparison of observed with predicted NO_2 concentrations (Chicago, IL) using the derived short-term NO_2/NO_x ratios (Scire and Borissova, 2011)
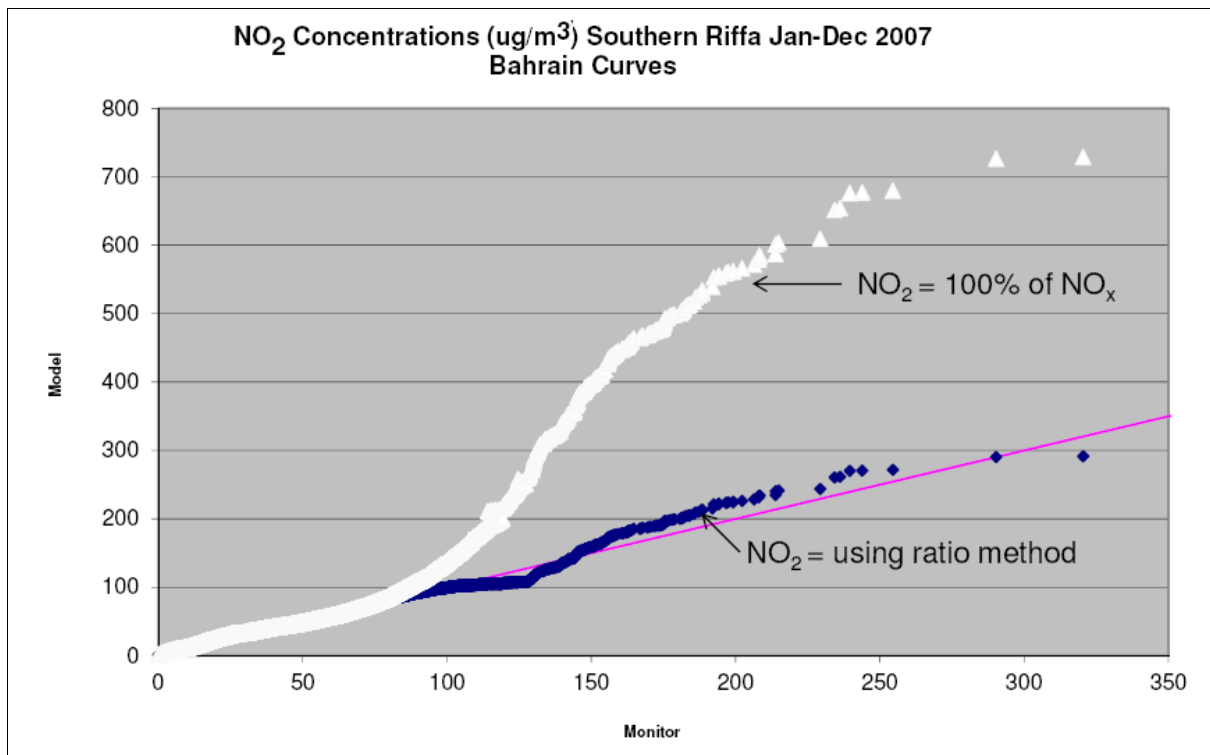

Figure F-3: Observed versus predicted NO_2 concentrations (Bahrain) using the derived short-term NO_2/NOx ratios (Scire and Borissova, 2011)

It was decided that the NO_2/NO_x conversion factors described by Scire and Borissova (2011) and as given in Table F-1, will be employed in this study. Observed NO_2/NO_x ratios at the Sasolburg monitoring stations were also analysed and compared to the factors in the table (Figure F-1). It is shown in the table and Figure F-4, that the Scire and Borissova ratios would also be applicable in the current study since it would produce estimates similar or more conservative than if the actual NO_2/NO_x ratios at the site would have been used instead.

Table F-1: NO_2/NO_x conversation ratios for NO_2 formation

Bin	Concentration (µg/m³)			NO₂/NOx Ratios			
				Sasolburg		Scire and Borissova 2011	
	Min	Max	Centre	AJ Jacobs 2010-2012	Ecopark 2012	Bin Average	1-Hour Max
1	0	19	9	0.658	0.521	0.7980	0.9938
2	19	38	28	0.714	0.605	0.8130	0.9922
3	38	75	56	0.657	0.501	0.7306	0.9844
4	75	113	94	0.506	0.428	0.5544	0.9094
5	113	150	132	0.380	0.305	0.4370	0.7477
6	150	188	169	0.309	0.117	0.3553	0.6085
7	188	235	212	0.265	0.311	0.3013	0.4976
8	235	282	259	0.222	0.019	0.2559	0.4173
9	282	329	306	0.208	0.114	0.2276	0.3543
10	329	376	353	0.184	0.105	0.2081	0.3056
11	376	423	400	0.216	0.164	0.1852	0.2684
12	423	470	447	0.161	0.114	0.1809	0.2404
13	470	517	494	0.135	0.101	0.1767	0.2194
14	517	564	541		0.153	0.1546	0.2035
15	564	611	588		0.119	0.1524	0.1912
16	611	658	635		0.071	0.1476	0.1813
17	658	705	682		0.169	0.1402	0.1726
18	705	752	729		0.157	0.1363	0.1645
19	752	846	799		0.133	0.1422	0.1527
20	846	940	893		0.164	0.1223	0.1506
21	940	1128	1034		0.164	0.1087	0.1474
22	1128	1316	1222			0.1110	0.1432
23	1316	1504	1410			0.1112	0.139
24	1504	1786	1645			0.1165	0.1337
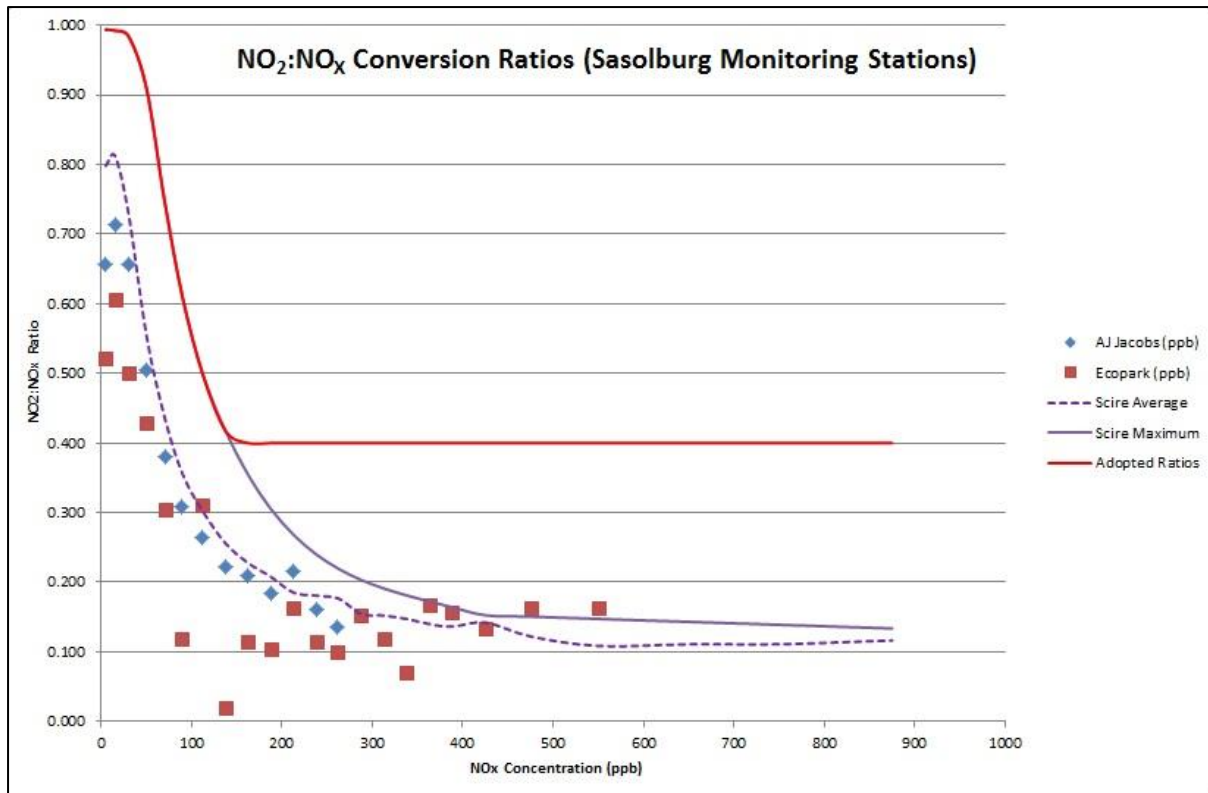
Figure F-4: NO$_2$/NO$_x$ conversation ratios for **Sasol's** Sasolburg monitoring stations

