

Table 5-27: Simulated baseline hourly NO₂ 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/m ³)	Concentration (µg/m ³)	Relative change	Concentration (µg/m ³)	Relative change
Emalenhle AQMS	56.9	51.6	-9.3%	57.9	1.8%
Secunda Club AQMS	56.9	51.6	-9.3%	57.9	1.8%
Secunda AQMS	52.5	48.0	-8.5%	54.6	4.1%
Bosjesspruit AQMS	59.2	54.8	-7.4%	60.5	2.2%
Roodebank Combined School	45.3	34.3	-24.3%	47.4	4.5%
Zamokuthle Primary School	51.6	44.7	-13.3%	52.9	2.5%
Osizweni Secondary School	49.0	38.8	-20.7%	51.2	4.5%
Isibanisesizwe Primary School	52.8	46.5	-11.8%	53.7	1.9%
Maphala-Gulube Primary School	53.7	49.7	-7.3%	55.9	4.2%
Kiriyatswane Secondary School	52.8	45.8	-13.3%	53.3	1.0%
Osizweni Primary School	49.0	38.7	-21.0%	50.9	3.8%
Kusasaletu Secondary School	52.8	47.2	-10.7%	53.6	1.4%
Laerskool Oranjegloed	57.5	53.3	-7.4%	58.6	1.8%
Highveld Medi Clinic/Hydromed	54.0	49.5	-8.2%	55.2	2.3%
Tholukwazi Primary School	51.1	43.5	-14.9%	52.5	2.7%
TP Stratten Primary School	46.7	35.6	-23.7%	48.8	4.6%
School	56.1	51.5	-8.2%	57.1	1.8%
Laerskool Goedeheop	55.8	51.9	-6.9%	57.6	3.4%
Laerskool Kruinpark	58.2	54.1	-7.1%	59.7	2.5%
Lifalethu Primary School	51.6	45.2	-12.4%	53.7	4.1%
Secunda Mediclinic	54.8	50.2	-8.4%	56.1	2.5%
Embalenhle Primary School	51.0	43.6	-14.6%	52.7	3.3%
Buyani Primary School	51.4	44.1	-14.3%	52.6	2.4%
Allan Makhunga Primary School	52.7	46.4	-12.0%	53.8	2.1%

Table 5-28: Simulated baseline annual NO₂ 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 (µg/m ³)	Concentration (µg/m ³)	Relative change	Concentration (µg/m ³)	Relative change
Emalenhle AQMS	3.0	2.3	-23.3%	3.4	12.2%
Secunda Club AQMS	3.0	2.3	-23.3%	3.4	12.2%
Secunda AQMS	1.9	1.4	-25.8%	2.3	19.0%
Bosjesspruit AQMS	4.1	3.3	-19.7%	4.5	10.6%
Roodebank Combined School	1.4	1.0	-25.3%	1.6	16.1%
Zamokuthle Primary School	1.8	1.3	-25.4%	2.1	17.8%
Osizweni Secondary School	1.5	1.1	-24.0%	1.7	14.7%
Isibanisesizwe Primary School	1.9	1.4	-26.0%	2.3	19.8%
Maphala-Gulube Primary School	2.2	1.6	-26.3%	2.6	20.5%
Kiriyatswane Secondary School	1.9	1.4	-26.5%	2.3	19.6%
Osizweni Primary School	1.5	1.1	-24.2%	1.7	14.2%
Kusasaletu Secondary School	1.9	1.4	-25.9%	2.3	19.0%
Laerskool Oranjegloed	3.1	2.5	-21.3%	3.5	10.3%
Highveld Medi Clinic/Hydromed	2.5	1.9	-22.0%	2.7	9.4%
Tholukwazi Primary School	1.7	1.3	-25.3%	2.0	17.0%
TP Stratten Primary School	1.3	1.0	-24.4%	1.5	11.8%
School	2.9	2.2	-24.1%	3.3	13.4%
Laerskool Goedehoop	2.8	2.2	-21.1%	3.1	10.1%
Laerskool Kruinpark	3.3	2.6	-19.7%	3.6	9.3%
Lifalethu Primary School	1.8	1.3	-25.5%	2.1	18.6%
Secunda Mediclinic	2.4	1.9	-23.5%	2.7	12.4%
Embalenhle Primary School	1.7	1.3	-25.2%	2.0	17.1%
Buyani Primary School	1.8	1.3	-25.3%	2.1	17.6%
Allan Makhunga Primary School	1.9	1.4	-26.3%	2.3	20.2%

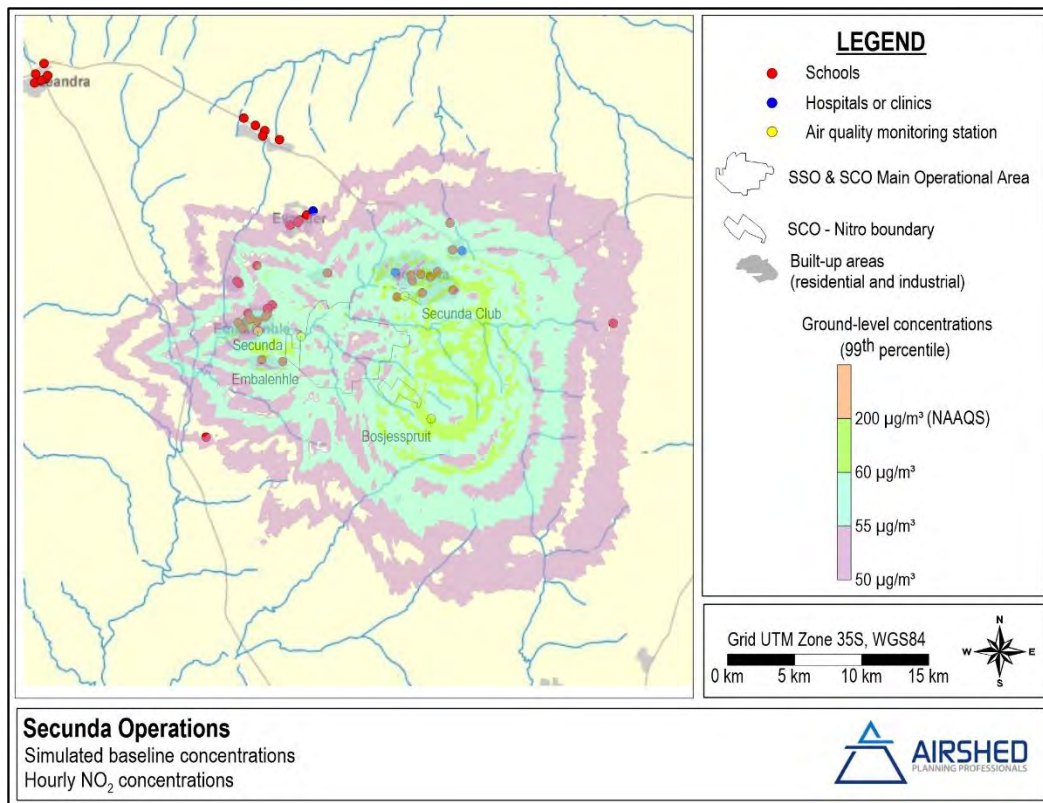


Figure 5-73: Simulated hourly NO₂ concentrations (99th percentile) as a result of baseline emissions

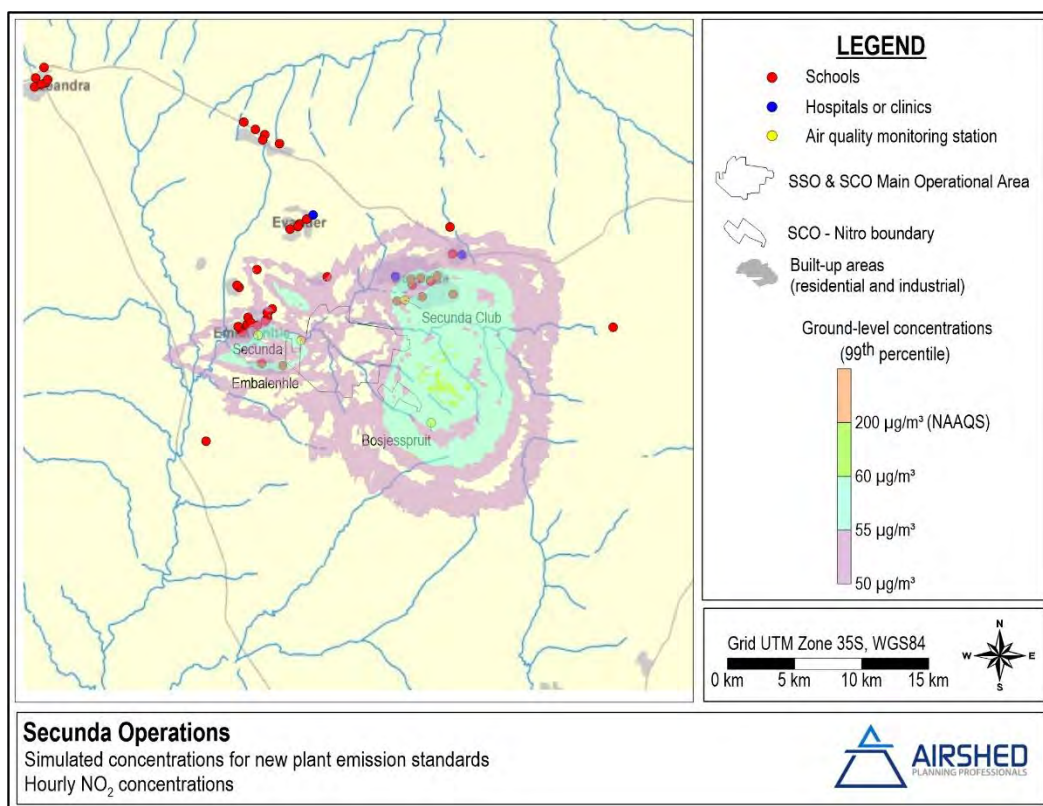


Figure 5-74: Simulated hourly NO₂ concentrations (99th percentile) as a result of theoretical compliance with new plant emission standards

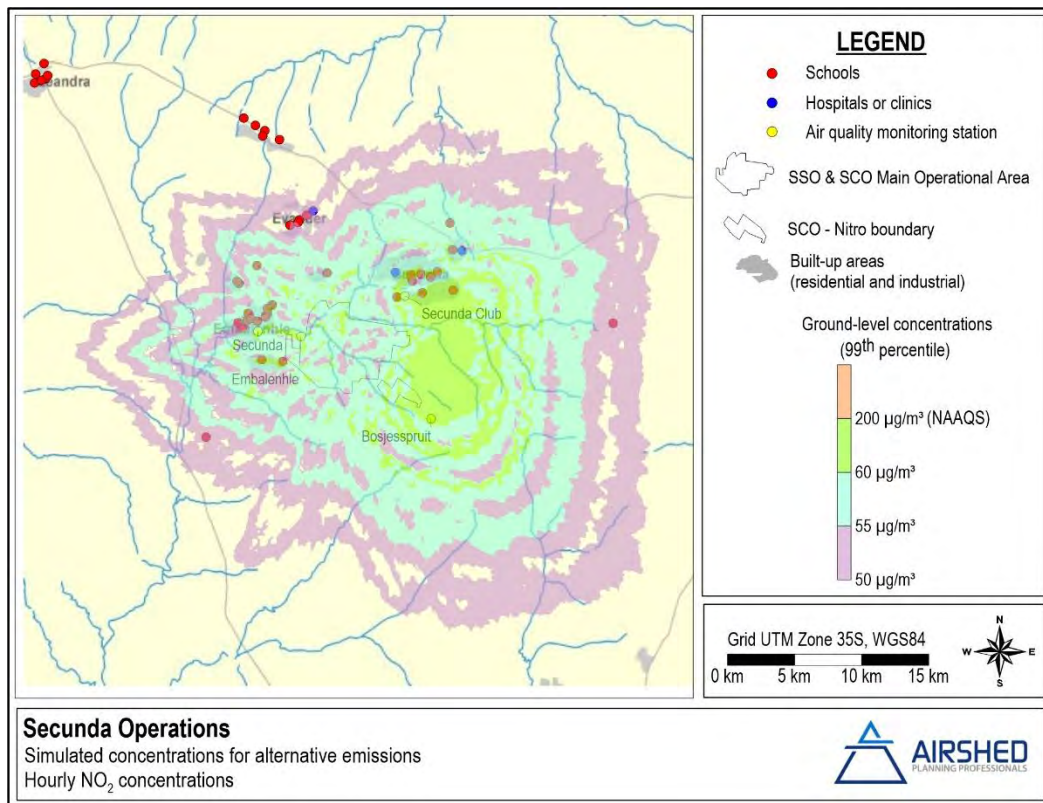


Figure 5-75: Simulated hourly NO₂ concentrations (99th percentile) as a result of alternative emissions

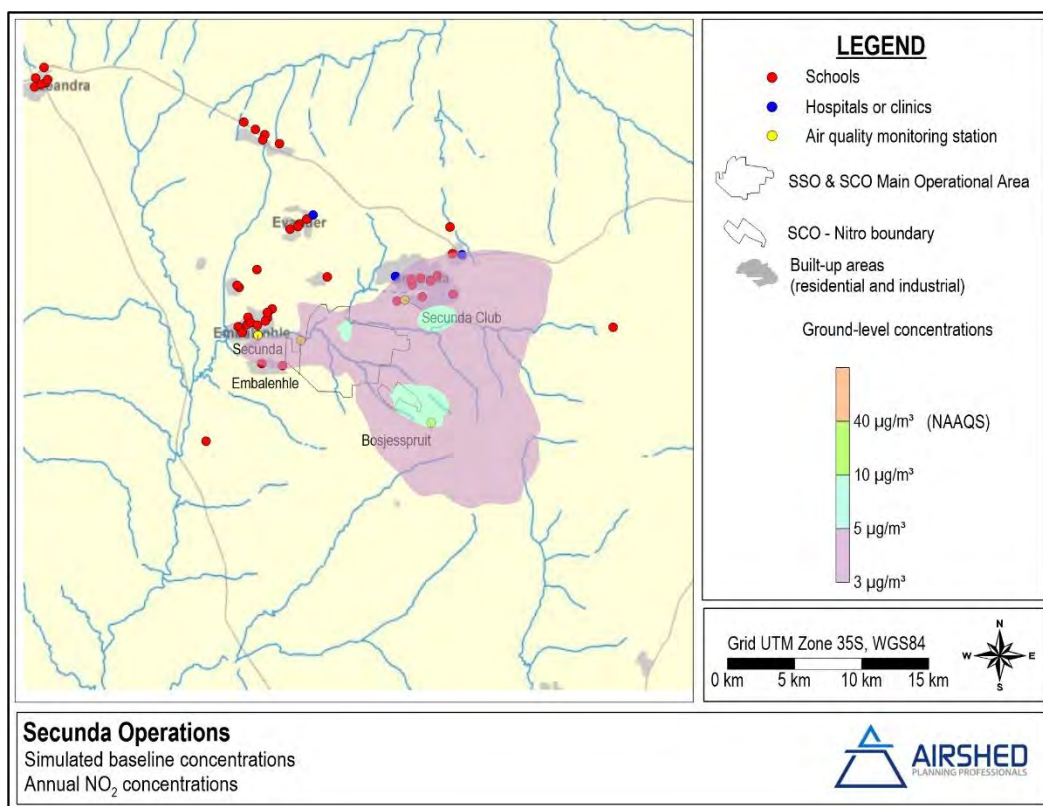


Figure 5-76: Simulated annual NO₂ concentrations as a result of baseline emissions

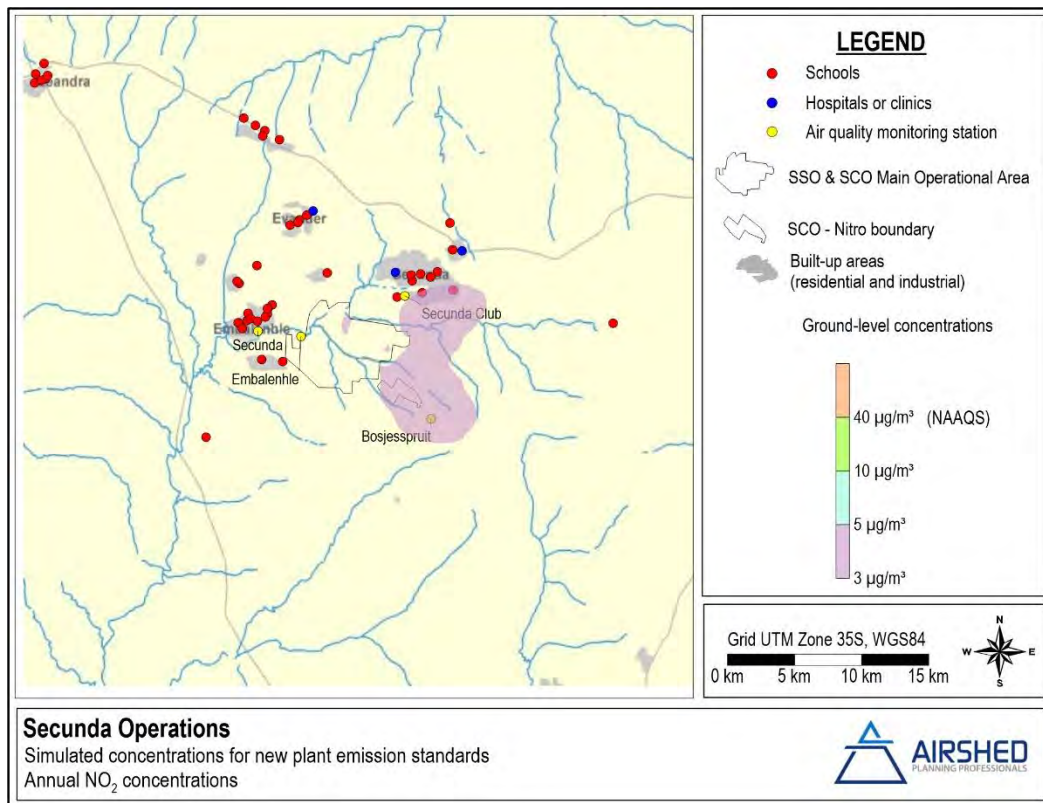


Figure 5-77: Simulated annual NO₂ concentrations as a result of theoretical compliance with new plant emission standards

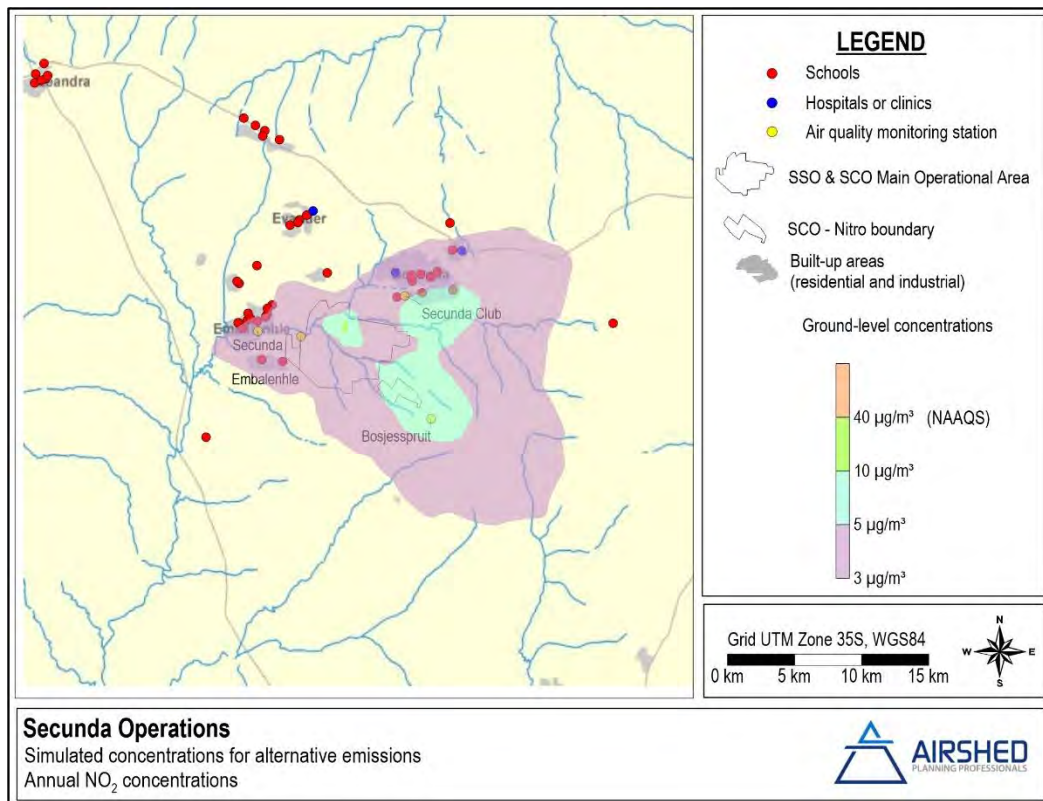


Figure 5-78: Simulated annual NO₂ concentrations as a result of alternative emissions

5.1.8.1.3 Particulate Matter (PM₁₀ and PM_{2.5})

The baseline emissions from Secunda Operations result in low ground-level concentrations of PM; less than 10 µg/m³ daily concentrations at all AQMS (Figure 5-79). Simulated annual PM concentrations are less than 2 µg/m³ at all AQMS (Figure 5-80). Theoretical compliance with the new plant standards will result in reduction of ground-level PM concentrations by up to 48%, while the alternative emissions result in an increase of ground-level PM concentrations by up to 122% (Table 5-29 and Table 5-30).

For particulate matter, NAAQS are available for PM₁₀ and PM_{2.5}. Ambient air quality impacts for both particulate fractions (i.e. PM₁₀ 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}/PM₁₀ split of emissions from Secunda Operations only. Figure 5-79 and Figure 5-80 present predicted PM concentrations at the AQMS relative to both the PM₁₀ and PM_{2.5} NAAQS.

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 5-29 and Table 5-29).

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

Scenario	Daily	Annual
Baseline concentrations	Figure 5-81	Figure 5-84
New Plant standards	Figure 5-82	Figure 5-85
Alternative emissions	Figure 5-83	Figure 5-86

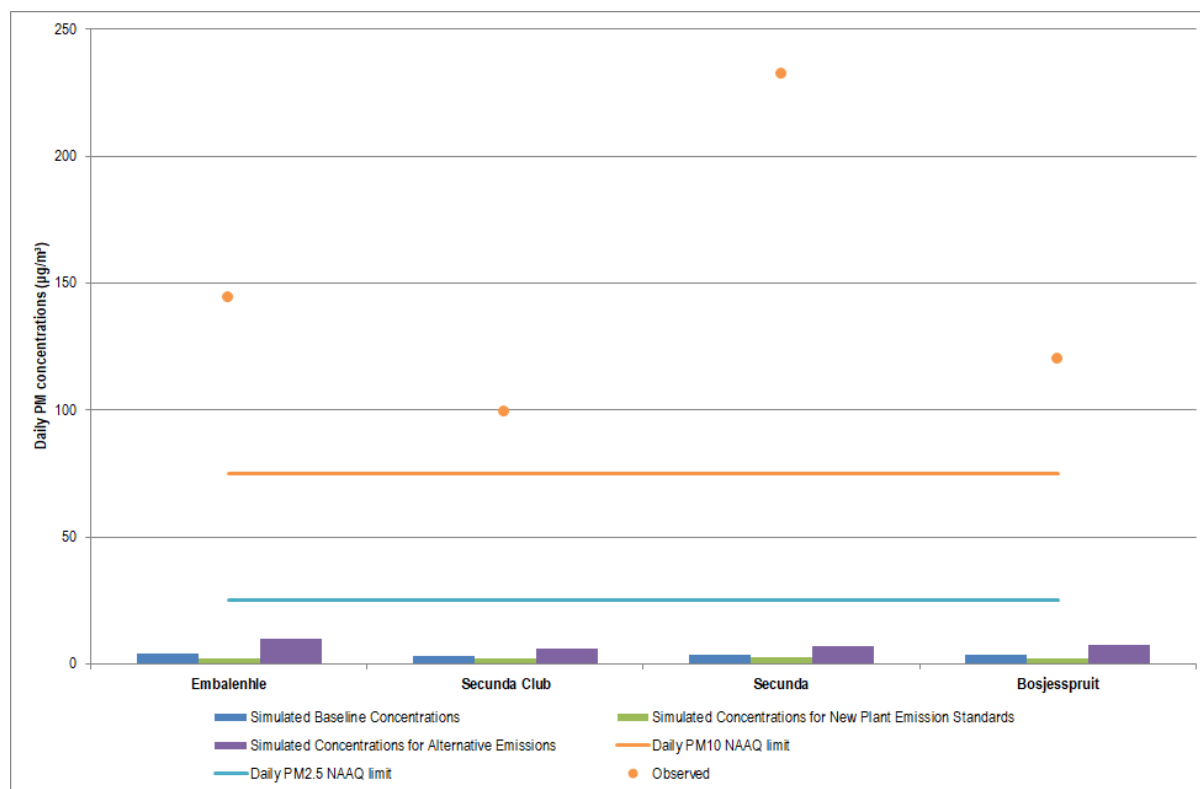


Figure 5-79: Simulated daily PM concentrations (99th percentile) at AQMS for Secunda Operations

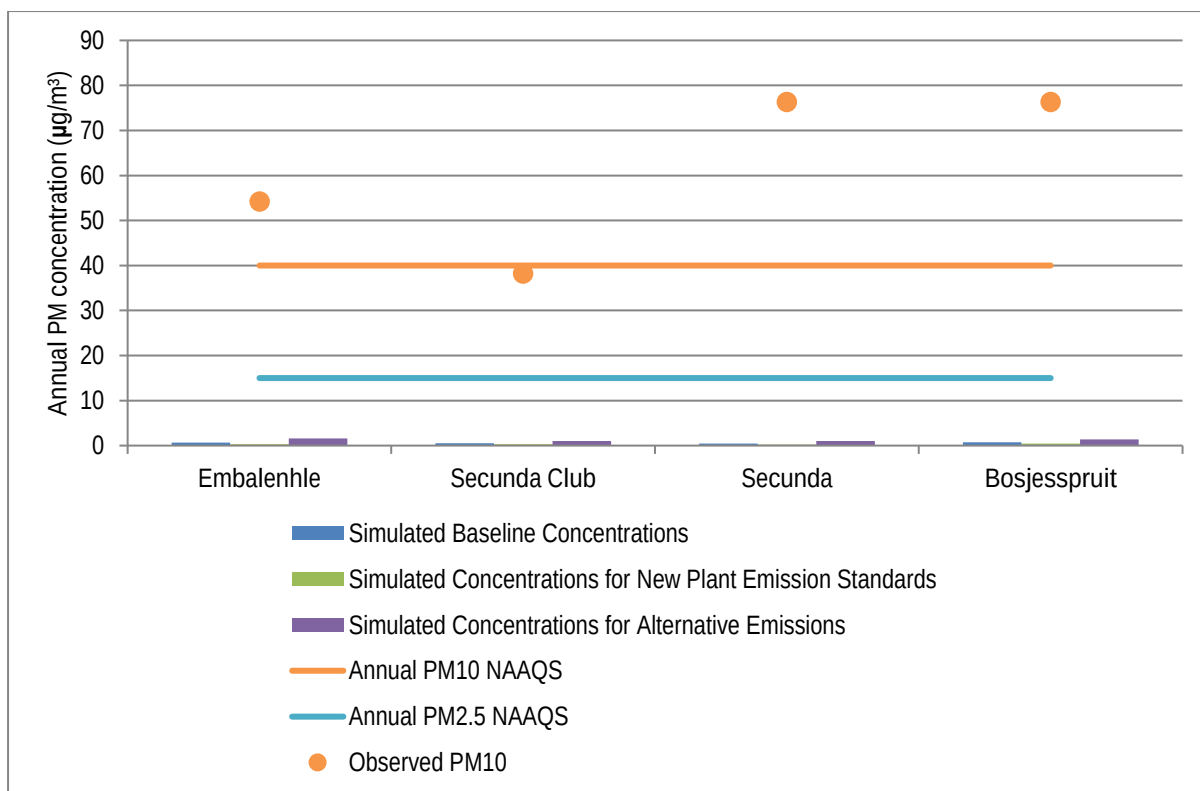


Figure 5-80: Simulated annual PM concentrations at AQMS for Secunda Operations

Table 5-29: 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 ($\mu\text{g}/\text{m}^3$)	Concentration ($\mu\text{g}/\text{m}^3$)	Relative change	Concentration ($\mu\text{g}/\text{m}^3$)	Relative change
Emalenhle AQMS	2.8	2.1	-27%	5.0	77%
Secunda Club AQMS	2.8	2.1	-27%	5.0	77%
Secunda AQMS	3.1	2.0	-36%	6.0	95%
Bosjesspruit AQMS	3.3	2.1	-36%	7.0	112%
Roodebank Combined School	2.2	1.6	-27%	3.8	75%
Zamokuthle Primary School	2.8	1.8	-38%	5.2	84%
Osizweni Secondary School	2.1	1.4	-33%	4.3	105%
Isibanisesizwe Primary School	3.0	1.9	-38%	6.3	109%
Maphala-Gulube Primary School	3.6	2.4	-34%	6.8	92%
Kiriyatswane Secondary School	2.9	1.7	-41%	6.2	112%
Osizweni Primary School	2.1	1.4	-31%	4.2	105%
Kusasaletu Secondary School	3.0	2.0	-33%	6.0	101%
Laerskool Oranjegloed	2.7	1.8	-31%	4.5	71%
Highveld Medi Clinic/Hydromed	2.2	1.6	-29%	3.7	68%
Tholukwazi Primary School	2.6	1.7	-35%	5.1	98%
TP Stratten Primary School	2.0	1.3	-34%	3.5	71%
School	2.8	2.0	-29%	4.9	76%
Laerskool Goedehoop	2.5	1.8	-31%	4.4	72%
Laerskool Kruinpark	2.7	1.9	-29%	4.6	71%
Lifalethu Primary School	2.9	1.9	-34%	6.1	109%
Secunda Mediclinic	2.5	1.8	-28%	4.4	73%
Embalenhle Primary School	2.6	1.7	-35%	5.1	98%
Buyani Primary School	2.8	1.8	-36%	5.6	99%
Allan Makhunga Primary School	3.1	1.8	-42%	6.8	121%

Note:

Conservatively assumes all PM is either PM₁₀ or PM_{2.5}.

Table 5-30: 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 ($\mu\text{g}/\text{m}^3$)	Concentration ($\mu\text{g}/\text{m}^3$)	Relative change	Concentration ($\mu\text{g}/\text{m}^3$)	Relative change
Emalenhle AQMS	0.5	0.3	-36%	0.9	91%
Secunda Club AQMS	0.5	0.3	-36%	0.9	91%
Secunda AQMS	0.4	0.2	-46%	0.9	117%
Bosjesspruit AQMS	0.7	0.4	-35%	1.3	88%
Roodebank Combined School	0.3	0.2	-39%	0.6	101%
Zamokuthle Primary School	0.4	0.2	-44%	0.8	112%
Osizweni Secondary School	0.3	0.2	-41%	0.5	100%
Isibanisesizwe Primary School	0.4	0.2	-48%	0.9	121%
Maphala-Gulube Primary School	0.5	0.3	-46%	1.1	120%
Kiriyatswane Secondary School	0.4	0.2	-48%	0.9	121%
Osizweni Primary School	0.3	0.2	-40%	0.5	98%
Kusasaletu Secondary School	0.4	0.2	-47%	0.9	119%
Laerskool Oranjegloed	0.5	0.3	-33%	0.9	82%
Highveld Medi Clinic/Hydromed	0.3	0.2	-33%	0.6	77%
Tholukwazi Primary School	0.3	0.2	-44%	0.7	112%
TP Stratten Primary School	0.2	0.1	-36%	0.4	88%
School	0.5	0.3	-38%	0.9	97%
Laerskool Goedehoop	0.4	0.3	-34%	0.7	82%
Laerskool Kruinpark	0.5	0.3	-32%	0.8	76%
Lifaletu Primary School	0.4	0.2	-46%	0.8	116%
Secunda Mediclinic	0.4	0.2	-38%	0.7	94%
Embalenhle Primary School	0.3	0.2	-44%	0.7	112%
Buyani Primary School	0.3	0.2	-45%	0.7	113%
Allan Makhunga Primary School	0.4	0.2	-48%	0.9	122%

Note:

Conservatively assumes all PM is either PM₁₀ or PM_{2.5}.