APPENDIX G: Time Series Plots for the Measured Ambient Air Quality in the Study Area

A summary of the time series plots for the measured data as provided by Sasol is given in the following section.
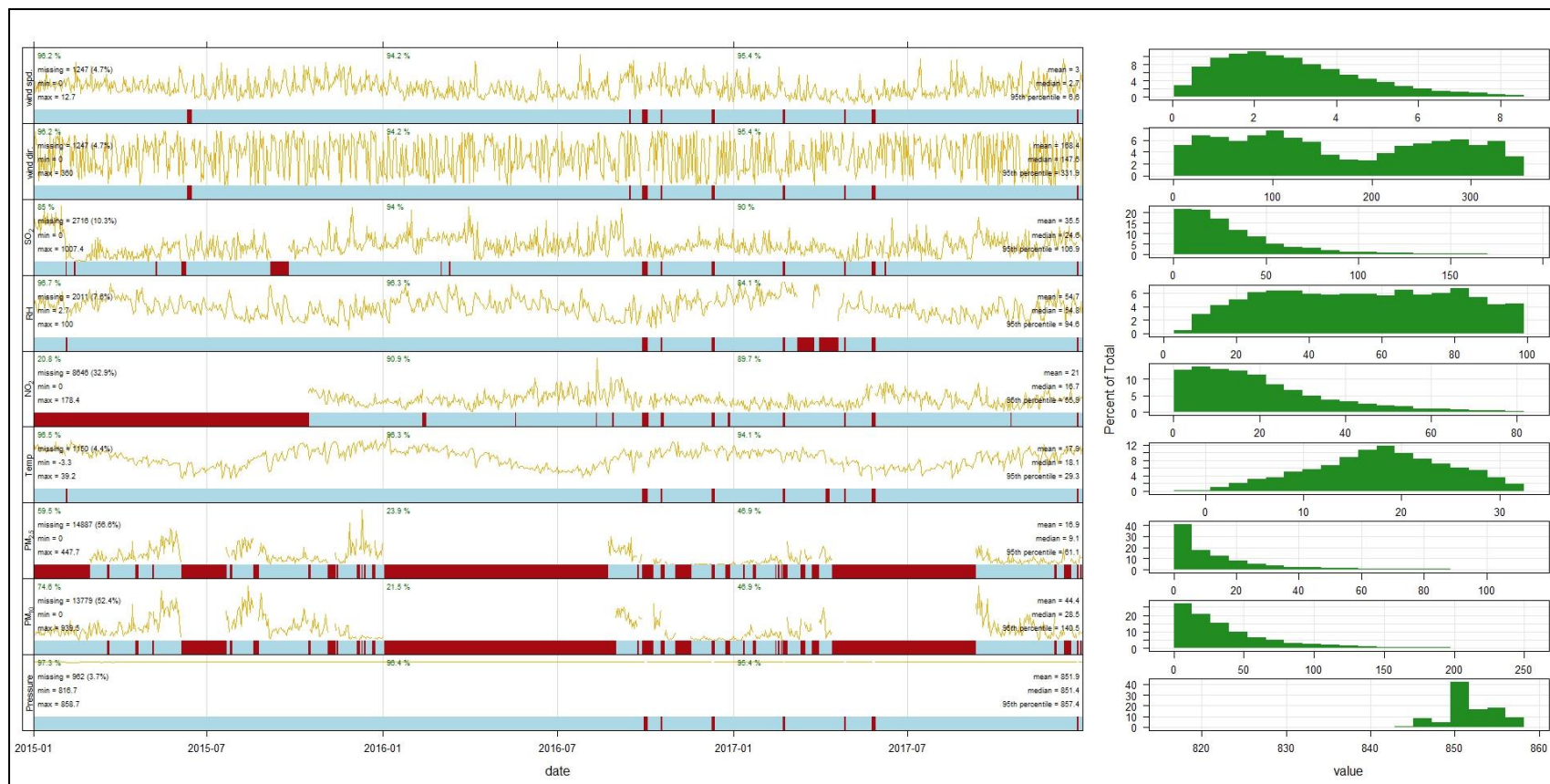
Figure G-1: Summary of meteorological and ambient air quality data received for Leitrim (2015-2017)