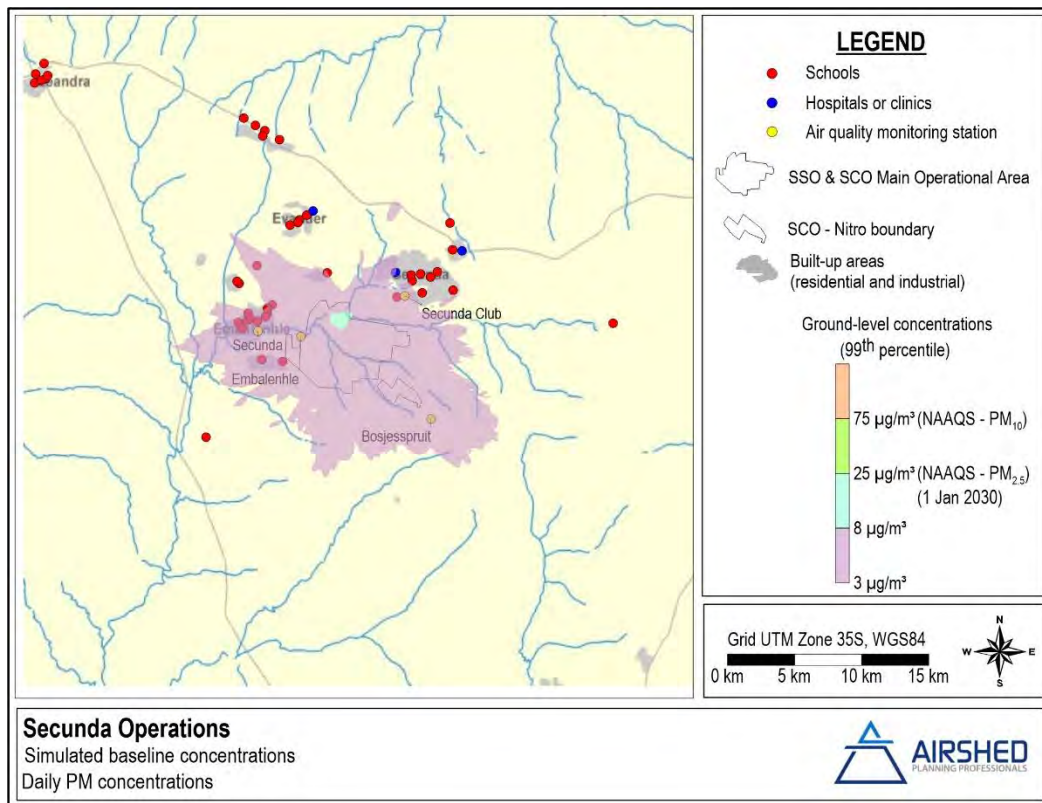


Figure 5-81: Simulated daily PM concentrations (99th percentile) as a result of baseline emissions

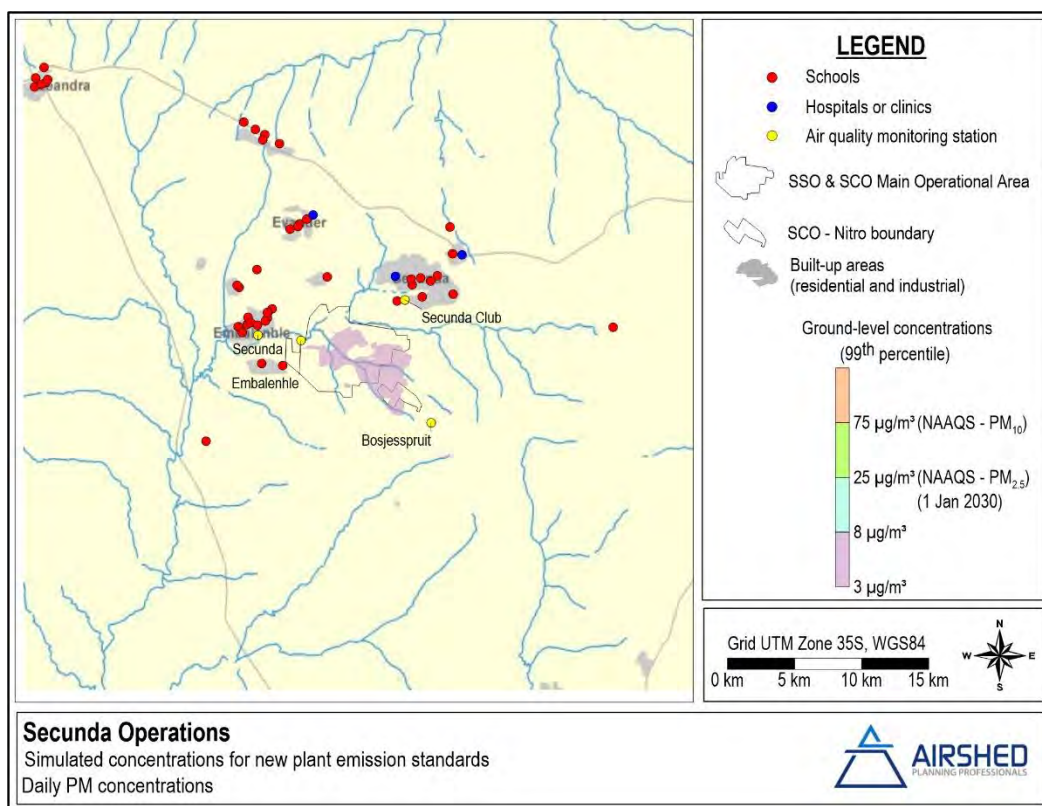


Figure 5-82: Simulated daily PM concentrations (99th percentile) as a result of theoretical compliance with new plant emission standards

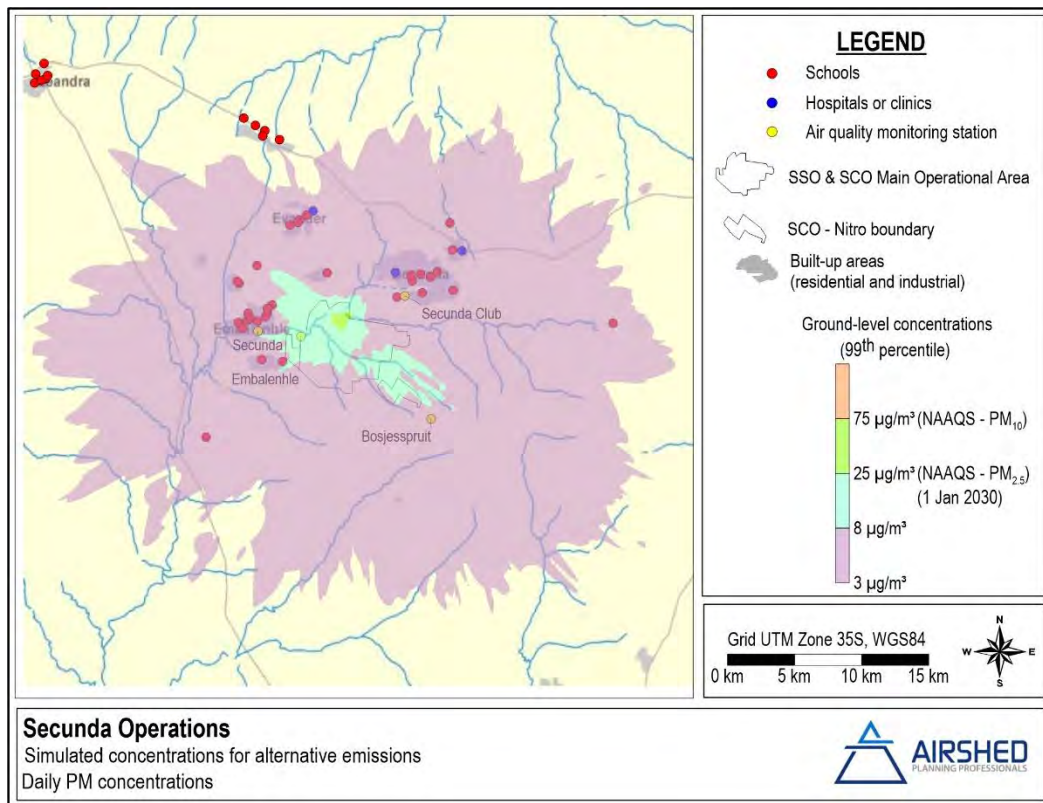


Figure 5-83: Simulated daily PM concentrations (99th percentile) as a result of alternative emissions

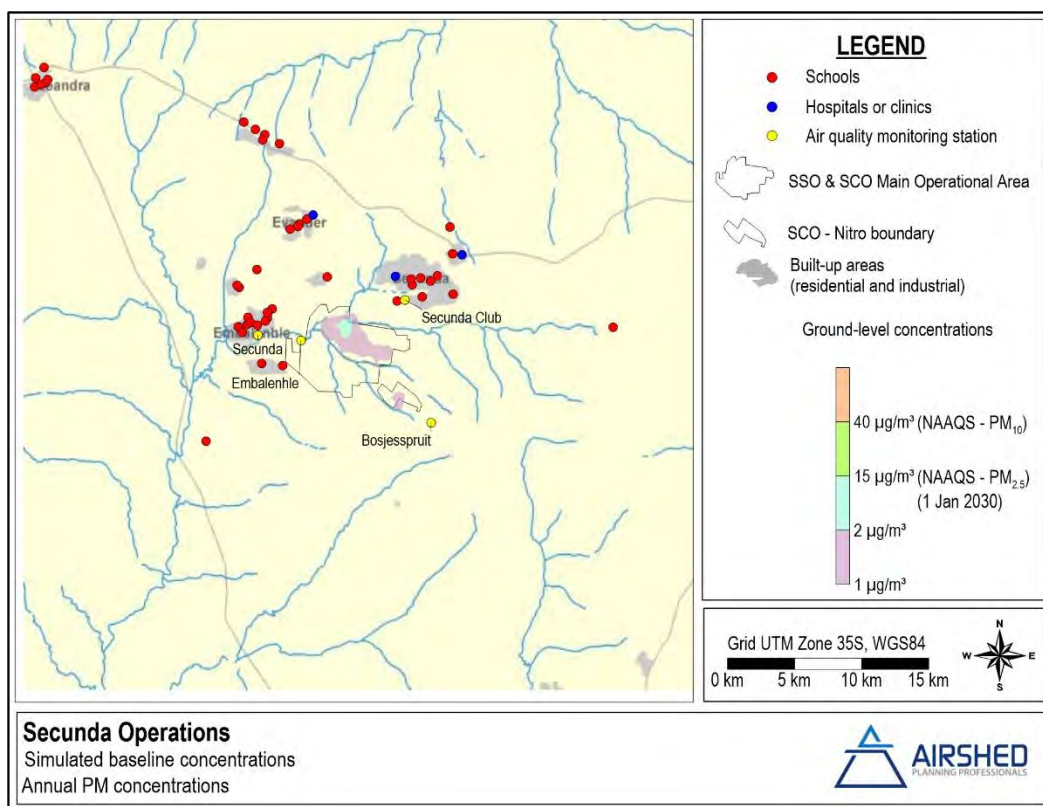


Figure 5-84: Simulated annual PM concentrations as a result of baseline emissions

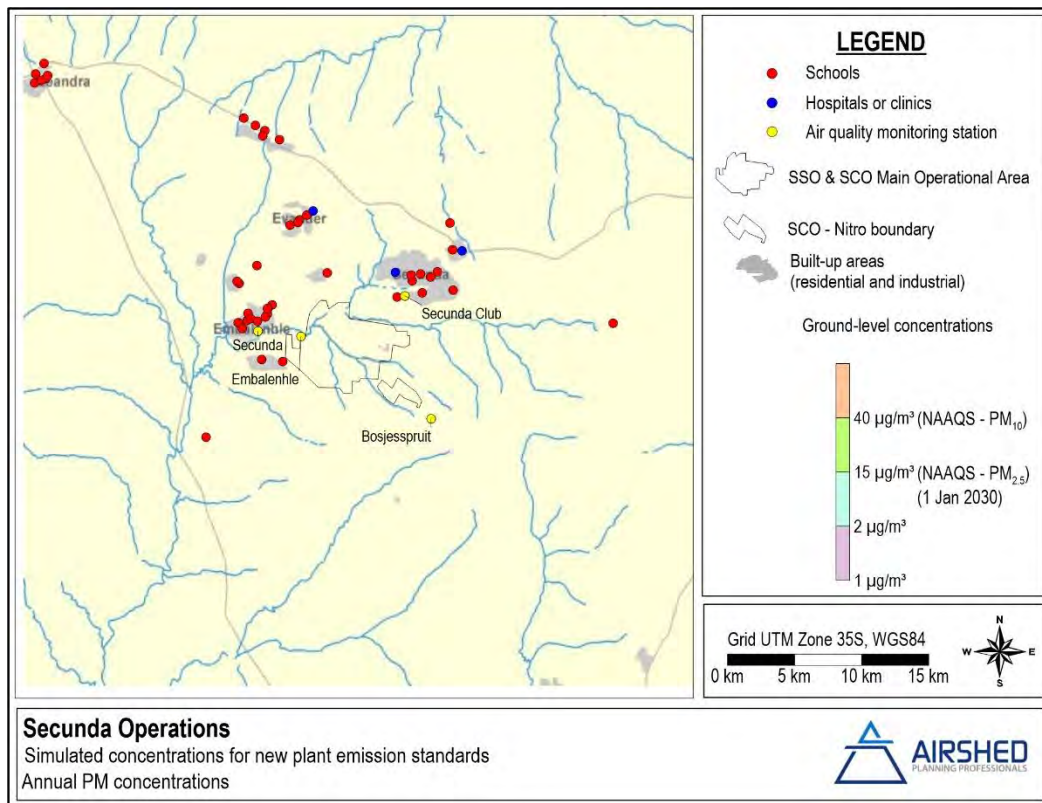


Figure 5-85: Simulated annual PM concentrations as a result of theoretical compliance with new plant emission standards

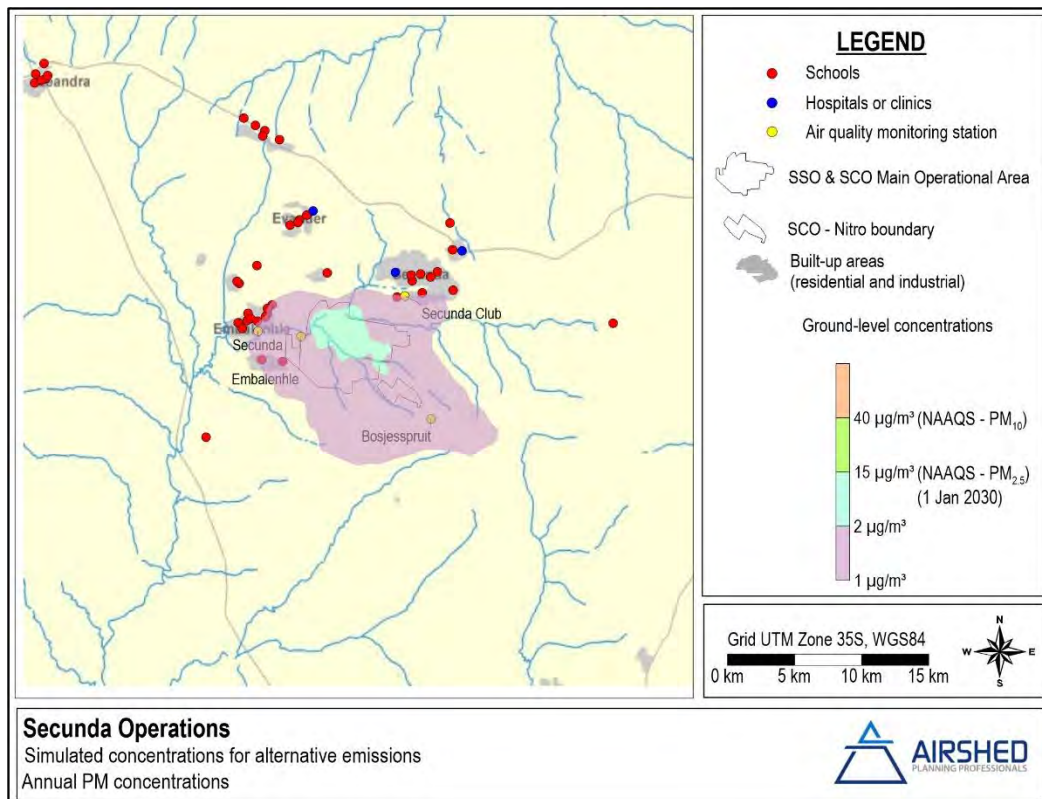


Figure 5-86: Simulated annual PM concentrations as a result of alternative emissions

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 and well below the observed concentrations (Figure 5-87) and receptors (Table 5-31) 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 98% (Table 5-31). Alternative emissions will result in an increase in ground-level concentrations by up to a maximum of 95% (Table 5-31). 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 Secunda Operations, as per the figure numbers below:

Scenario	Hourly
Baseline concentrations	Figure 5-88
New Plant standards	Figure 5-89
Alternative emissions	Figure 5-90

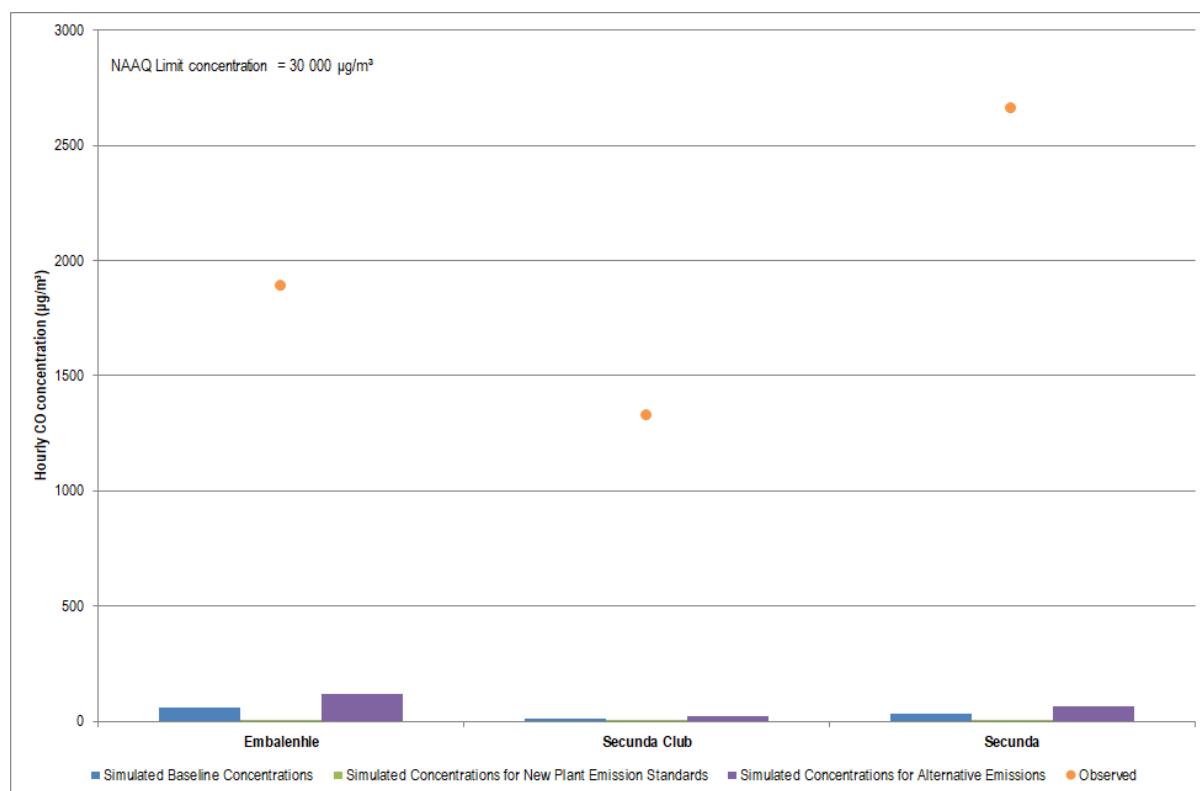


Figure 5-87: Simulated hourly CO concentrations (99th percentile) at AQMS for Secunda Operations

Table 5-31: 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
Sasol Emalenhle Monitoring Station	12.1	0.3	-98%	23.3	93%
Sasol Secunda Club Monitoring Station	12.1	0.3	-98%	23.3	93%
HPA Secunda/ Embalenhle Monitoring Station	32.7	0.7	-98%	61.9	90%
Sasol Bosjesspruit Monitoring Station	24.0	0.5	-98%	44.9	87%
Roodebank Combined School	17.8	0.4	-98%	33.6	88%
Zamokuthle Primary School	27.3	0.6	-98%	52.1	91%
Osizweni Secondary School	18.4	0.4	-98%	35.1	90%
Isibanisesizwe Primary School	36.3	0.8	-98%	68.2	88%
Maphala-Gulube Primary School	46.5	1.0	-98%	87.2	87%
Kiriyatswane Secondary School	36.1	0.8	-98%	68.3	89%
Osizweni Primary School	17.1	0.4	-98%	32.5	90%
Kusasaletu Secondary School	34.8	0.8	-98%	65.8	89%
Laerskool Oranjegloed	9.4	0.2	-98%	18.0	93%
Highveld Medi Clinic/Hydromed	7.4	0.2	-98%	14.0	90%
Tholukwazi Primary School	26.9	0.6	-98%	51.6	92%
TP Stratten Primary School	8.3	0.2	-98%	15.7	90%
School	13.6	0.3	-98%	26.3	93%
Laerskool Goedehoop	8.6	0.2	-98%	16.5	91%
Laerskool Kruinpark	7.8	0.2	-98%	15.2	93%
Lifalethu Primary School	30.8	0.7	-98%	58.8	91%
Secunda Mediclinic	11.7	0.3	-98%	22.8	95%
Embalenhle Primary School	27.1	0.6	-98%	51.8	91%
Buyani Primary School	28.6	0.6	-98%	53.5	87%
Allan Makhunga Primary School	38.3	0.8	-98%	72.4	89%

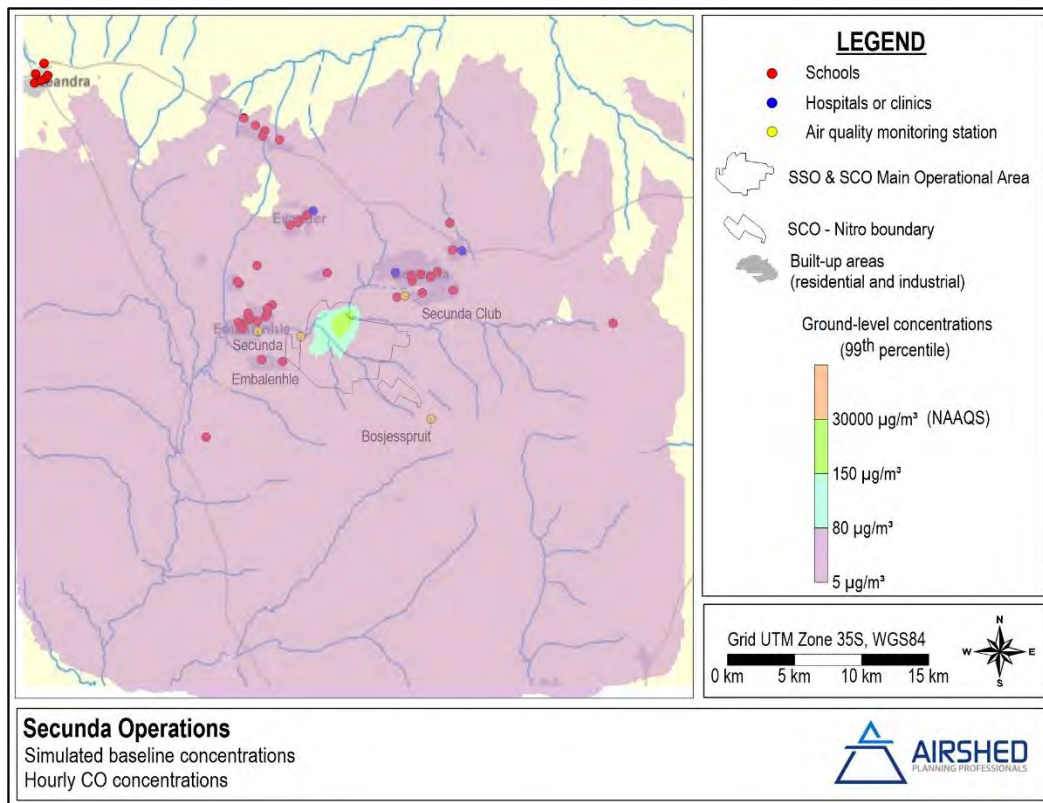


Figure 5-88: Simulated hourly CO concentrations (99th percentile) as a result of baseline emissions

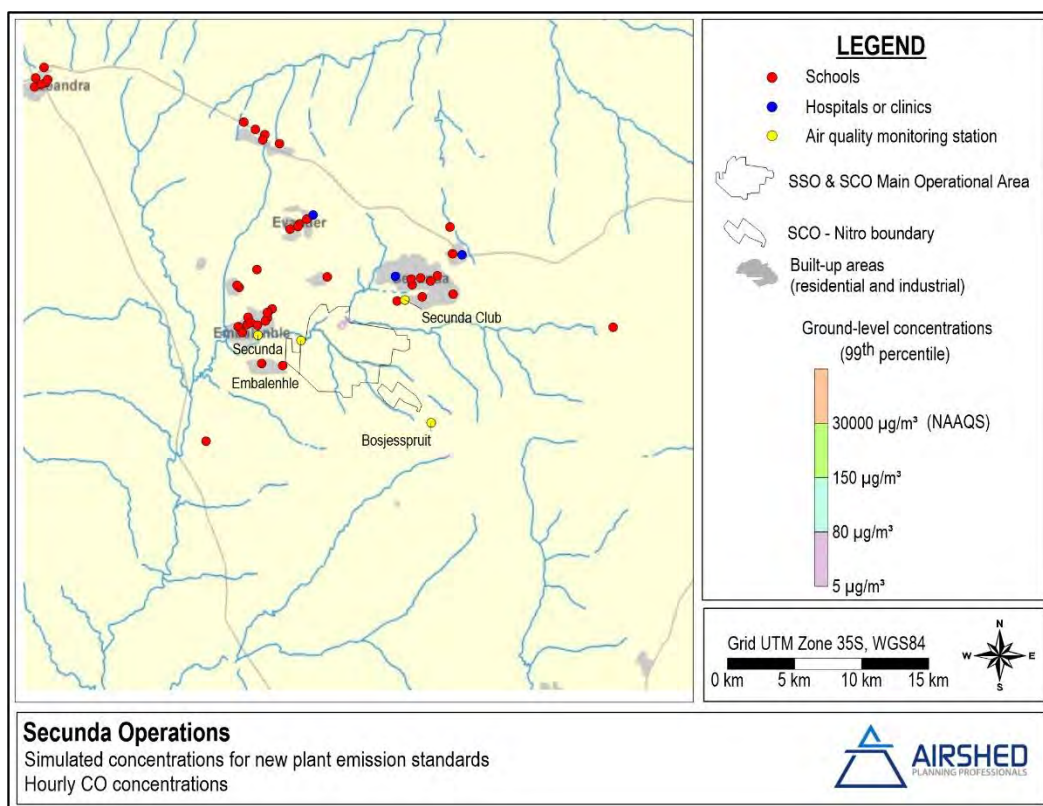


Figure 5-89: Simulated hourly CO concentrations (99th percentile) as a result of theoretical compliance with new plant emission standards

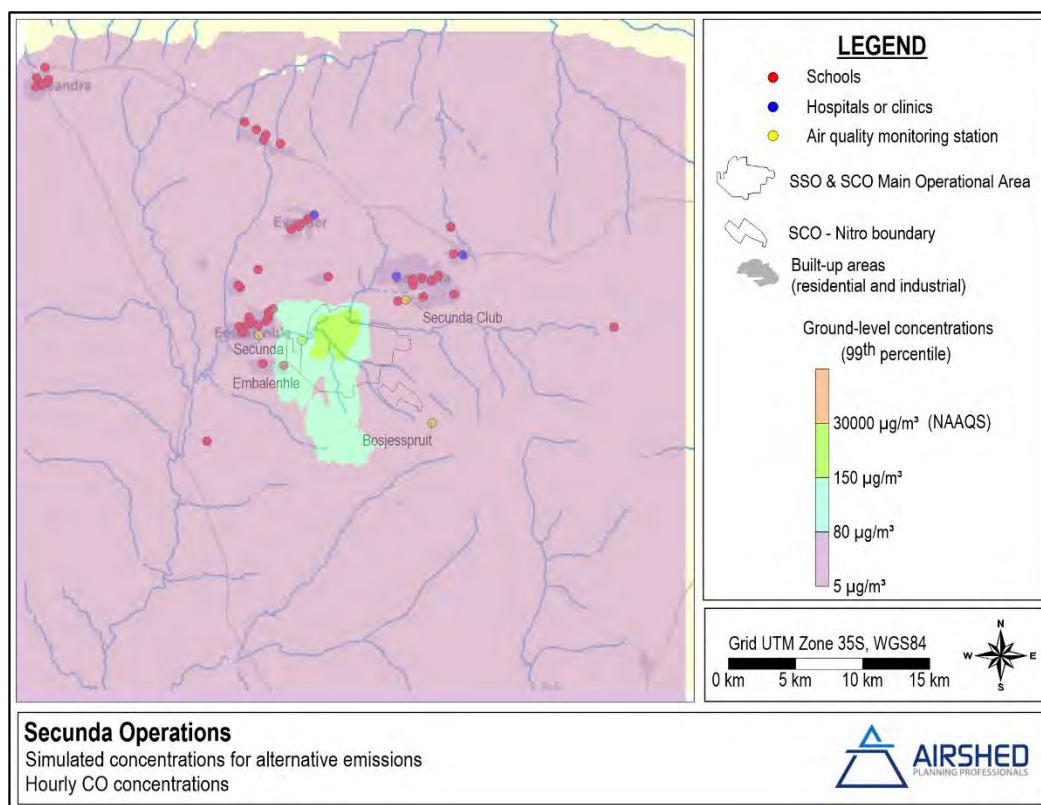


Figure 5-90: Simulated hourly CO concentrations (99th percentile) as a result of alternative emissions

5.1.8.1.5 Benzene (C₆H₆)

Benzene emissions from three source groups (i.e. Rectisol, Phenosolvan saturation columns and tanks) at Secunda Operations were simulated. Three emission scenarios were simulated as described in Section 5.1.1.2. The TOC emissions from the incinerator units are likely to be associated with complex hydrocarbon molecules. In addition, TOCs were measured as a total and a fractional breakdown of components was not possible. Simulated annual benzene concentrations are below the NAAQS at all off-site sensitive receptors (Table 5-31).

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

Scenario	Hourly
Baseline concentrations	Figure 5-91
New Plant standards	Figure 5-92
Alternative emissions	Figure 5-93

Table 5-32: Simulated baseline hourly benzene concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors

Receptor	Annual Benzene				
	Baseline	New		Alternative	
	Concentration (µg/m³)	Concentration (µg/m³)	Relative change	Concentration (µg/m³)	Relative change
Sasol Emalenhle Monitoring Station	0.9	0.007	-1.4%	0.8	-0.1%
Sasol Secunda Club Monitoring Station	0.8	0.004	-1.7%	0.7	-0.1%
HPA Secunda/ Embalenhle Monitoring Station	0.4	0.002	-1.5%	0.3	-0.1%
Sasol Bosjesspruit Monitoring Station	0.5	0.002	-2.2%	0.5	-0.1%
Roodebank Combined School	0.2	0.001	-1.7%	0.2	-0.1%
Zamokuthle Primary School	0.3	0.002	-1.6%	0.3	-0.1%
Osizweni Secondary School	0.2	0.001	-1.6%	0.2	-0.1%
Isibanisesizwe Primary School	0.4	0.003	-1.5%	0.4	-0.1%
Maphala-Gulube Primary School	0.7	0.005	-1.5%	0.7	-0.1%
Kiriyatswane Secondary School	0.4	0.003	-1.5%	0.4	-0.1%
Osizweni Primary School	0.2	0.001	-1.6%	0.2	-0.1%
Kusasaletu Secondary School	0.4	0.002	-1.5%	0.3	-0.1%
Laerskool Oranjegloed	0.6	0.003	-1.8%	0.5	-0.1%
Highveld Medi Clinic/Hydromed	0.2	0.001	-2.0%	0.2	-0.1%
Tholukwazi Primary School	0.3	0.002	-1.6%	0.3	-0.1%
TP Stratten Primary School	0.9	0.005	-1.6%	0.8	-0.1%
School	0.1	0.001	-1.8%	0.1	-0.1%
Laerskool Goedehoop	0.3	0.002	-1.9%	0.3	-0.1%
Laerskool Kruinpark	0.4	0.002	-2.0%	0.4	-0.1%
Lifalethu Primary School	0.3	0.002	-1.6%	0.3	-0.1%
Secunda Mediclinic	0.5	0.003	-1.6%	0.5	-0.1%
Embalenhle Primary School	0.3	0.002	-1.6%	0.3	-0.1%
Buyani Primary School	0.3	0.002	-1.6%	0.3	-0.1%
Allan Makhunga Primary School	0.4	0.003	-1.5%	0.4	-0.1%

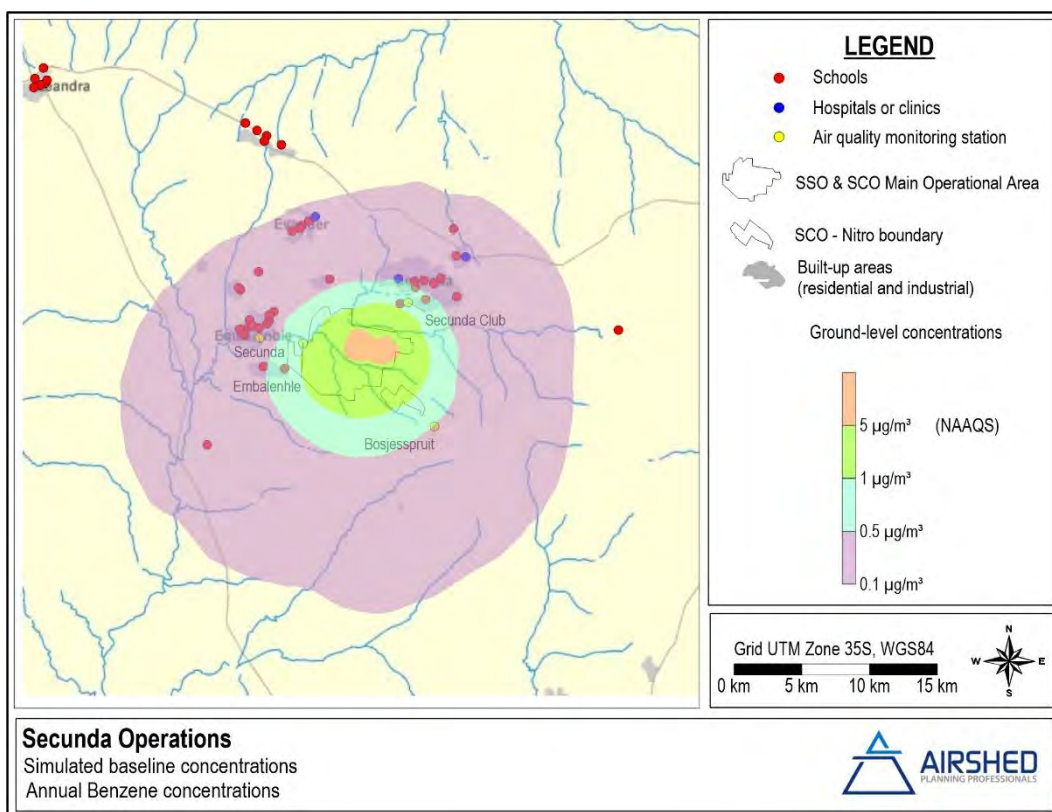


Figure 5-91: Simulated annual benzene concentrations as a result of baseline emissions (from Rectisol, Phenosolvan saturation columns and tanks only)