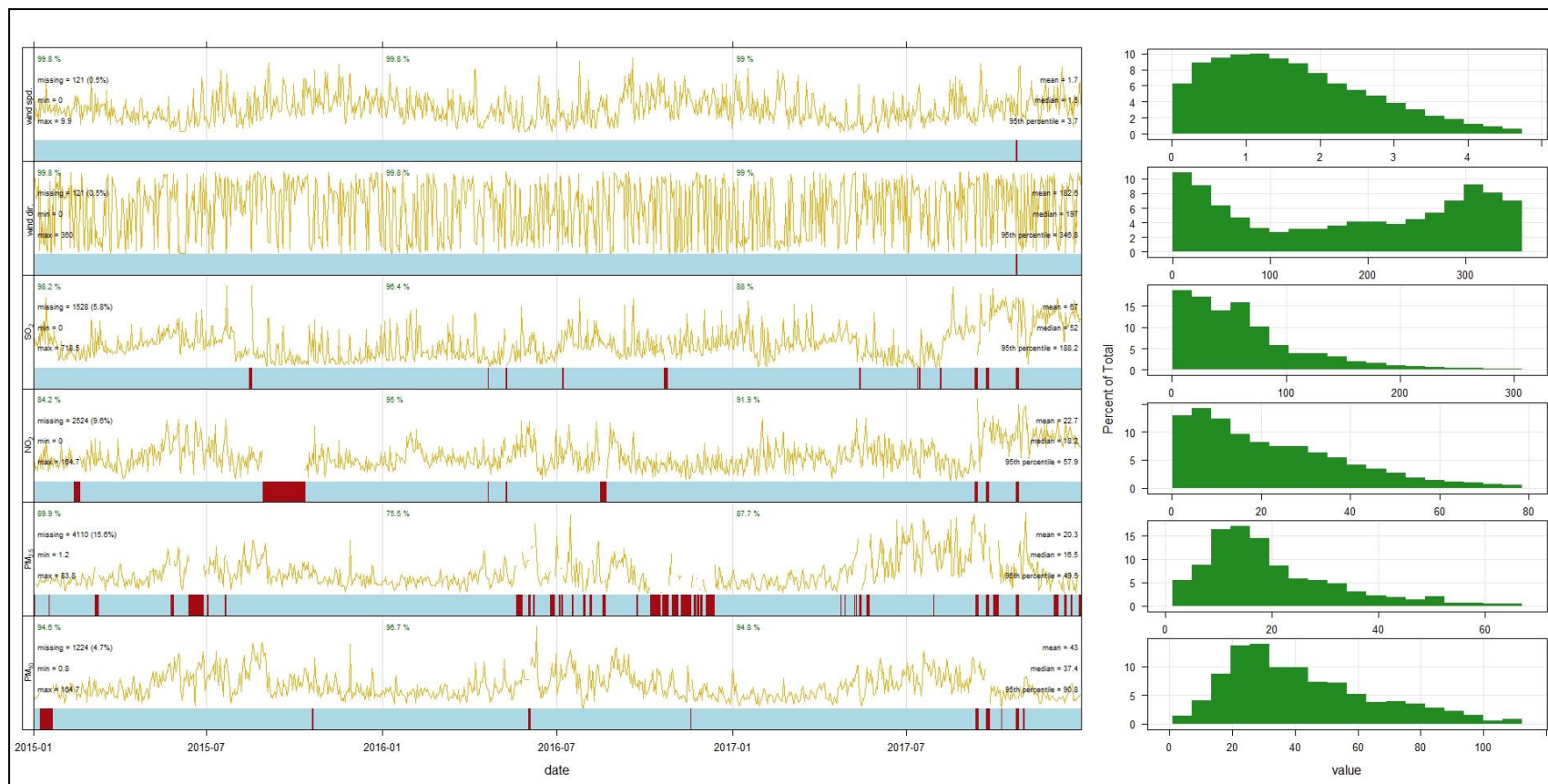
Figure G-2: Summary of meteorological and ambient air quality data received for AJ Jacobs (2015-2017)
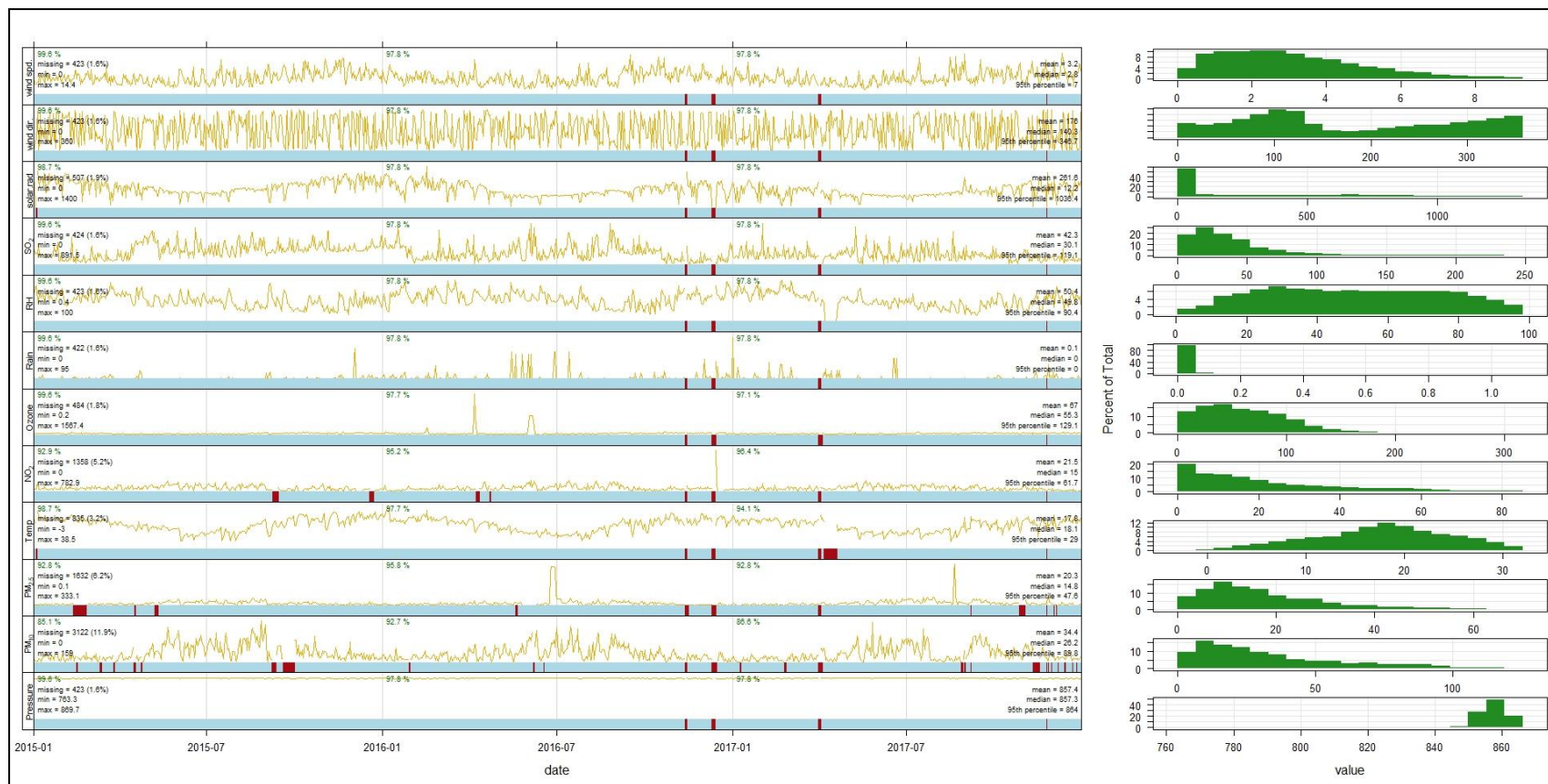
Figure G-3: Summary of meteorological and ambient air quality data received for Eco Park (2015-2017)
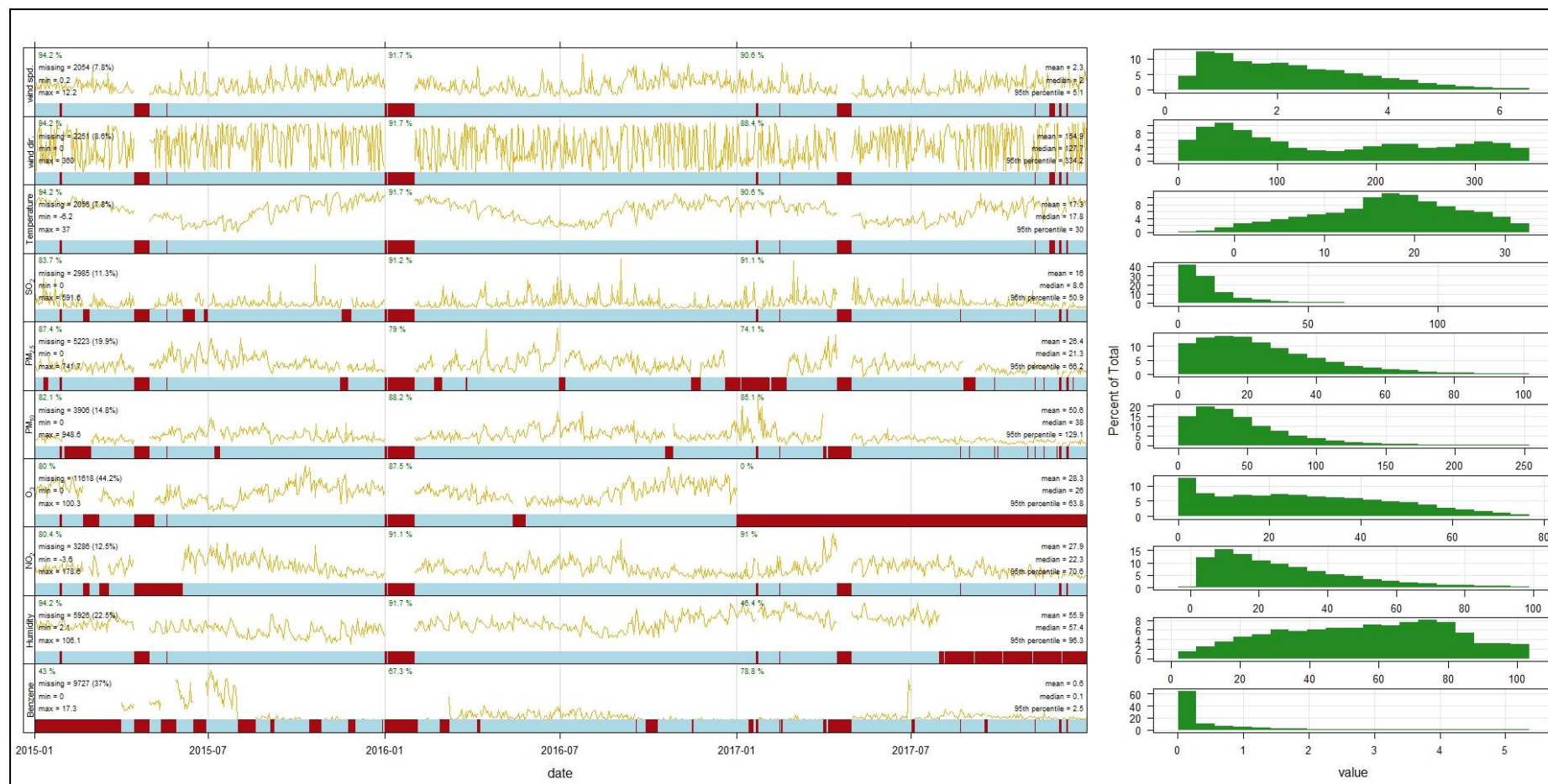