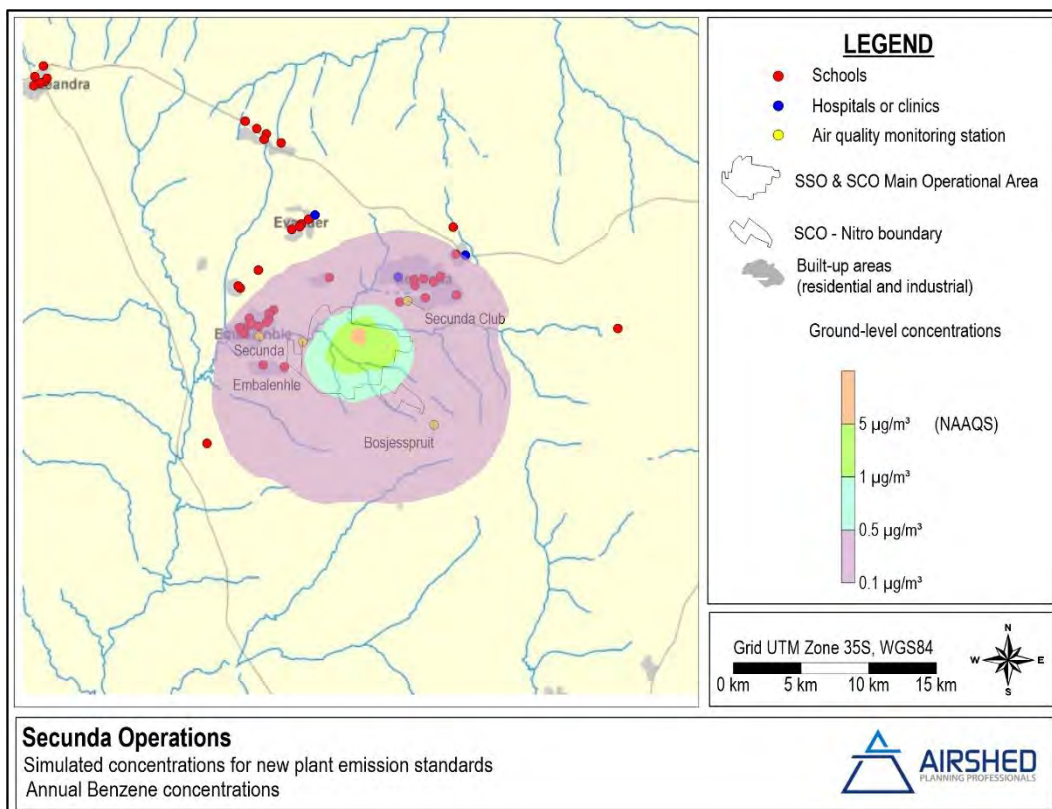


Figure 5-92: Simulated annual benzene concentrations as a result of theoretical compliance with new plant emission standards (from Rectisol, Phenosolvan saturation columns and tanks only)

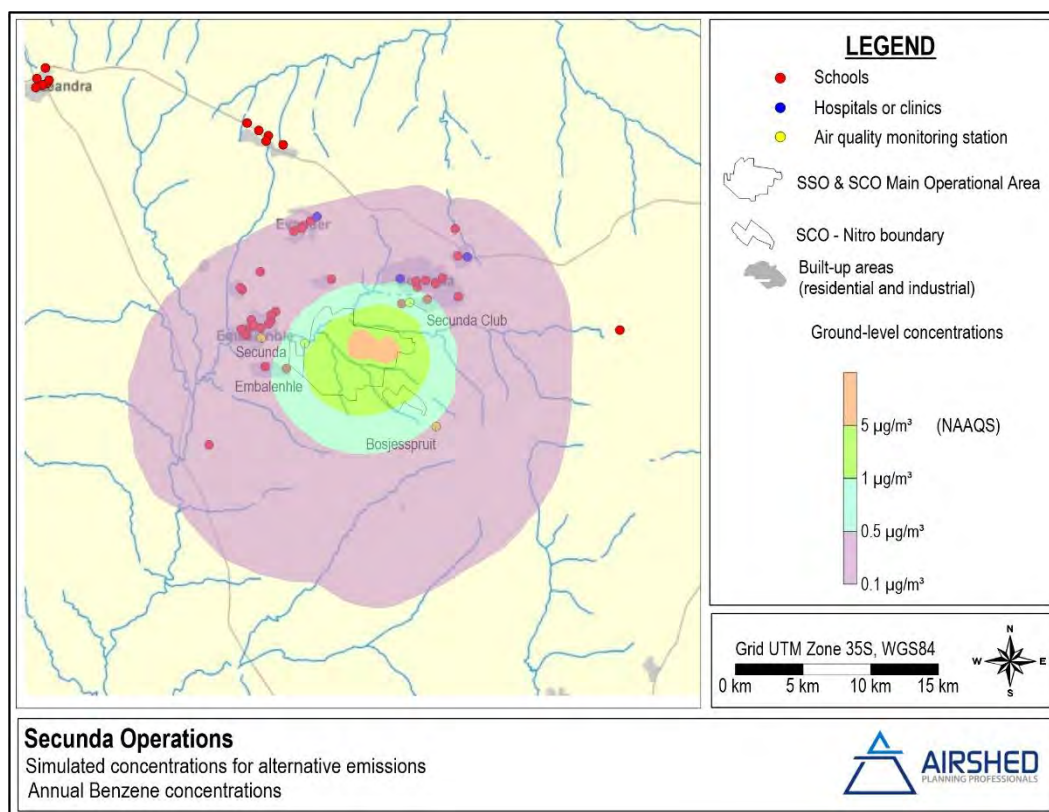


Figure 5-93: Simulated annual benzene concentrations as a result of alternative emissions (from Rectisol, Phenosolvan saturation columns and tanks only)

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 Secunda Operations, 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 (NH₃) and dioxins and furans. The health-effect screening levels used are listed in Table 5-33.

Table 5-33: Most stringent health-effect screening level identified for all non-criteria pollutants assessed

Compound	Acute exposure ^(a) [units: µg/m ³]	Chronic exposure ^(b) [units: µg/m ³]
Lead (Pb)	(c)	(d)
Arsenic (As)	0.2 (g)	0.015 (g)
Antimony (Sb)	(c)	(d)

Compound	Acute exposure ^(a) [units: µg/m ³]	Chronic exposure ^(b) [units: µg/m ³]
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 (NH ₃)	1 184 ^(f)	20 ^(g)
Hydrogen chloride (HCl)	2 100 ^(g)	(d)
Hydrogen fluoride (HF)	240 ^(g)	14 ^(g)
Total organic compounds (TOC)	(c)	100 ^(k)
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/m ³) – chronic (f) US ATSDR Maximum Risk Levels (MRLs) (µg/m ³) - acute (g) Californian OEHHA (µg/m ³) (h) NAAQS for benzene (surrogate) (i) TCEQ ESL (µg/m ³) (November 2016) (j) WHO guideline (µg/m ³) (k) Texas Commission on Environmental Quality long-term Effects Screening Level for diesel fuel vapour		

5.1.8.2.1 Metal Elements

A screening exercise of non-criteria pollutants emitted from the incinerators at Secunda Operations, including all non-criteria pollutants listed in Table 5-21, was undertaken to identify pollutants that would be likely to exceed the most stringent health-effect screening levels identified (Table 5-33). The non-criteria pollutants that would possibly exceed the screening level concentrations included: As, Ni, Mn, V and Hg. 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.

The analysis of individual metal elements showed that simulated ground-level concentrations of these pollutants exceeded the acute screening levels for As, Ni and Hg and the chronic screening levels for As and Hg (Table 5-34). All potential As, Ni and Hg exceedances of the acute and chronic health effect screening levels occur on-site for all scenarios (Figure 5-91, Figure 5-93, Figure 5-94, Figure 5-95, Figure 5-97, Figure 5-98) with the exception of acute As (Figure 5-93) (extending ~1 km north of the plant boundary) and Hg concentrations (Figure 5-96) (extending ~1 km north of the plant boundary) due to alternative scenario.

Table 5-34: Screening of non-criteria pollutants against health risk guidelines

Metallic element	Acute exposure ^(a) [units: µg/m ³]			Chronic exposure ^(b) [units: µg/m ³]		
	Minimum concentration ^(c)	Maximum concentration ^(d)	Strictest health effect screening level	Minimum concentration ^(c)	Maximum concentration ^(d)	Strictest health effect screening level
<i>Baseline Emissions</i>						
As	0.00146	0.38	0.2 ^(g)	0.000007	0.0001	0.015 ^(g)
Cr				0.000001	0.00	0.1 ^(e)
Co				0.00000008	0.0001	0.1 ^(f)
Mn				0.000007	0.0056	0.05 ^(e)
Ni	0.0004	0.1	0.2 ^(g)	0.000002	0.001	0.014 ^(g)
V	0.0003	0.04	0.8 ^(f)	0.000001	0.001	0.1 ^(f)
Hg	0.0025	0.43	0.25 ^(h)	0.00001	0.0100	0.025 ^(h)
<i>New Plant Standards</i>						
As	0.00037	0.09	0.2 ^(g)	0.000002	0.001	0.015 ^(g)
Cr				0.0000002	0.0002	0.1 ^(e)
Co				0.00000002	0.00002	0.1 ^(f)
Mn				0.000002	0.001	0.05 ^(e)
Ni	0.00001	0.001	0.2 ^(g)	0.0000004	0.0003	0.014 ^(g)
V	0.000293	0.045	0.8 ^(f)	0.000001	0.0009	0.1 ^(f)
Hg	0.0030	0.47	0.25 ^(h)	0.00001	0.01	0.025 ^(h)
<i>Alternative Emissions</i>						
As	0.006	1.5	0.2 ^(g)	0.00003	0.02	0.015 ^(g)
Cr				0.000004	0.003	0.1 ^(e)
Co				0.0000004	0.0003	0.1 ^(f)
Mn				0.00003	0.02	0.05 ^(e)
Ni	0.002	0.3	0.2 ^(g)	0.000008	0.007	0.014 ^(g)
V	0.001	0.2	0.8 ^(f)	0.000006	0.004	0.1 ^(f)
Hg	0.01	1.43	0.25 ^(h)	0.00005	0.035	0.025 ^(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) minimum concentration simulated across the domain (d) maximum concentration simulated across the domain (e) US-EPA IRIS Inhalation Reference Concentrations (µg/m ³) – chronic (f) US ATSDR Maximum Risk Levels (MRLs) (µg/m ³) - acute (g) Californian OEHHHA (µg/m ³) (h) TCEQ ESL (Nov 2016)						

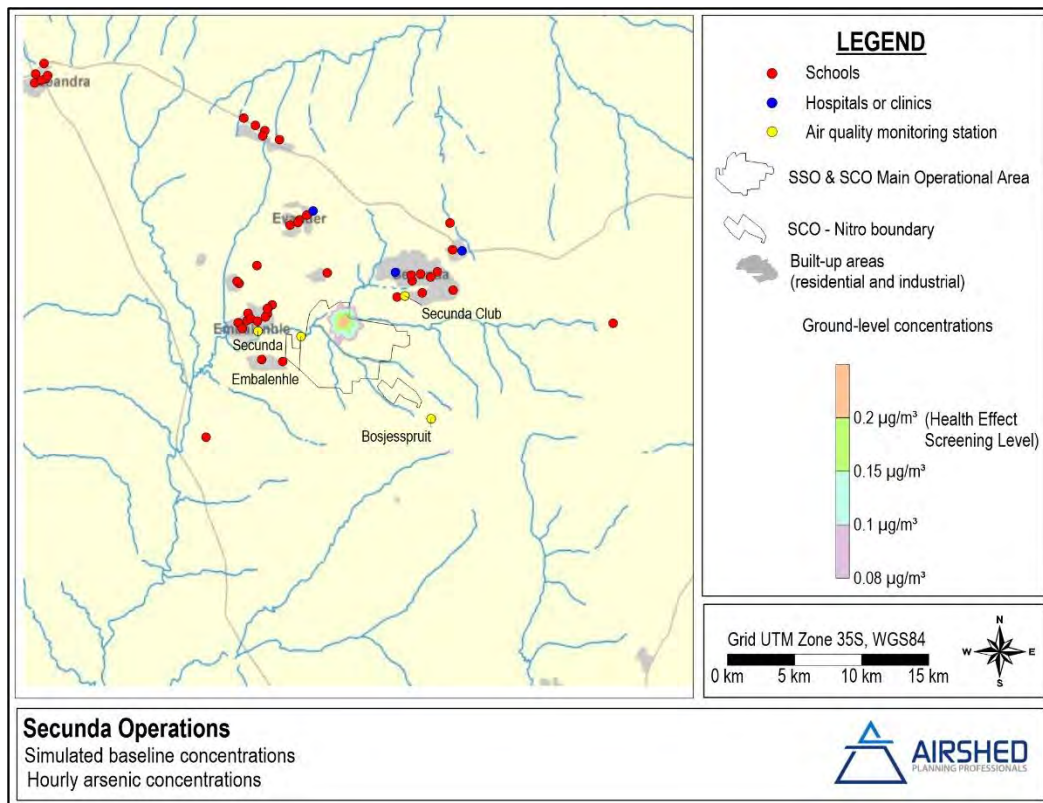


Figure 5-94: Simulated hourly As concentrations as a result of baseline emissions

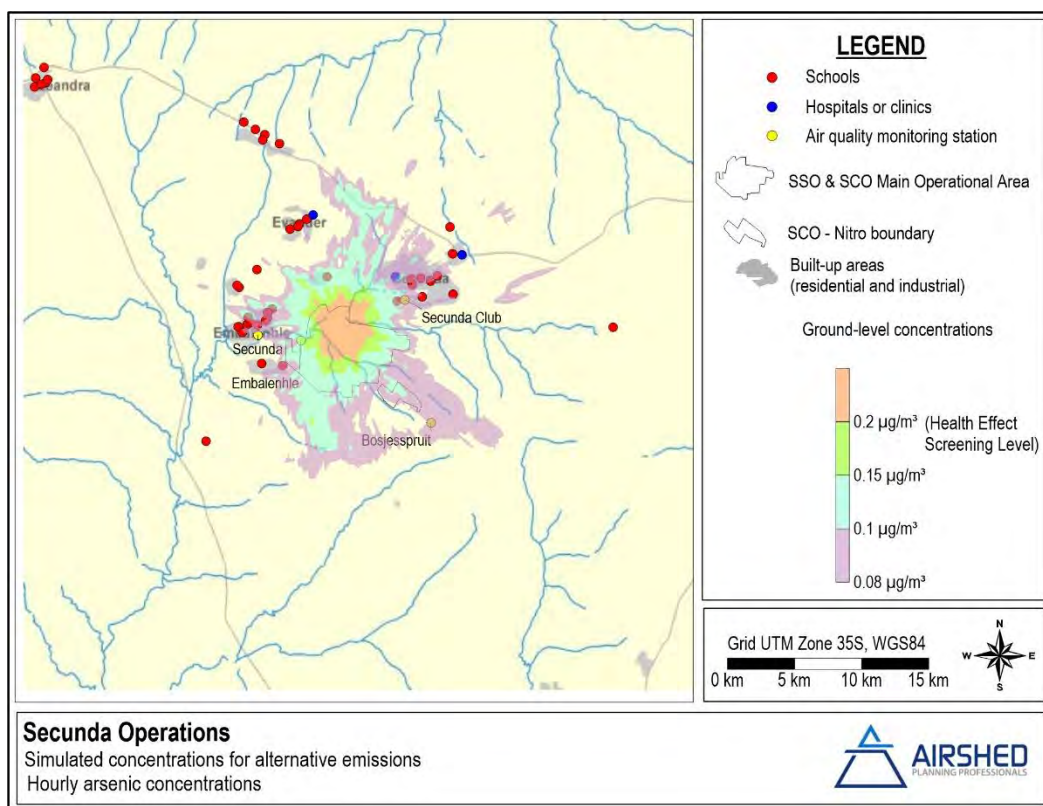


Figure 5-95: Simulated hourly As concentrations as a result of alternative emissions

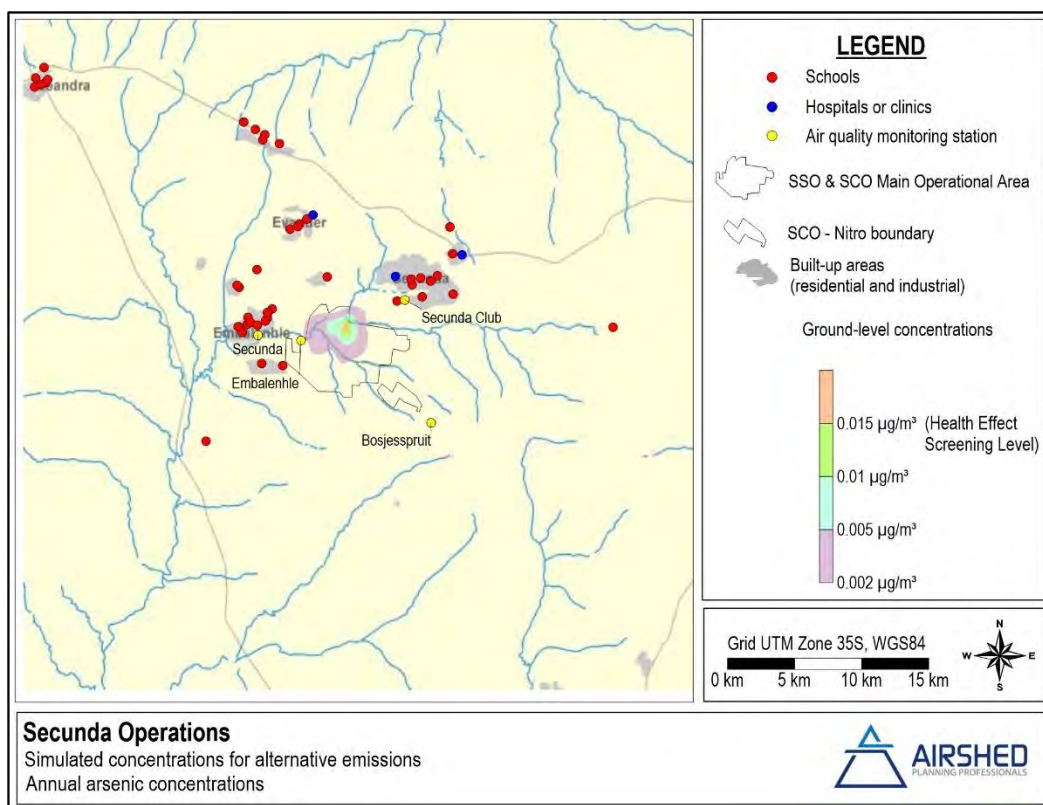


Figure 5-96: Simulated annual As concentrations as a result of alternative emissions