Figure G-4: Summary of meteorological and ambient air quality data received for Three Rivers (2015-2017)
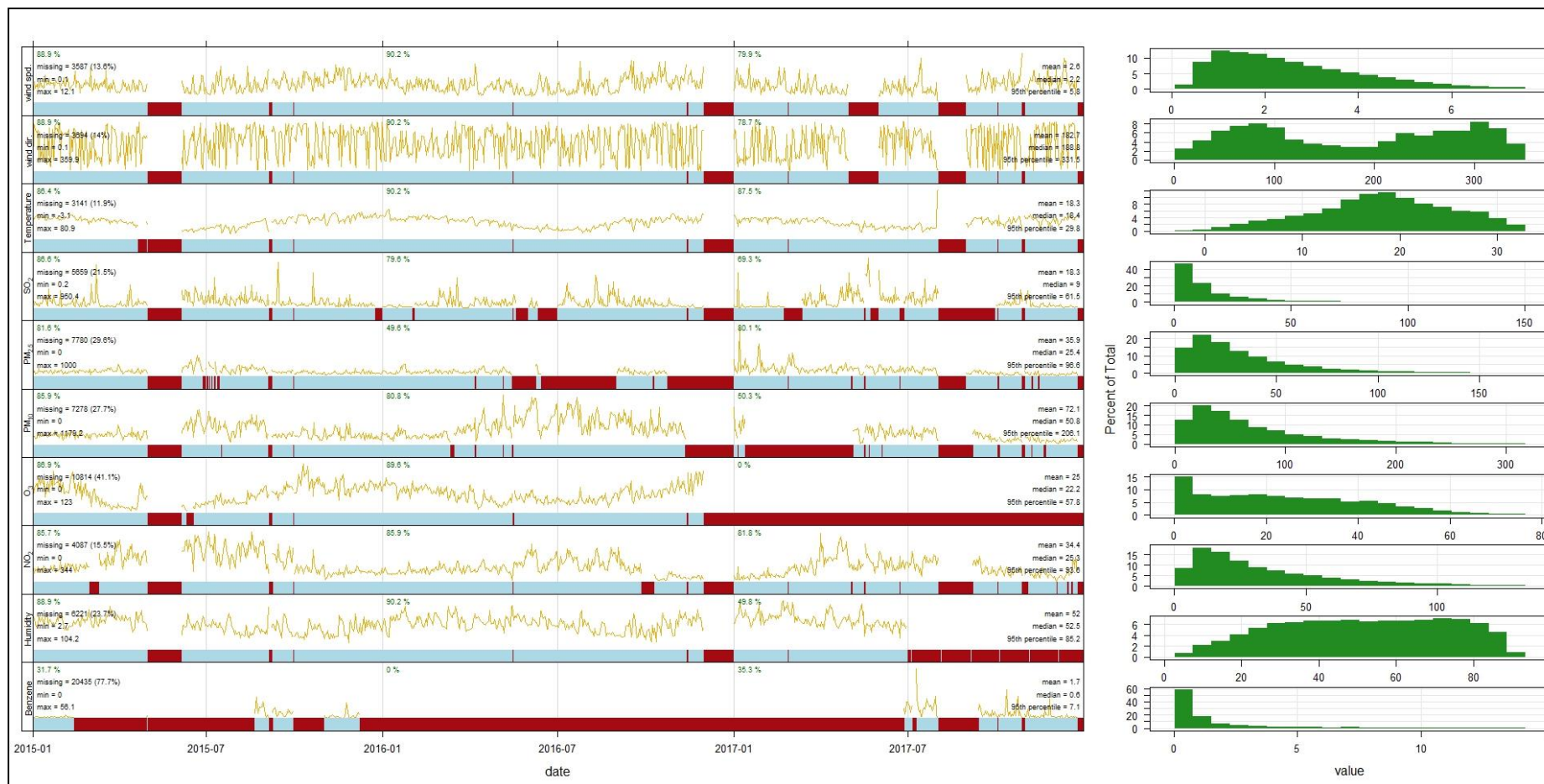
Figure G-5: Summary of meteorological and ambient air quality data received for Sharpeville (2015-2017)
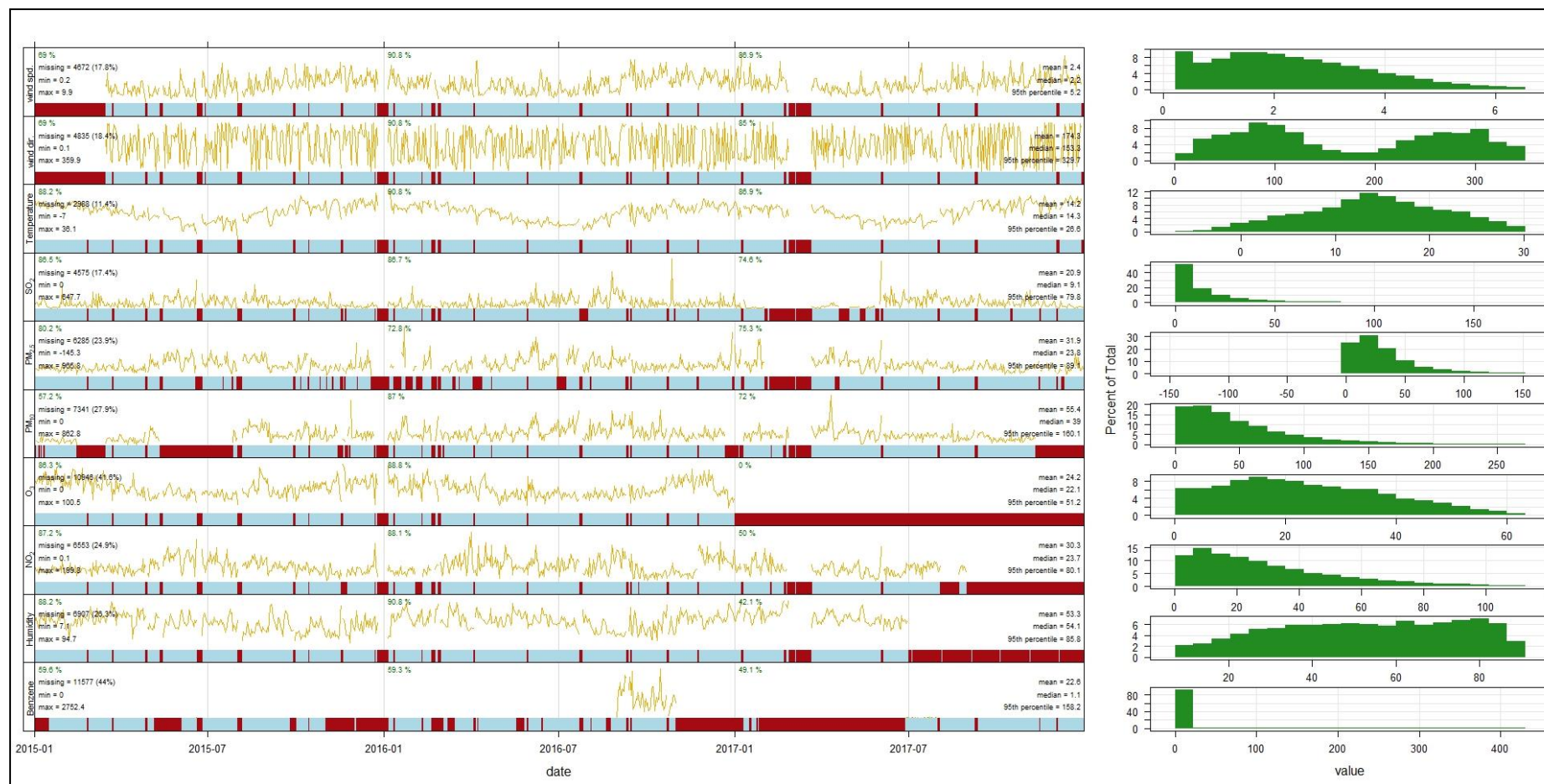
Figure G-6: Summary of meteorological and ambient air quality data received for Zamdela (2015-2017)