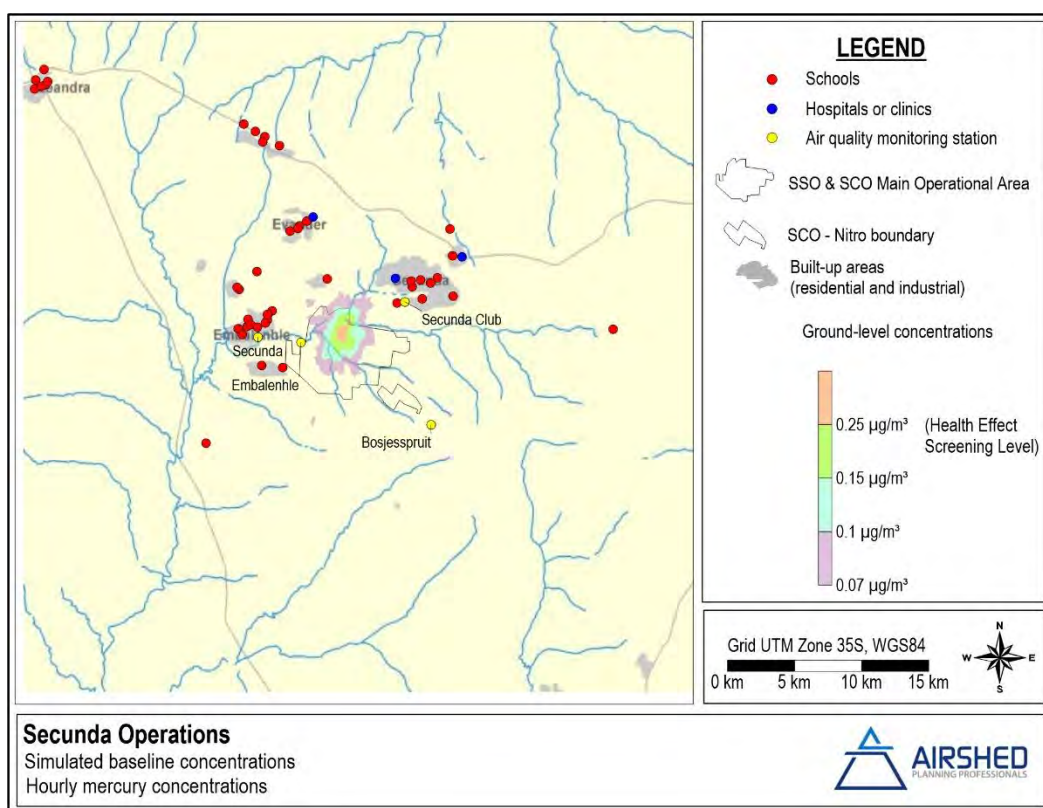


Figure 5-97: Simulated hourly Hg concentrations as a result of baseline emissions

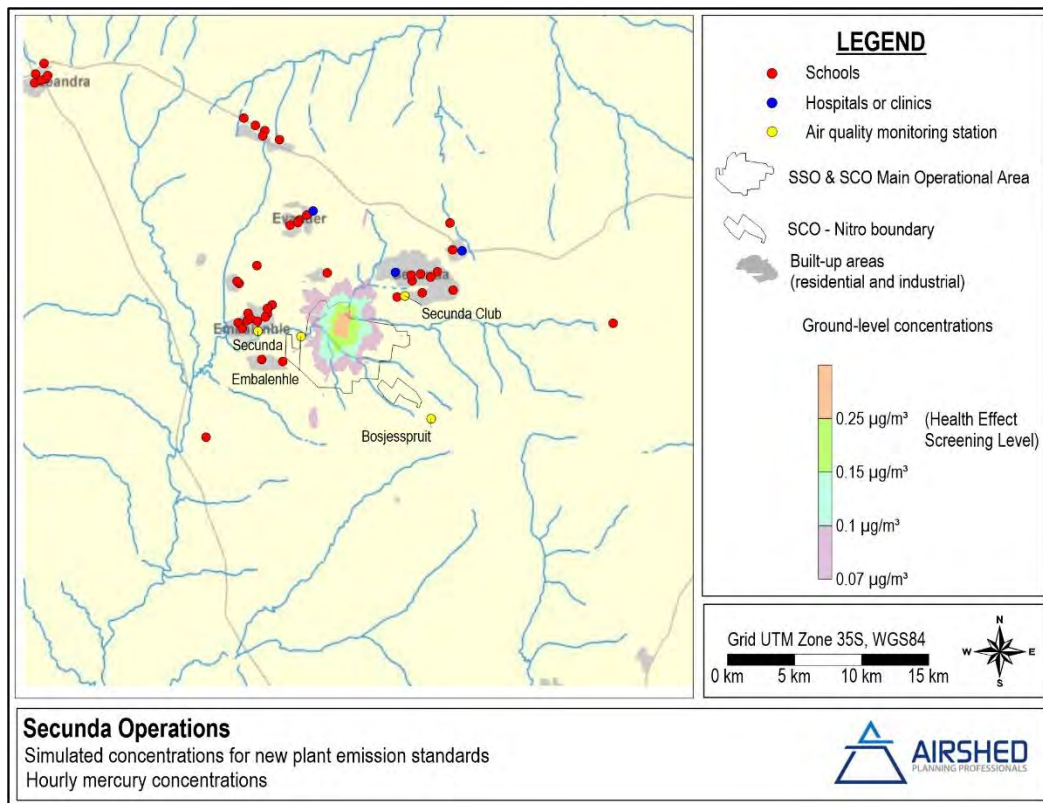


Figure 5-98: Simulated hourly Hg concentrations as a result of theoretical compliance with new plant emission standards

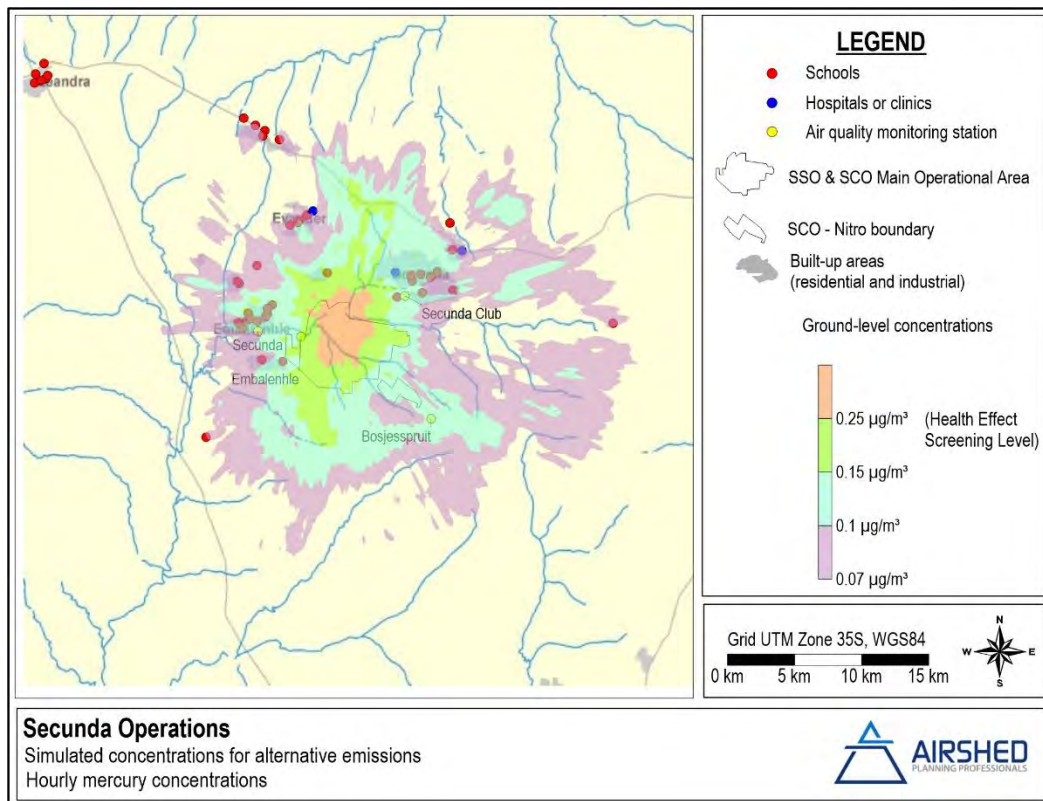


Figure 5-99: Simulated hourly Hg concentrations as a result of alternative emissions

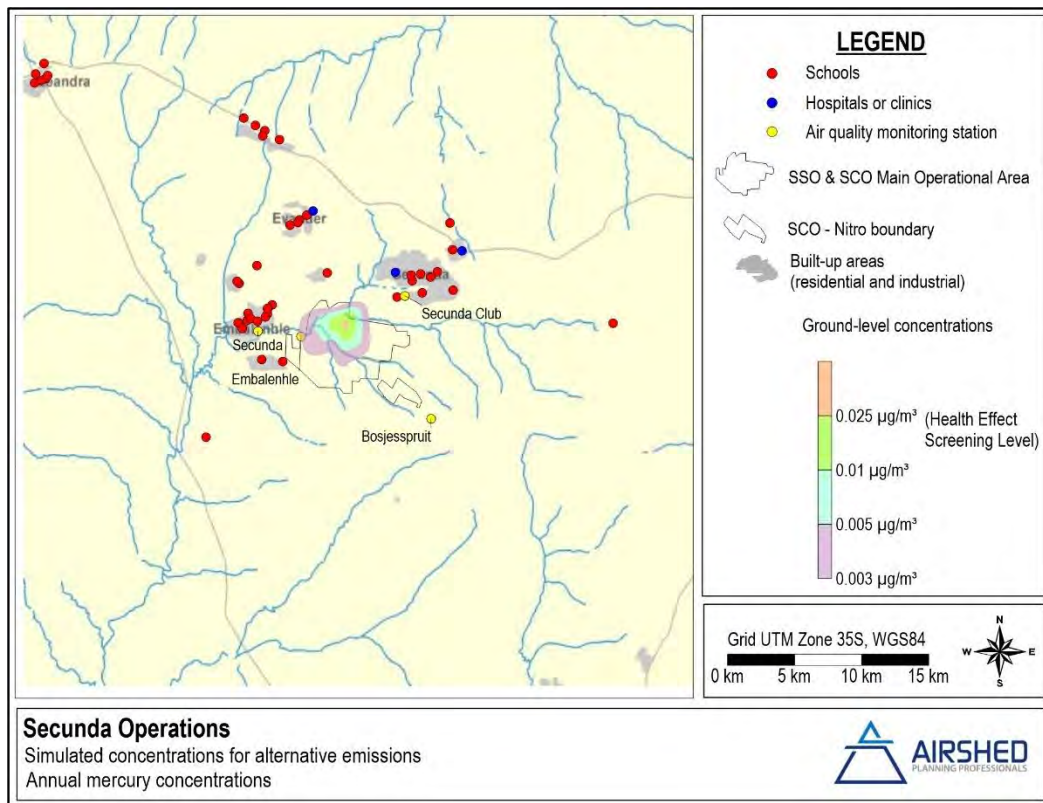


Figure 5-100: Simulated annual Hg concentrations as a result of alternative emissions

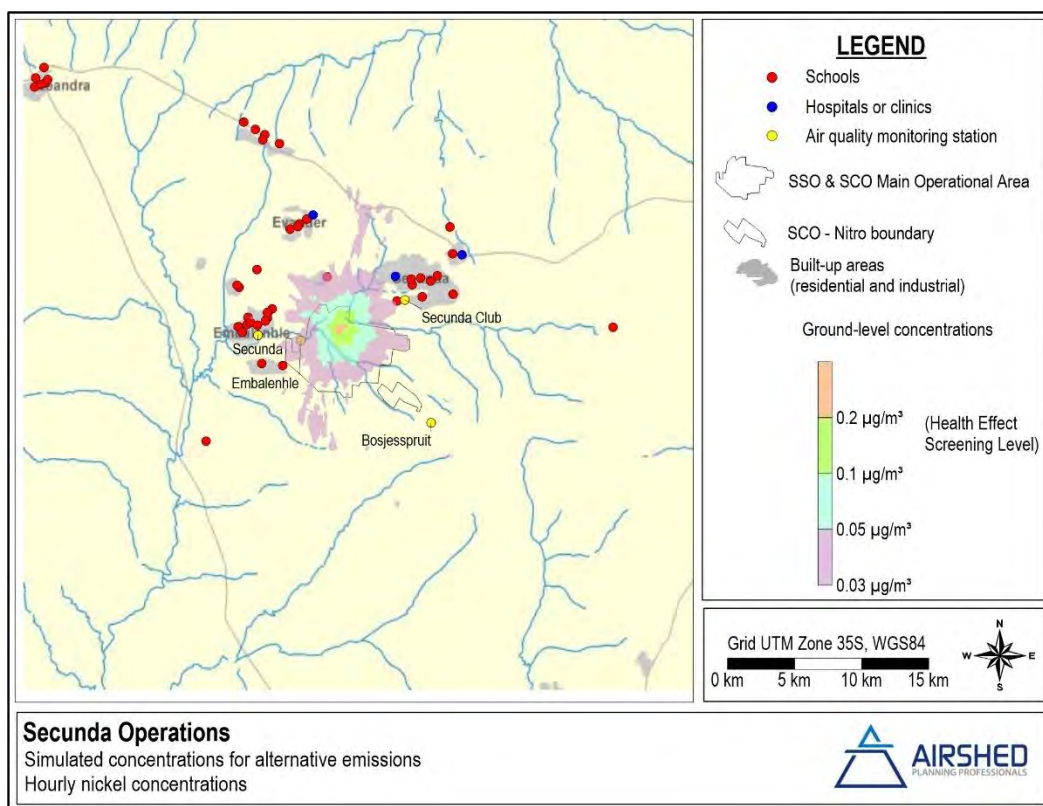


Figure 5-101: Simulated hourly Ni concentrations as a result of alternative emissions

5.1.8.2.2 Total Organic Compounds (TOCs)

The approach followed to quantify the TOC impacts is conservative as the ground level concentrations are compared to a screening level that is for diesel fumes and the conservative assumption has been made that all TOC is volatile and representative of diesel fume.

Emissions of total organic compounds (TOCs) were simulated for the following source groups:

- Rectisol (VOCs, with known benzene fraction)
- Phenosolvan saturation columns (VOCs, with known benzene fraction)
- Thermal oxidiser units (TOCs, speciation unknown)
- Petroleum product storage tanks (Total Hydrocarbons, with some tanks sources with known BTEX fraction).

Three emission scenarios were simulated as described in Section 5.1.1.2. The simulated annual TOC concentrations exceed the evaluation criterion of 100 µg/m³ off-site (assuming that all TOC emissions are volatile and similar to those from diesel fuel) extending ~1km from the northern site boundary for all scenarios and ~500 m from the eastern site boundary for the baseline and alternative scenarios. The potential off-site exceedances, however, are not at sensitive receptors (Table 5-34).