APPENDIX H: PREDICTED BASELINE AND OBSERVED AIR CONCENTRATIONS

The following tables summarise the predicted baseline SO_2 and NO_2 concentrations at the Sasol and DEA monitoring site locations, respectively. The peak (maximum), 99th, 90th, 50th and annual average values are given for each of the simulated (SO and Natref combined) years, 2015, 2016 and 2017. The corresponding observed concentration values are also summarised in the tables for comparison. Estimates of background concentrations were obtained from the observed values at the ranked position when no contributions from the simulated sources were predicted.

Table H-1: Simulated SO$_2$ concentration from routine emissions and observed SO$_2$ concentration statistics

Description	Year	SO$_2$ Concentration (µg/m³)											
		Leitrim		AJ Jacobs		Eco Park		Three Rivers		Sharpeville		Zamdela	
		Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed
Maximum	2015	196.6	1007.4	435.5	603.6	176.5	881.5	37.9	591.6	65.4	950.4	337.0	414.5
	2016	254.7	515.9	454.6	676.0	157.7	842.4	31.6	474.8	59.3	512.3	344.4	647.7
	2017	187.0	425.8	409.3	718.5	311.6	891.5	66.6	539.3	75.8	462.8	290.8	356.1
	Average	*212.8*	*649.7*	*433.2*	*666.0*	*215.3*	*871.8*	*45.4*	*535.2*	*66.8*	*641.8*	*324.1*	*472.8*
99th Percentile	2015	65.4	185.0	156.0	284.1	33.4	239.4	10.7	110.1	12.9	135.8	101.1	172.7
	2016	68.6	204.6	157.2	307.3	53.3	261.6	10.2	163.3	15.3	127.1	98.2	185.3
	2017	66.8	172.6	197.7	320.6	45.7	230.4	11.7	141.6	14.0	180.7	96.1	165.6
	Average	*66.9*	*187.4*	*170.3*	*304.0*	*44.1*	*243.8*	*10.9*	*138.3*	*14.1*	*147.9*	*98.4*	*174.6*
90th Percentile	2015	22.9	82.3	4.3	111.2	0.7	89.9	0.5	30.3	0.4	38.3	31.8	52.4
	2016	22.1	78.5	7.1	120.8	1.2	82.5	0.5	30.5	0.6	34.0	29.9	52.6
	2017	22.4	70.3	12.6	173.4	1.2	65.5	0.5	36.2	0.7	49.0	30.0	44.3
	Average	*22.4*	*77.0*	*8.0*	*135.2*	*1.0*	*79.3*	*0.5*	*32.3*	*0.6*	*40.4*	*30.6*	*49.8*
50th Percentile	2015	0.0	20.0	0.0	46.4	0.0	42.8	0.0	8.0	0.0	10.9	0.1	9.2
	2016	0.0	28.4	0.0	40.7	0.0	28.2	0.0	7.6	0.0	7.0	0.1	9.8
	2017	0.0	24.6	0.0	78.0	0.0	21.2	0.0	10.1	0.0	8.8	0.0	8.2
	Average	*0.0*	*24.3*	*0.0*	*55.0*	*0.0*	*30.7*	*0.0*	*8.6*	*0.0*	*8.9*	*0.1*	*9.1*
Annual Average	2015	5.7	33.3	5.7	56.3	1.1	51.5	0.4	14.5	0.5	19.1	8.1	21.4
	2016	5.7	39.3	6.9	57.1	1.8	41.8	0.4	15.5	0.6	15.2	8.1	22.1
	2017	5.5	33.5	9.4	89.7	1.8	33.4	0.5	17.9	0.6	20.8	7.8	18.7
	Average	*5.7*	*35.4*	*7.3*	*67.7*	*1.6*	*42.2*	*0.5*	*16.0*	*0.6*	*18.4*	*8.0*	*20.7*
Background (observed value when simulation indicated little	2015		26.7		64.3		72.7		22.4		30.3		10.4
	2016		36.6		54.3		59.1		21.3		22.8		10.9
	2017		30.0		101.3		44.3		26.2		34.4		9.9

Description	Year	SO₂ Concentration (µg/m³)											
		Leitrim		AJ Jacobs		Eco Park		Three Rivers		Sharpeville		Zamdela	
		Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed
contribution (0.1 µg/m³))	*Average*		*31.1*		*73.3*		*58.7*		*23.3*		*29.2*		*10.4*

Table H-2: Simulated NO_2 concentration from routine emissions and observed NO_2 concentration statistics

Description	Year	NO₂ Concentration (µg/m³)											
		Leitrim		AJ Jacobs		Eco Park		Three Rivers		Sharpeville		Zamdela	
		Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed
Maximum	2015	97.8	178.4	269.8	127.4	97.5	782.9	36.3	178.6	54.8	344.0	193.6	168.1
	2016	138.9	140.7	248.5	125.4	94.9	373.1	43.5	148.4	54.3	176.8	272.3	199.8
	2017	144.2	117.4	249.2	164.7	174.6	439.8	57.3	178.2	54.9	104.0	144.4	141.7
	Average	*127.0*	*145.5*	*255.8*	*139.2*	*122.3*	*531.9*	*45.7*	*168.4*	*54.6*	*208.3*	*203.4*	*169.9*
99th Percentile	2015	57.8	64.9	94.2	79.6	36.4	85.1	12.6	104.6	17.7	156.7	63.8	100.4
	2016	58.4	87.2	104.8	73.3	48.0	86.0	12.2	92.1	19.1	104.7	61.6	123.2
	2017	57.5	77.9	135.3	81.4	46.8	84.2	14.1	95.1	18.4	55.9	61.1	91.3
	Average	*57.9*	*76.7*	*111.4*	*78.1*	*43.7*	*85.1*	*12.9*	*97.3*	*18.4*	*105.8*	*62.2*	*105.0*
90th Percentile	2015	22.8	39.0	10.7	46.3	1.2	52.9	0.6	64.5	0.6	96.3	38.4	62.4
	2016	22.1	47.8	15.8	42.8	1.8	51.1	0.6	53.1	1.0	62.7	39.1	73.4
	2017	22.9	42.9	22.6	52.1	1.8	49.2	0.7	54.3	0.9	34.1	36.5	55.8
	Average	*22.6*	*43.2*	*16.3*	*47.1*	*1.6*	*51.1*	*0.6*	*57.3*	*0.8*	*64.4*	*38.0*	*63.9*
50th Percentile	2015	0.0	17.3	0.0	15.3	0.0	15.9	0.0	24.8	0.0	31.3	0.1	24.6
	2016	0.0	17.6	0.0	16.1	0.0	15.0	0.0	21.9	0.0	22.6	0.1	24.2

Description	Year	NO$_2$ Concentration (µg/m³)											
		Leitrim		AJ Jacobs		Eco Park		Three Rivers		Sharpeville		Zamdela	
		Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed
	2017	0.0	15.4	0.0	25.1	0.0	14.4	0.0	20.8	0.0	11.6	0.1	21.3
	Average	*0.0*	*16.8*	*0.0*	*18.8*	*0.0*	*15.1*	*0.0*	*22.5*	*0.0*	*21.8*	*0.1*	*23.4*
Annual Average	2015	6.0	21.2	5.2	21.0	1.2	22.3	0.5	31.5	0.7	43.9	8.0	30.1
	2016	6.0	22.8	6.6	20.3	1.7	21.5	0.5	26.4	0.8	29.7	8.3	32.6
	2017	5.9	19.2	8.2	26.6	1.8	20.5	0.6	26.3	0.8	15.7	7.6	26.4
	Average	*6.0*	*21.1*	*6.7*	*22.7*	*1.6*	*21.5*	*0.6*	*28.1*	*0.8*	*29.8*	*8.0*	*29.7*
Background (observed value when simulation indicated little contribution (0.1 µg/m³))	2015		19.3		23.3		39.2		53.8		77.1		24.6
	2016		20.6		20.5		33.4		43.6		48.9		24.2
	2017		18.9		30.1		32.8		44.6		27.0		22.2
	Average		*19.6*		*24.6*		*35.1*		*47.3*		*51.0*		*23.6*

APPENDIX I: MANAGEMENT OF UNCERTAINTIES

Dispersion Model Uncertainties

In the US EPA Guideline on Air Quality Models (U.S. EPA, 2017), the need to address the uncertainties associated with dispersion modelling is acknowledged as an important issue that should be considered. The US Guideline divides the uncertainty associated with dispersion model predictions into two main types (U.S. EPA, 2017), as follows:

- Reducible uncertainty, which results from (1) Uncertainties in the input values of the known conditions (i.e., emission characteristics and meteorological data); (2) errors in the measured concentrations which are used to **compute the concentration residuals; and (3) inadequate model physics and formulation. The "reducible"** uncertainties can be minimized through better (more accurate and more representative) measurements and better model physics.
- Inherent uncertainty is associated with the stochastic (turbulent) nature of the atmosphere and its representation (approximation) by numerical models. Models predict concentrations that represent an ensemble average of numerous repetitions for the same nominal event. An individual observed value can deviate significantly from the ensemble value. This uncertainty may be responsible for a $\pm$ 50% deviation from the measured value.

Atmospheric dispersion models are often criticised for **being inadequate since "…***it is only a model approximating reality***",** and therefore include inherent uncertainty. Both reducible and inherent uncertainties mean that dispersion modelling results may over- or under-estimate measured ground-level concentrations at any specific time or place. However, the US EPA Guideline on Air Quality Models (U.S. EPA, 2017) also states that:

"Models are more reliable for estimating longer time-averaged concentrations than for estimating short-term concentrations at specific locations; and the models are reasonably reliable in estimating the magnitude of highest concentrations occurring sometime, somewhere within an area. For example, errors in highest estimated concentrations of $\pm$ 10 to 40 percent are found to be typical, certainly well within the often-quoted factor-of-two accuracy that has long been recognized for these models."

To minimise the overall uncertainty, but specifically the "reducible uncertainty", the following simple principles were followed in the investigation:

- Understanding the objectives of the investigation;
- Demonstrating that the model inputs are as correct as possible;
- Understanding and stating the model performance limitations;
- Demonstrating that the modelling process has been conducted appropriately and in line with both local DEA requirements and international practice;
- Including any validating information from monitoring that might be available; and,
- To be conservative in cases where there is greater uncertainty (e.g. conversion of NO to NO_2).

Although the existence of model uncertainty is well-accepted, it does not exclude the use of dispersion modelling results in making important air quality impact decisions. The uncertainties should simply be acknowledged and understood that, given **their inherent uncertainty, current dispersion models are a "best-case" approximation of what are otherwise very complex** physical processes in the atmosphere. An accepted dispersion model (i.e., CALPUFF) was selected for the analysis to minimize some of these uncertainties. The US EPA states that when dispersion models such as CALPUFF are used to assess ground-level concentration and when a sufficiently large number of meteorological conditions are considered, the

modelling results should ideally fall well within the often quoted "factor of two" accuracy for these modelled (U.S. EPA, 2017).