Isopleth plots are presented for annual average ground-level TOC concentrations as a result of all emission scenarios for Secunda Operations, as per the figure numbers below:

Scenario	Annual
Baseline concentrations	Figure 5-102
New Plant standards	Figure 5-103
Alternative emissions	Figure 5-104

Table 5-35: Simulated baseline annual TOC concentrations and the theoretical change in concentrations relative to the baseline at the AQMs and 20 closest receptors

Receptor	Annual SO ₂				
	Baseline	New		Alternative	
	Concentration (µg/m ³)	Concentration (µg/m ³)	Relative change	Concentration (µg/m ³)	Relative change
Emalenhle AQMS	62.9	48.7	-22%	65.7	5%
Secunda Club AQMS	45.1	32.6	-28%	45.5	1%
Secunda AQMS	23.9	18.1	-24%	25.5	6%
Bosjesspruit AQMS	22.0	15.2	-31%	23.1	5%
Roodebank Combined School	10.8	8.0	-26%	11.8	8%
Zamokuthle Primary School	18.3	13.8	-25%	19.6	7%
Osizweni Secondary School	11.2	8.5	-25%	12.0	7%
Isibanisesizwe Primary School	25.5	19.4	-24%	27.1	6%
Maphala-Gulube Primary School	46.7	35.7	-24%	48.4	4%
Kiriyatswane Secondary School	25.0	19.1	-24%	26.7	7%
Osizweni Primary School	10.7	8.0	-25%	11.4	7%
Kusasaletu Secondary School	23.6	17.9	-24%	25.2	7%
Laerskool Oranjegloed	31.0	22.1	-29%	31.4	1%
Highveld Medi Clinic/Hydromed	10.2	7.4	-28%	10.6	4%
Tholukwazi Primary School	16.8	12.6	-25%	18.0	7%
TP Stratten Primary School	54.1	39.8	-27%	54.6	1%
School	7.7	5.8	-25%	8.1	6%
Laerskool Goedehoop	18.1	13.0	-28%	18.6	3%
Laerskool Kruinpark	18.2	12.9	-29%	18.5	2%
Lifalethu Primary School	20.1	15.2	-24%	21.5	7%
Secunda Mediclinic	30.3	22.7	-25%	30.9	2%
Embalenhle Primary School	16.9	12.7	-25%	18.1	7%
Buyani Primary School	18.3	13.8	-24%	19.6	7%
Allan Makhunga Primary School	26.4	20.1	-24%	28.1	7%

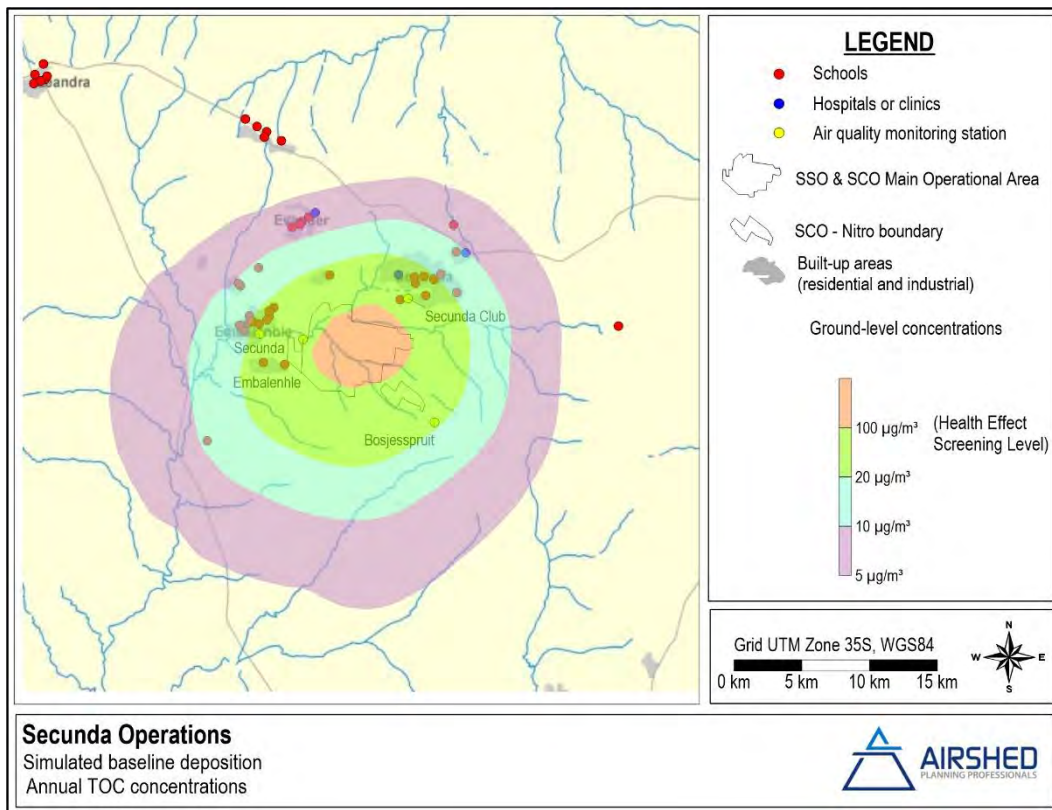


Figure 5-102: Simulated annual TOC concentrations as a result of baseline emissions

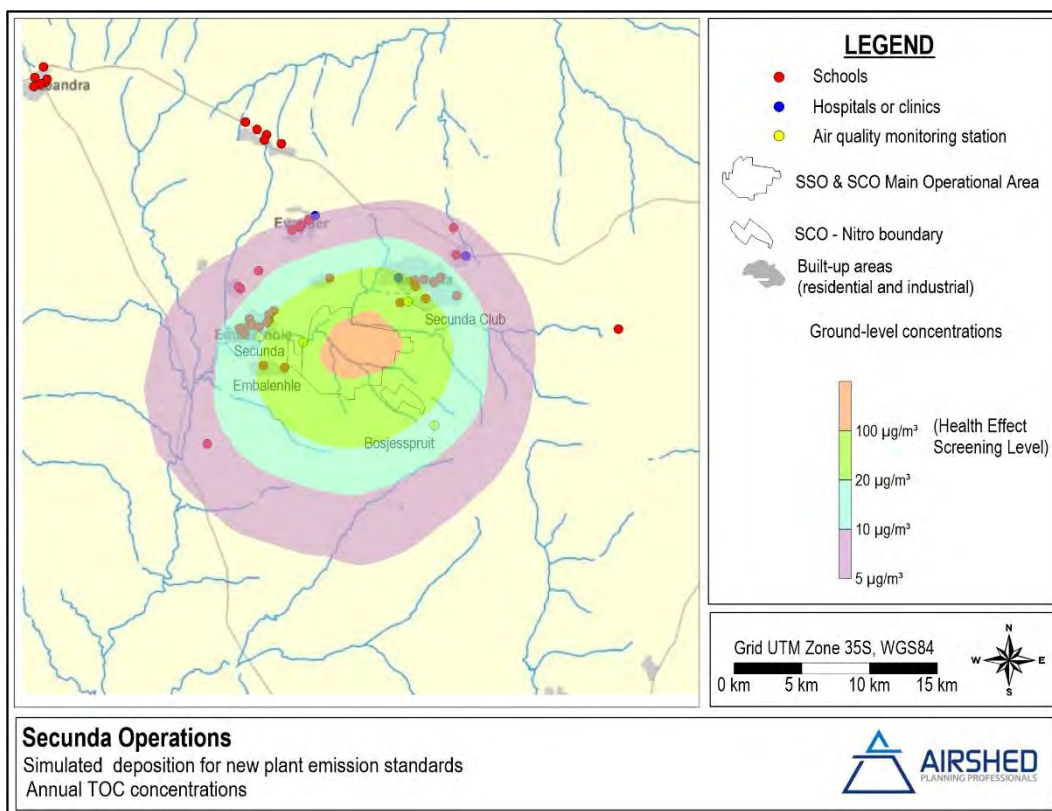


Figure 5-103: Simulated annual TOC concentrations as a result of theoretical compliance with new plant emission standards

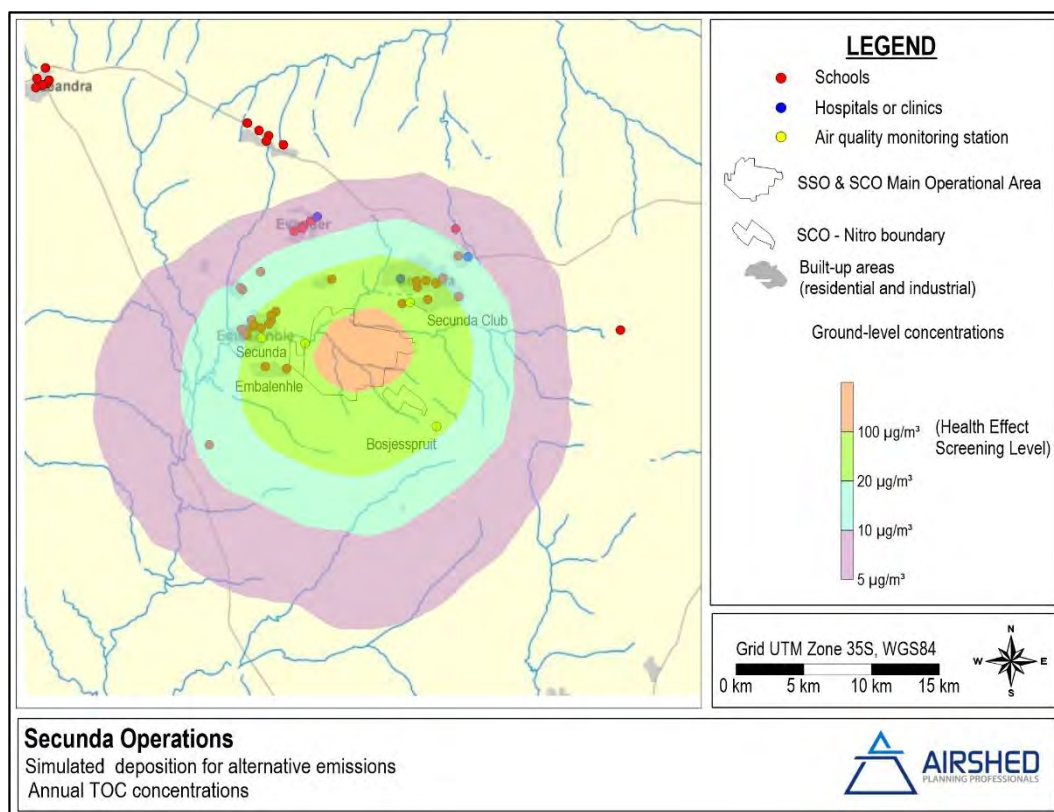


Figure 5-104: Simulated annual TOC concentrations as a result of alternative emissions

5.1.8.2.3 Hydrogen Sulfide (H₂S)

Dispersion modelling included assessing the ambient impact of baseline H₂S emissions from the Secunda Operations Sulfur Recovery Plant. Predicted daily H₂S concentrations were compared against the WHO (2000) 24-hour health-based guideline (150 µg/m³) for Sulfur Recovery Plant Emissions (Figure 5-105) where no exceedances of the guideline were predicted.

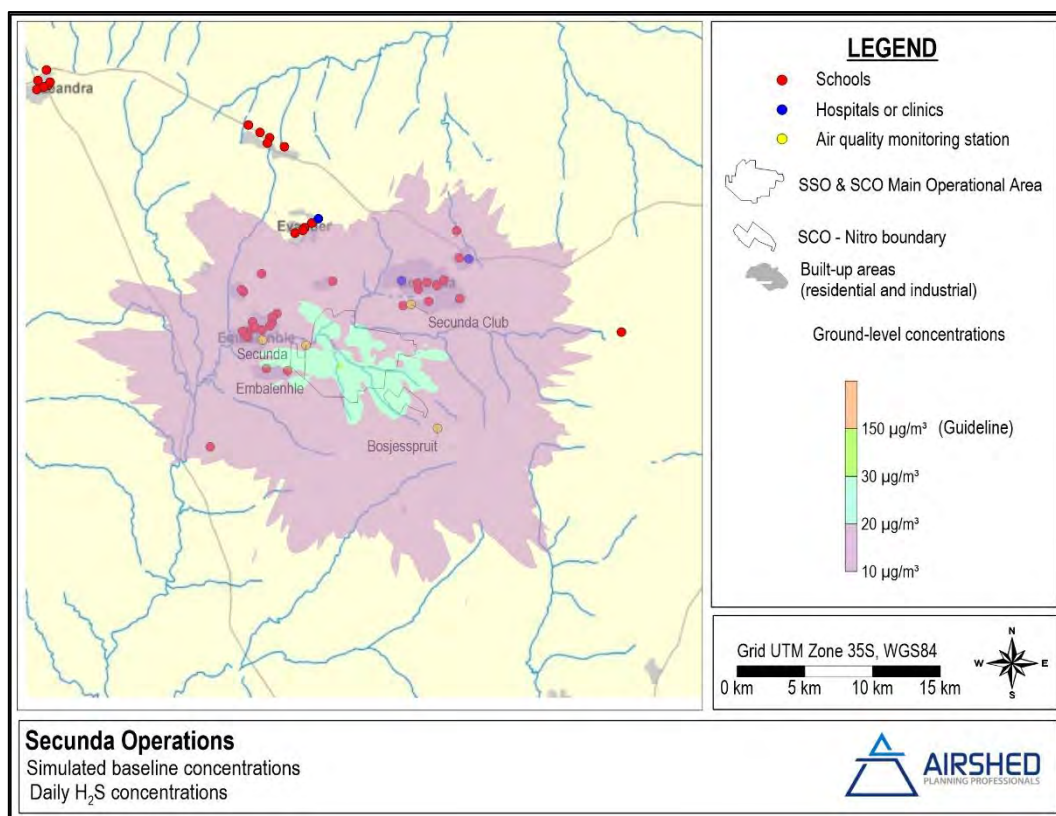


Figure 5-105: Simulated daily H₂S concentrations as a result of baseline emissions from the Sulfur Recovery Plant

After consultation with Dr WCA van Niekerk (Infotox³), the simulated 4-hourly ambient H₂S concentrations were compared against the more conservative 135 µg/m³ health effect screening level (4-hour average) recommended by Haahtele *et al.* (1992). At this exposure level, health effects include difficulty breathing, irritation of eyes, headache and nausea.

The dispersion modelling findings show that for the baseline emissions, off-site receptors are not likely to experience H₂S concentrations above the health-effect screening level (Figure 5-106).

³ Report to SASOL Document number 032-2013 Rev 1.0: Toxicological review for Hydrogen Sulphide

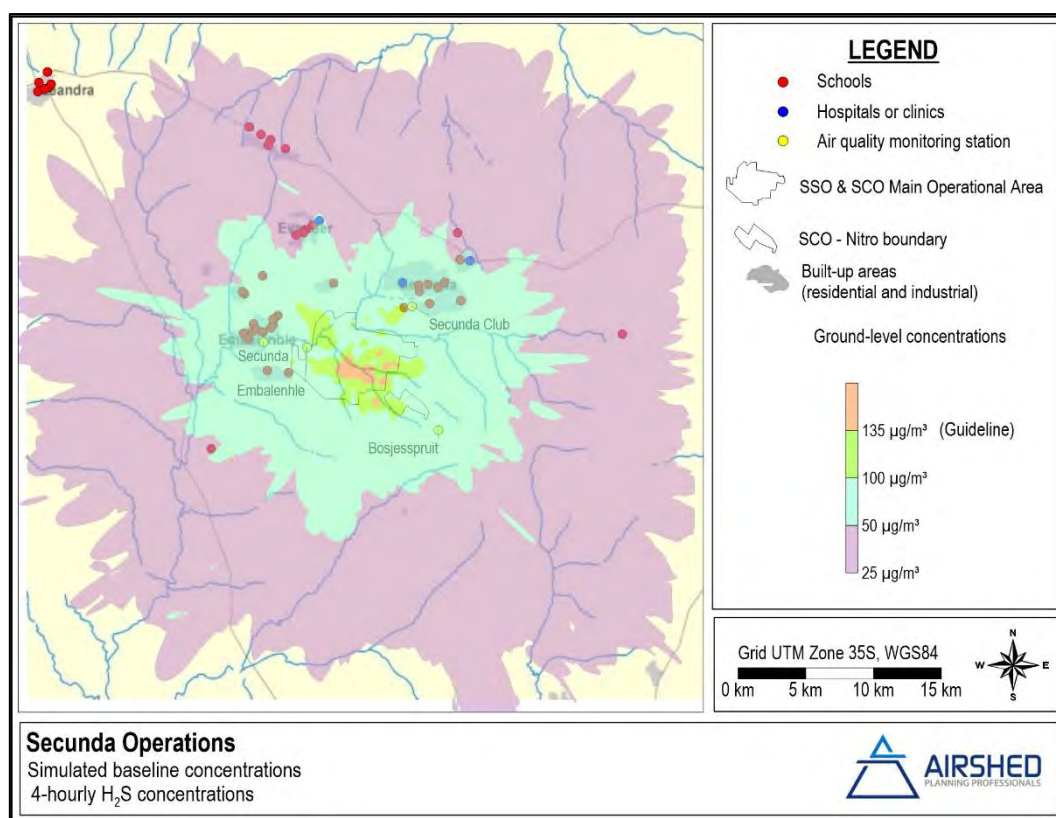


Figure 5-106: Simulated 4-hourly H₂S concentrations as a result of baseline emissions from the Sulfur Recovery Plant

5.1.8.2.4 Potential Carcinogens

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 5-35.

Table 5-36: Proposed unit risk factors for pollutants of interest in the current assessment

Compound	Selected Criteria (µg/m³) ⁻¹	Source
Arsenic	4.3 x 10 ⁻³	IRIS
Benzene	2.9 x 10 ⁻⁵	CALEPA
Cadmium	4.2 x 10 ⁻³	CALEPA
Chromium (VI)	1.5 x 10 ⁻¹	CALEPA
Nickel	3.8 x 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 5-37: 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 Secunda Operations for all scenarios is “low” to “very low” (with the exception of Cr(IV) which is “moderate” for the alternative scenario). It should be noted, however, that total Cr emissions was assumed to be Cr(IV) and thus provides a very conservative estimate of the potential cancer risk from this pollutant.

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.

However, with the incremental differences between scenarios expressed as a ratio of the baseline concentration, the impact of model inaccuracies are essentially eliminated. As discussed in Appendix I, 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 -22.9% and +27.4%.

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, albeit based only on three monitoring sites, i.e. “medium evidence”.

5.2 Analysis of Emissions’ Impact on the Environment

5.2.1 Critical Levels for Vegetation

The impact of Secunda Operation emissions on surrounding vegetation was assessed by comparing the simulated annual SO₂ and NO₂ 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 5-38).

Table 5-38: Critical levels for SO₂ and NO₂ by vegetation type (CLRTAP, 2015)

Pollutant	Vegetation type	Critical Level (µg/m³)	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 SO₂ (Figure 5-107 to Figure 5-109) and NO₂ (Figure 5-110 to Figure 5-112) are likely to be below the critical levels for all vegetation types.