Validation of Predictions

Model verification and validation (V&V) are the primary processes for quantifying and building credibility in numerical models. There are distinct differences between the two processes, as described below:

- **Verification is the process of determining that a model implementation accurately represents the developer's** conceptual description of the model and its solution.
- Validation is the process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model.

Whilst V&V cannot prove that a model is correct and accurate for all possible scenarios, it can provide evidence that the model is sufficiently accurate for its intended use.

A rigorous V&V programme was not completed as part of the study; however, regular sanity checks on model results and comparisons with observations were done, as discussed in Section 5.1.6. An attempt was also made to quantify the level of agreement between observed data and model prediction, as well as the predictive accuracy of the model once the necessary adjustments have been made (such as including the estimated background concentrations). In this regard, the **CALPUFF model's performance was evaluated by comparing the modelling results for the years 201**5, 2016 and 2017 to the monitoring data collected over the same time period. In particular, the predicted SO_2 and NO_2 concentrations arising from both the SO and Natref plant were include in the comparison.

The performance evaluation was completed using the fractional bias method, since this statistical technique is one of the evaluation methods recommended by the U.S. EPA for determining dispersion model performance (U.S. EPA 1992). The fractional bias was computed for SO_2 and NO_2 as predicted and observed at monitoring stations within the study area. The fractional biases of the means were shown to be well within a factor of two, which the U.S. EPA consider to be a reasonable performance target for a dispersion model before it is used for refined regulatory analysis (U.S. EPA 1992).

Scenario Simulations

Since the focus of the study has been to illustrate the relative changes with the introduction of different emission conditions (i.e. emission rates, exit gas temperatures and velocities), whilst maintaining the same stack heights and diameters, it is expected that the model errors would mostly be carried between the different modelling scenarios. Therefore, expressing the changes as incremental and relative to the baseline scenario, it is expected that these errors would be mostly cancel each other out.

Ambient Monitoring Uncertainty

Sasol operates a total of four ambient air quality monitoring stations in and around Sasolburg, namely at Sasol 1 Fence Line, AJ Jacobs, Leitrim and Eco Park. No data was provided for the Sasol 1 Fence Line monitoring station. The DEA operate three monitoring stations in the study area, namely Zamdela, Three Rivers and Sharpeville. Data from the Sasol and DEA monitoring stations for 2015, 2016 and 2017 were included in this investigation.

All of the abovementioned Sasol monitoring stations are ISO/IEC17025 accredited, to ensure data integrity and data quality as well as to ensure that the data obtained from the monitoring stations are representative of the ambient air when measured. Data availability and credibility is maximised through:

- Regular (at least on a weekly basis) visits of the monitoring stations to ensure the stations are functioning properly.
- Dynamic calibrations are conducted on at a quarterly basis, however where possible more frequent calibrations have been done.
- Certified calibration gas is used and obtained from reputable vendors
- Inter-laboratory comparisons are done between Sasol's Sasolburg and Secunda monitoring stations as well as between Sasolburg, Secunda and a third-party calibration laboratory.
- Participation in the National Metrological Laboratory's national inter-laboratory comparisons to ensure that the system is in line with the rest of the accredited laboratories in South Africa.

Although the ISO/IEC 17025 System requires a quarterly data availability of 80%, Sasol's internal data availability, tracked on a monthly Scorecard, is a monthly data availability of 90%.

Based on the uncertainty calculations completed as per the ISO/IEC17025 requirements, Sasol's uncertainty in measurements on its ambient air quality monitoring stations is between 3% and 5% with a level of confidence of 95%. This has been confirmed through inter-laboratory comparisons and is confirmed on a regular basis.

Upper Air Meteorological Data

Although meteorological data from the monitoring stations described in the previous section are available for input into the CALPUFF dispersion model, there is a lack of upper air meteorology. Furthermore, it is anticipated that the wind observations at AJ Jacobs may be compromised due to nearby trees and building structures (see Section 5.1.5.1). The lack of appropriate meteorological information is often the single most important limiting factor in modelling accuracy. It is also the most subjective in deciding just how many data are needed, from which location and how accurate they must be.

The CALMET wind field model requires, as a minimum, meteorological data from at least one surface and an upper air station. This information is then used to "seed" the three-dimensional wind field with an initial solution of a relatively simple mass conservation model. CALMET does not include momentum, energy, or moisture conservation equations, and is therefore classified as a diagnostic model.

It is expected, that a wind field developed using all the parameters that could influence the flow, thermal and turbulence mechanisms should improve the accuracy of the dispersion predictions. For simulated data, the Weather Research and Forecasting mesoscale model (known as WRF) was used. The WRF Model is a next-generation mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting needs. It features two dynamical cores, a data assimilation system, and a software architecture facilitating parallel computation and system extensibility. The model serves a wide range of meteorological applications across scales from tens of meters to thousands of kilometres. WRF can generate atmospheric simulations using real data (observations, analyses) or idealized conditions. WRF offers operational forecasting a flexible and computationally-efficient platform, while providing recent advances in physics, numeric, and data assimilation contributed by developers across the very broad research community.

WRF data for the study domain was purchased from Lakes Environmental that has proven record of generating WRF data ready for use in the CALMET modelling suite. The dataset included the years 2015, 2016 and 2017 at 4 km resolution for a

200 km by 200 km study area. The model setup used for WRF was provided by Lakes Environmental and is included in Appendix L.

The WRF model together with the meteorological observations provide a 'first-guess field', which is then modified by the CALMET diagnostic model to take account of terrain and land-use features that are at a smaller spatial scale than the terrain used by the prognostic model. The main purpose of this approach is to increase the horizontal resolution of the meteorological fields.

Emission Inventory Uncertainty

In addition to meteorological input data, the uncertainty associated with the emissions inventory needs to be accommodated in the results. All emissions used in the simulations of the baseline scenario were based on either iso-kinetic measurement campaigns or continuous emissions monitoring (CEM).

Natref makes use of reputable sampling companies for its third-party measurement campaign and also operates CEM devices in certain of its plants. Although there is currently no quality accredited system for online monitoring devices within a stack, Sasol is using the same principles as for its ambient air quality monitoring stations, i.e. the ISO/IEC17025 principles to manage the quality of the data received from its online monitoring network.

All third party (and *ad hoc*) sampling requests (or requirements) within the Sasol Group has to comply with AQA Section 21, Schedule 2 of the Listed Activities and Minimum Emission Standard. Furthermore, Sasol has, as far as possible, standardised on US EPA sampling methodologies. Analyses of the samples are also done by an ISO/IEC17025 accredited laboratory to further control the quality of the results.

Where *ad hoc* sampling is done, Sasol's philosophy is aligned with the requirements of the AQA Section 21, namely that all point sources must be sampled at least once a year.

Third-Party Emission Monitoring

The uncertainty associated with third-party emission's measurements is considered to be up to 10% with a level of confidence of 95%. This uncertainty is based on the isokineticity of the isokinetic sampling, as well as the uncertainty associated with the sample taking and chemical analysis of gaseous components.

According to the SO quality control system, all third-party contractors for isokinetic sampling need to comply with the following control criteria:

- Their entire sampling staffs undergo the training associated with the UK-based Monitoring Certification Scheme (MCERTS): Manual Stack emissions monitoring program (MCERTS 2011);
- An electronic automated sampler is used for all isokinetic sampling;
- The pitot tubes used for sampling is calibrated at least on a quarterly basis;
- The pneumatic pressure sensors on the sampler is also calibrated on at least a quarterly basis; and
- The dry gas meters are checked on a regular basis and replaced every 6 months.

The CEM data is logged per second, and then averaged. In this way, all process upsets are captured within the database. The CEM data used in this investigation were based on an hourly average mass flow and concentration.

Ad-Hoc Emissions Sampling

SANAS is compiling an accreditation system for *ad hoc* sampling and as soon as this system is in place, the uncertainty of the measurements will be confirmed; however, it is not expected to be higher than 10%.

Sasol is also in the process of conducting an international peer review on its third-party contractors to determine whether there is a potential higher uncertainty in its measurements.

The Minimum Emission Standards requires that sampling be conducted at normal operating conditions; therefore, the emissions information included in the dispersion model is aligned with normal operating conditions on site. The sampling schedule is communicated to the plant managers with the aim of having process conditions as representative as possible to normal operations. Sampling upset conditions often poses a challenge from both a logistical and safety point of view, since safety requirements require as few people as possible on the plant during severe upset conditions and therefore sampling cannot be done during such conditions.

$PM_{2.5}$ and PM_{10} Air Emissions

All particulate matter was assumed to be $PM_{2.5}$ since it was not possible to establish the $PM_{2.5}/PM_{10}$ split.

Non-Sasol Air Emissions

No attempt was made to estimate the emissions from non-industrial activities within regional communities. Instead, the community contribution (and other sources) of a particular compound was discussed in Section 5.1.5.4. and Section 5.1.6.

APPENDIX J: GUIDANCE NOTE ON TREATMENT OF UNCERTAINTIES

The Intergovernmental Panel on Climate Change (IPCC) produced a Guidance Note for lead authors of the IPCC Fifth Assessment Report on consistent treatment of uncertainties. These notes define a common approach and calibrated language that can be used broadly for developing expert judgments and for evaluating and communicating the degree of certainty in findings of the assessment process. Communicating the degree of certainty in key findings relies on expressing the:

- Confidence in the validity of a finding, based on the type, amount, quality, and consistency of evidence (e.g., mechanistic understanding, theory, data, models, expert judgment) and the degree of agreement. Confidence is expressed qualitatively.
- Quantified measures of uncertainty in a finding expressed probabilistically (based on statistical analysis of observations or model results, or expert judgment).

The Guidance Note proposes the use of the following dimensions to evaluate the validity of a finding: the type, amount, quality, and consistency of evidence (summary terms: "limited," "medium," or "robust"), and the degree of agreement (summary terms: "low," "medium," or "high"), as summarised in the figure below.
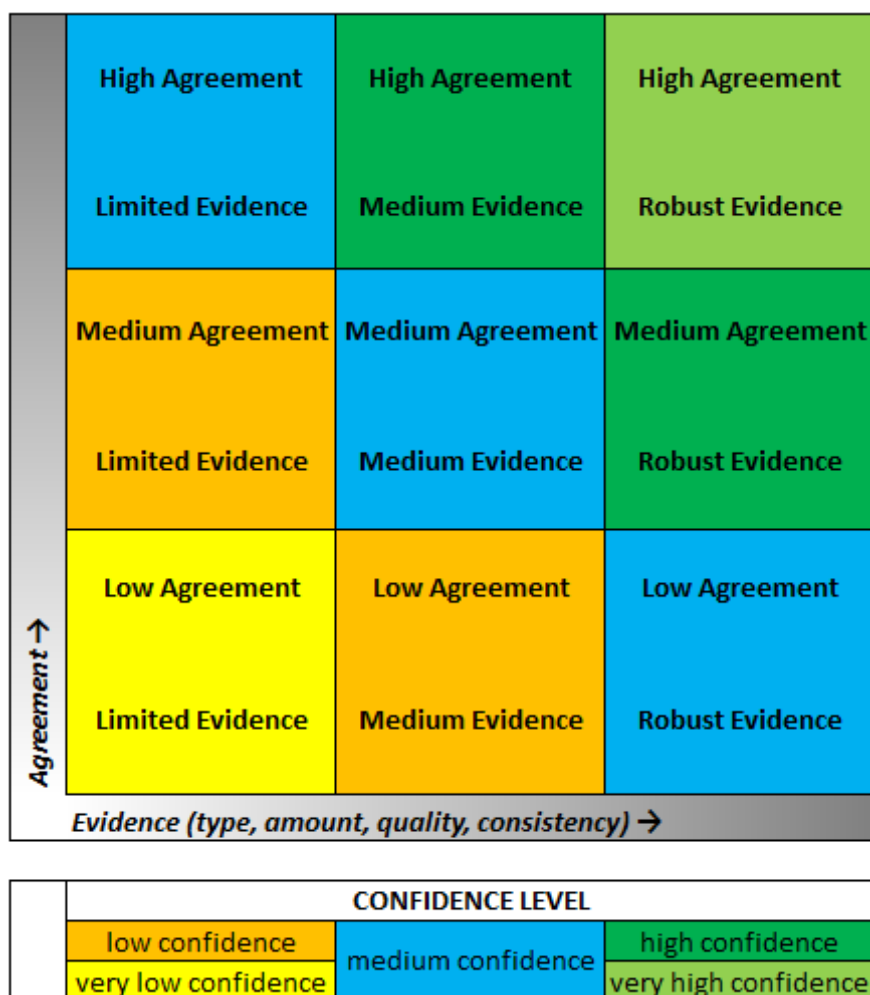

Figure J-1: A depiction of evidence and agreement statements and their relationship to confidence. Confidence increases towards the top-right corner as suggested by the increasing strength of shading. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality evidence.

Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality evidence. The guide further provides advice for a traceable account describing the evaluation of evidence and agreement, as follows:

- For findings with high agreement and robust evidence, present a level of confidence or a quantified measure of uncertainty.
- For findings with high agreement or robust evidence, but not both, assign confidence or quantify uncertainty when possible. Otherwise, assign the appropriate combination of summary terms for your evaluation of evidence and agreement (e.g., robust evidence, medium agreement).
- For findings with low agreement and limited evidence, assign summary terms for your evaluation of evidence and agreement.
- In any of these cases, the degree of certainty in findings that are conditional on other findings should be evaluated and reported separately.

A level of confidence is expressed using five qualifiers: "very low," "low," "medium," "high," and "very high." It synthesizes the author teams' judgments about the validity of findings as determined through evaluation of evidence and agreement. Figure J-1 depicts summary statements for evidence and agreement and their relationship to confidence. There is flexibility in this relationship; for a given evidence and agreement statement, different confidence levels could be assigned, but increasing levels of evidence and degrees of agreement are correlated with increasing confidence. Confidence cannot necessarily be assigned for all combinations of evidence and agreement in Figure J-1. Presentation of findings with "low" and "very low" confidence should be reserved for areas of major concern, and the reasons for their presentation should be carefully explained. Confidence should not be interpreted probabilistically, and it is distinct from "statistical confidence." Additionally, a finding that includes a probabilistic measure of uncertainty does not require explicit mention of the level of confidence associated with that finding if the level of confidence is "high" or "very high."

Likelihood, as defined in Table J-1, provides calibrated language for describing quantified uncertainty. It can be used to express a probabilistic estimate of the occurrence of a single event or of an outcome (e.g., a climate parameter, observed trend, or projected change lying in a given range). Likelihood may be based on statistical or modelling analyses, elicitation of expert views, or other quantitative analyses.

Table J-1: Likelihood scale

Term	Likelihood of the Outcome
Virtually certain	99-100% probability
Very likely	90-100% probability
Likely	66-100% probability
About as likely as not	33 to 66% probability
Unlikely	0-33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability

The categories defined in this table can be considered to have "fuzzy" boundaries. A statement that an outcome is "likely" means that the probability of this outcome can range from ≥66% (fuzzy boundaries implied) to 100% probability. This implies that all alternative outcomes are "unlikely" (0-33% probability). When there is sufficient information, it is preferable to specify the full probability distribution or a probability range (e.g., 90-95%) without using the terms in Table J-1. "About as likely as not" should not be used to express a lack of knowledge.

APPENDIX K: SENSITIVE RECEPTORS INCLUDED IN THE DISPERSION MODEL SIMULATIONS

Table K-1: Discrete sensitive receptors included in the dispersion model simulations

Receptor code name	Receptor details	Distance from centre of operations (km)
Zamdela	VTAPA Zamdela monitoring station	2.1
Leitrim	Sasol Leitrim monitoring station	3.1
AJ Jacobs	Sasol AJ Jacobs monitoring station	3.2
EcoPark	Sasol EcoPark monitoring station	5.7
Sharpeville	VTAPA Sharpville monitoring station	15.1
Three Rivers	VTAPA Three Rivers monitoring station	23.4
25	Malakabeng Primary School	1.7
32	Cedar Secondary School	1.9
15	Bofula- Tshepe Primary School	2.0
49	Clinic A Zamdela	2.1
51	Zamdela Hospital Zumayear	2.2
35	Iketsetseng Secondary School	2.2
48	Clinic B Zamdela	2.2
29	Tsatsi Primary School	2.3
20	Isaac Mhlambi Primary School	2.3
37	Nkopoleng Secondary School	2.4
34	HTS Secondary School	2.4
44	Zamdela Community Clinic	2.8
14	AJ Jacobs Primary School	2.9
28	Theha Setjhaba Primary School	3.0
52	Sasolburg Clinic	3.2
18	Credo Primary School	3.3
23	Lehutso Primary School	3.6
50	Harry Gwala Clinic	Creche	3.7
36	Kahobotjha-sakubusha Secondary School	4.1
43	Sasolburg Provincial Hospital	4.2
19	Fonteine Primary School	4.3
33	Fakkel Secondary School	4.6
38	Sasolburg High School	4.6
24	Lumiere Primary School	5.4
31	Afrikaans Hoërskool	5.6
22	Leewspruit Primary School	5.7
42	Vaalpark Hospital	6.1
21	Kopanelang Thuto Primary School	6.2
39	Vaalpark Articon Secondary School	6.5
26	Noord Primary School	6.7
30	Vaalpark Primary School	7.1
27	Taaibos Primary School	9.2
41	Vaal Christian Secondary School	11.2
40	Pele-ya-pele Secondary School	11.6
17	Vukuzake Primary School	14.4
16	Bokantsho Primary School	17.9

LAKES ENVIRONMENTAL WRF MODELING

DRAFT

1   Introduction

This document provides a brief description of WRF modeling at *Lakes Environmental* and the type of outputs generated. Our WRF modeling focuses on generating high resolution data with enough information to create meteorological input files for the CALPUFF and AERMOD modeling systems.

2   WRF Description

The Weather Research and Forecasting model (WRF) is a prognostic meteorology model developed in a collaborative partnership between the U.S. National Center for Atmospheric Research (NCAR), the National Centers for Environmental Prediction (NCEP), and others. The WRF model is a limited-area, non-hydrostatic, terrain-following sigma-coordinate model designed to simulate or predict mesoscale and regional-scale atmospheric circulation.

3   WRF Processing Specifications

3.1   Input of Meteorological Data

WRF does not directly use conventional meteorological data from airport reports. Instead, the model uses objective analysis of global weather reports. Objective analysis is a process of analyzing the observed data and outputting them into a regular grid. The meteorological field is "balanced" to account for the energy and momentum equations of the atmosphere. These objective analyses are products of global models, which are maintained by national weather centers or federal agencies such as UKMO (United Kingdom Meteorological Office) or US NCEP.

Lakes Environmental used the NCEP Global Forecast System (GFS) 0.5-degree resolution data (approximately 50-km resolution) for input into WRF. GFS 0.5-deg data is given every 6 hours at 00, 06, 12, and 18Z.

Sea Surface Temperature (SST) data comes from the GFS 0.5 degree data but updated daily as each WRF simulation is done for 24 hours.

3.2   Nested Grids Domains

WRF uses a nested grid approach allowing an area of interest to be modeled without the penalty of excessive run times created by having a fine grid over the entire modeling domain. Depending on the application, Lakes Environmental employs 12-km or 4-km grid spacing at the highest resolution (inner grid).

Tables 1 presents the grid dimensions and number of grid points that that are commonly used.

Table 1. WRF Nested Domain Grids

Domain	Resolution (km)	Number of Grid Points in X and Y
Domain 1	36	31 x 31
Domain 2	12	31 x 31
Domain 3 (if necessary)	4	31 x 31

3.3   WRF Physics Options

The WRF model provides many modeling options which can greatly affect the final output. In Table 2 below, we have listed the physics options most commonly used for the WRF processing.

Table 2. Physics Options Used for WRF Modeling

\#	Type	Options Used
\#	**WRF Physics Options**	
\#	**Type**	**Options Used**
1	Microphysics	WSM 3-class scheme mp_physics = 3
2	Long-wave Radiation	RRTM Logwave scheme ra_lw_physics = 1
3	Short-wave Radiation	Dudhia Shortwave ra_sw_physics = 1
4	Surface Layer	Monin-Obukhov (MM5 MRF PBL) sf_sfclay_physics = 1
5	Land Surface	Unified Noah Land Surface model sf_surface_physics = 2
6	Planetary Boundary Layer	Yonsei University scheme (YSU) bl_pbl_physics = 1
7	Cumulus parameterization	Betts-Miller-Janjic scheme cu_physics = 2

See link below to the UCAR web site for descriptions and references of WRF physics options:

http://www2.mmm.ucar.edu/wrf/users/wrfv3.5/phys_references.html

3.4 Additional WRF Modeling Information

The information below describes other modeling parameters taken into account for *Lakes Environmental* WRF processing:

- WRF-ARW and WPS models Version 3.6
- Map projection in Lambert Conformal Conic (LCC)
- 35 ETA vertical pressure levels
- USGS 24 land use category data

In addition to the above options, a spin up time of 6 hours for each daily run was used. This means that every 24-hour run was composed of 30 hours where the 6 preceding hours are used for proper daily initialization. The initialization process discards these 6 initial hours which are not saved in the output as part of the meteorological modeling run.

3.5 WRF Output for AERMET

The US EPA Mesoscale Model Interface Program (MMIF) is a tool that retrieves data from NCAR's WRF-ARW model output in netCDF format and generates surface and upper air data files that can be used by the US EPA AERMET model (meteorological pre-processor for the US EPA AERMOD air dispersion model).

Data for use in AERMET/AERMOD are extracted from the innermost domain for the center of the grid cell closest to the user-defined latitude/longitude coordinate. Outer domains are used only to provide information to the innermost domain.

The latest version of the MMIF program is used. Table 3 contains a description of the files that were generated by the MMIF program where METxxxxxx is the order number, yyyy is the starting year, and zzzz is the ending year.

Table 3. Files Generated by MMIF

#	File Name	Description
1	METxxxxxx_AERMET_yyyy-zzzz.IN1	AERMET Stage 1 Input File
2	METxxxxxx _AERMET_ yyyy-zzzz.IN2	AERMET Stage 2 Input File
3	METxxxxxx _AERMET_ yyyy-zzzz.IN3	AERMET Stage 3 Input File
4	METxxxxxx _AERMET_ yyyy-zzzz.DAT	Onsite Surface Met File
5	METxxxxxx _AERMET_ yyyy-zzzz.FSL	FSL Upper Air Met File

3.6 WRF Output for CALMET

CALWRF is a tool that retrieves data from NCAR's WRF-ARW model output in netCDF format and creates a 3D.DAT file suitable for input into the CALMET model. The CALWRF output forms a grid covering the requested modeling domain with the requested resolution of either 4 km or 12 km. CALMET is a 3-D diagnostic meteorological pre-processor for CALPUFF model. CALPUFF is an advanced non-steady-state air quality dispersion model. CALWRF, CALMET, and CALPUFF are from Exponent. See below additional information on the CALWRF executable currently in use at Lakes Environmental:

- CALWRF.EXE, Version 2.0.1, Level 130418
- Generates 3D.DAT file in Version 2.1 format

The output from CALWRF is an ASCII file, known as the 3D.DAT format, which contains output variables for each hour, for each pressure level, and for each grid cell. Table 4 below describes the output variables.

Table 4. Variables Available in 3D.DAT File

#	Parameter	Units
1	Pressure	(mb)
2	Elevation	(m above mean sea level)
3	Temperature	(K)
4	Wind direction	(deg)
5	Wind speed	(m/s)
6	Vertical wind velocity	(m/s)
7	Relative humidity	(%)
8	Vapor mixing ratio	(g/kg)
9	Cloud mixing ratio	(g/kg)
10	Rain mixing ratio	(g/kg)

In addition, Table 5 describes the surface variables reported for each hour and each grid cell under the 3D.DAT file.

Table 5. Surface Variables Available in 3D.DAT File

#	Parameter	Units
1	Sea level pressure	(hPa)
2	Total rainfall accumulated for the past hour	(cm)
3	Snow cover indicator	-
4	Short wave radiation at the surface	(W / m²)
5	Long wave radiation at the top	(W / m²)
6	Air temperature at 2 m	(K)
7	Specific humidity at 2 m	(g/kg)
8	Wind direction of 10 m wind	(deg)
9	Wind speed of 10 m wind	(m/s)
10	Sea surface temperature	(K)

3.7   WRF Output for CALPUFF

The Mesoscale Model Interface Program (MMIF) converts prognostic meteorological model output fields to formats required for direct input into dispersion models. The utility was developed by ENVIRON International Corporation for the USEPA and is distributed via the USEPA's website. The utility reads data from NCAR's WRF-ARW model output in netCDF format and creates data in a user-specified format.

MMIF can be used to generate data for direct input to the CALPUFF model bypassing the CALMET model entirely. Output can be processed for use in either CALPUFF version 5.8.x or CALPUFF version 6 / 7. MMIF generates three sets of files:

- **Projection File:** This file contains information on the domain, projection, and met grid to be used in the CALPUFF project.
- **Terrain Grid File:** This is a gridded file containing terrain elevations (from mean sea level) to be used in the extraction of base elevations for sources and receptors in the CALPUFF project.
- **CALPUFF-Ready Meteorological Data Files:** The meteorological data to be input to CALPUFF.

4   Additional Information

If you require any further information, please contact us at support@webLakes.com. When contacting us, please provide the met data order number.

For more information about the WRF meteorological model, please visit the site below:

http://www.wrf-model.org/index.php