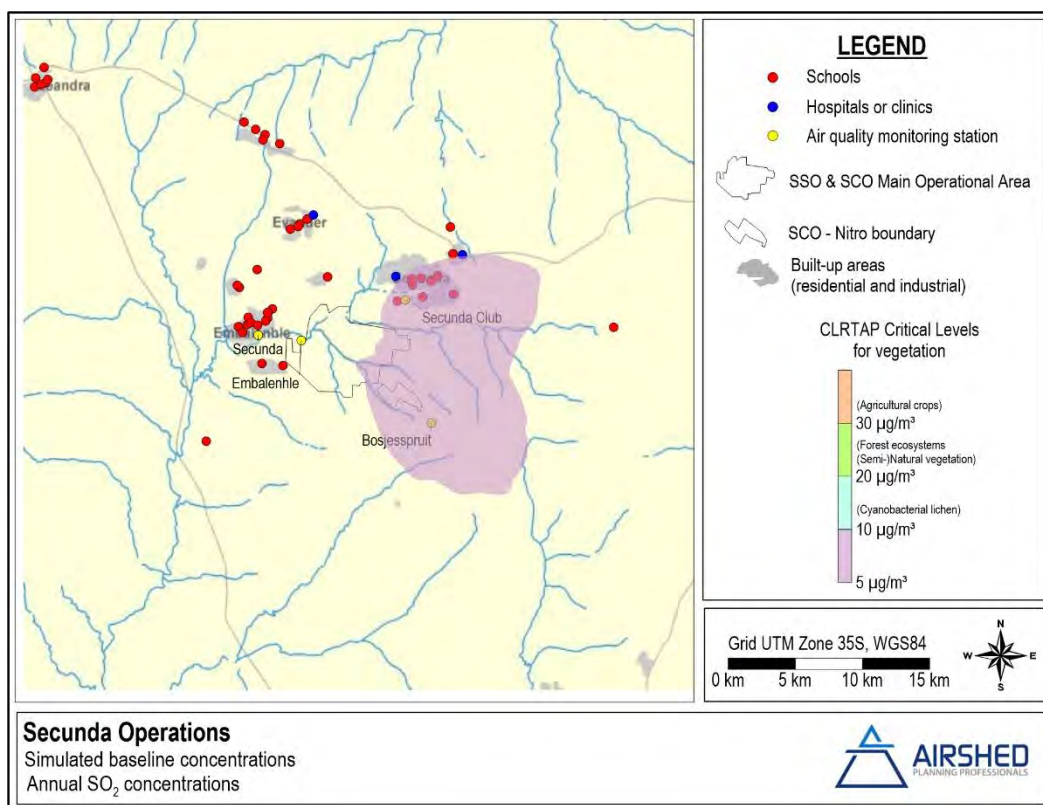


Figure 5-107: Annual SO₂ concentrations as a result of baseline emissions compared with CLRTAP critical levels

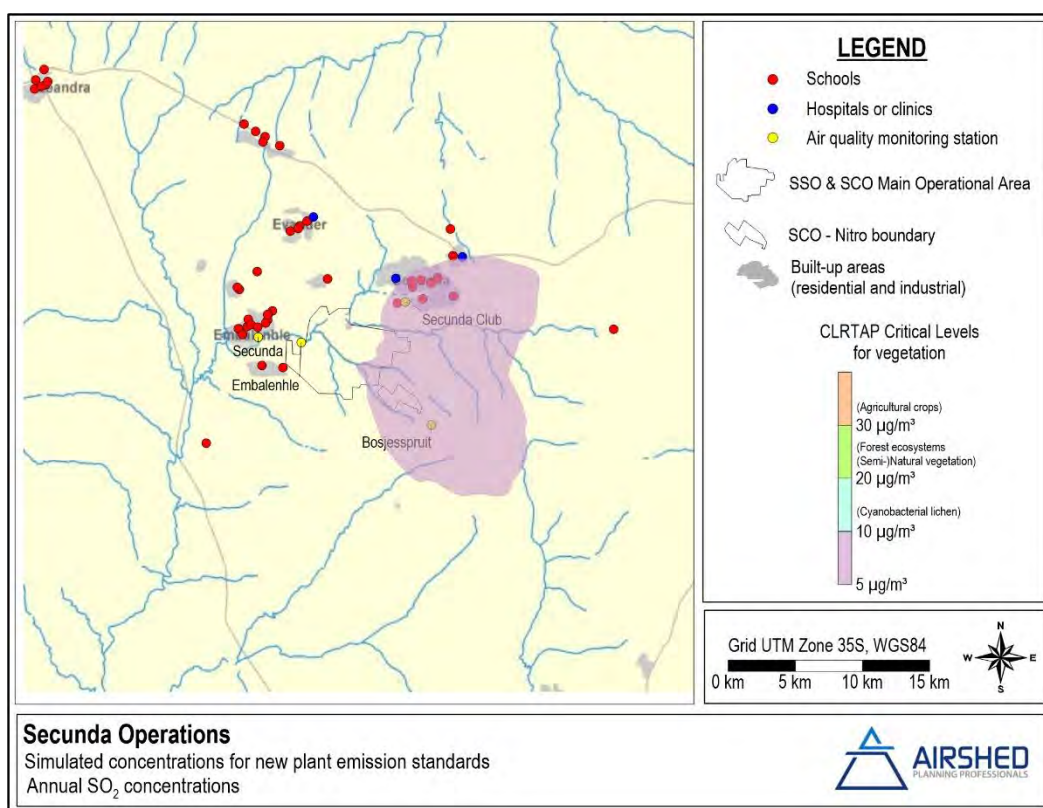


Figure 5-108: Annual SO₂ concentrations as a result of theoretical compliance with new plant emission standards compared with CLRTAP critical levels

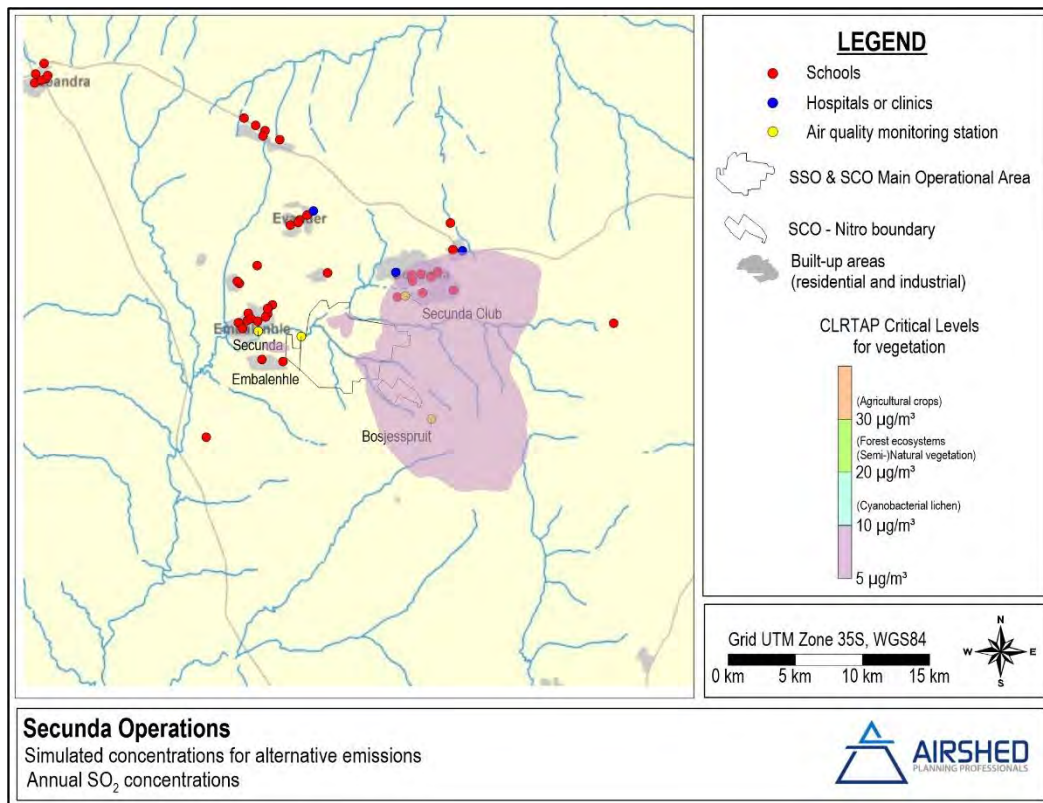


Figure 5-109: Annual SO₂ concentrations as a result of alternative emissions compared with CLRTAP critical levels

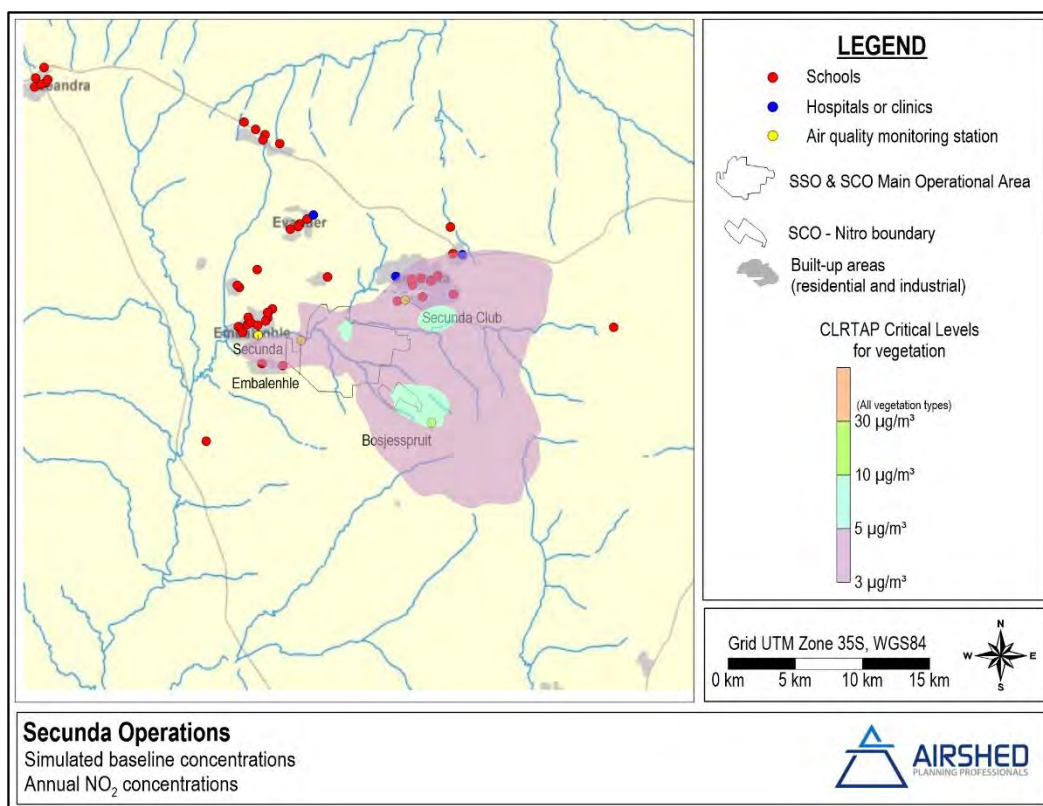


Figure 5-110: Annual NO₂ concentrations as a result of baseline emissions compared with CLRTAP critical levels

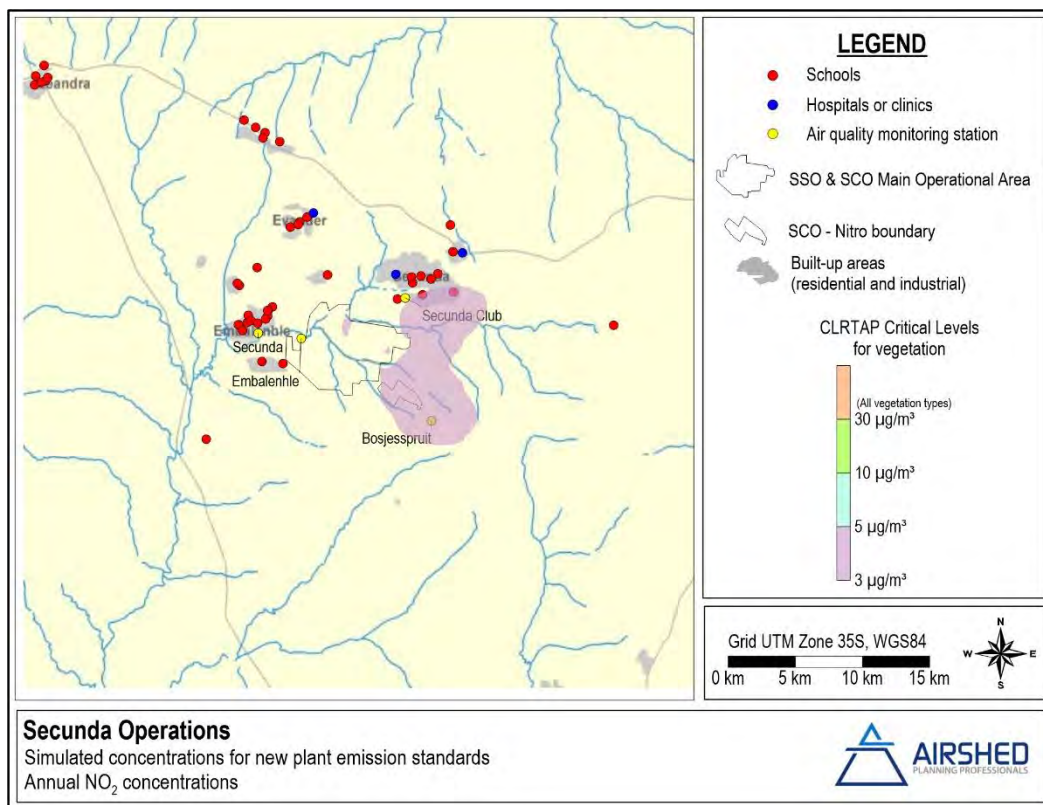


Figure 5-111: Annual NO₂ concentrations as a result of theoretical compliance with new plant emission standards compared with CLRTAP critical levels

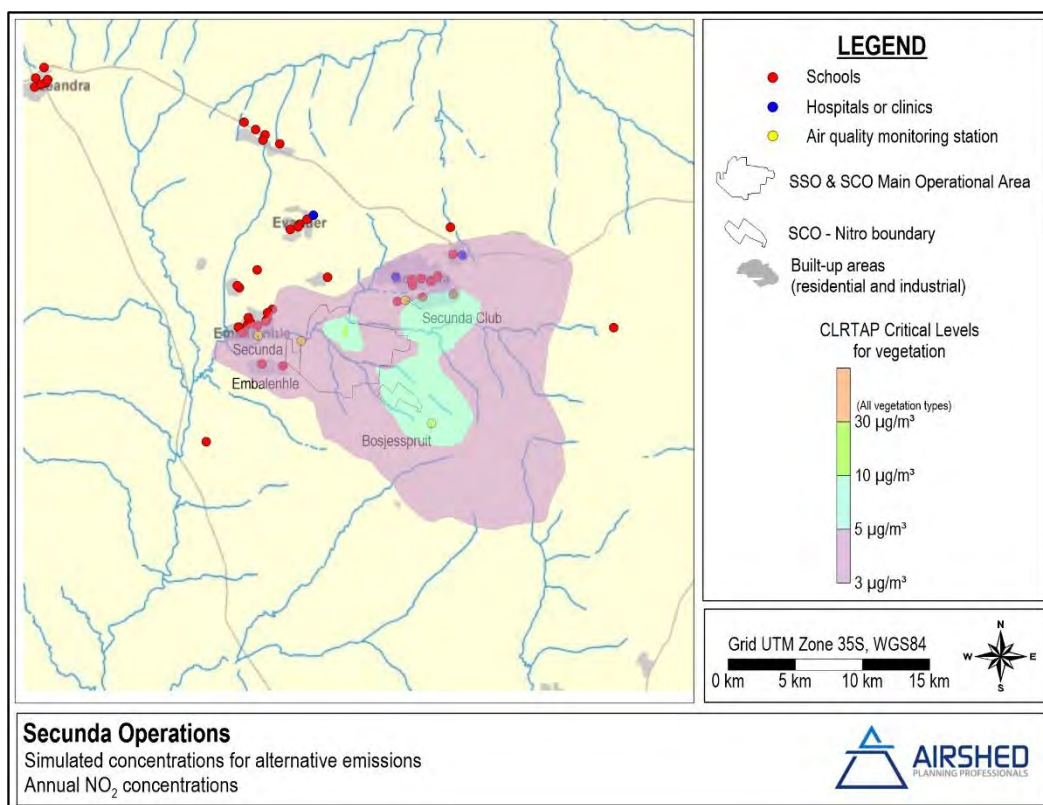


Figure 5-112: Annual NO₂ concentrations as a result of alternative emissions compared with CLRTAP critical levels

5.2.2 Dustfall

Dustfall deposition rates were estimated as a result of particulate emissions from the Secunda Operations 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 $10 \mu\text{m}$ particle with a density of 2.1 g/m^3). Estimated dustfall rates for the simulation scenarios ranged between 0.29 and 21.47 $\text{mg/m}^2\cdot\text{day}$, where the theoretical compliance with new plant standards would likely result in the lowest dustfall rates (Table 5-39). 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 5-39: Summary of dustfall deposition rates as a result of activities at Secunda Operations

Criteria	Daily dustfall rate ($\text{mg/m}^2\cdot\text{day}$)		
	Simulated Baseline Concentrations	Simulated Concentrations for New Plant Emission Standards	Simulated Concentrations for Alternative Emissions
Min	0.29	0.22	0.46
Max	7.30	2.76	21.47

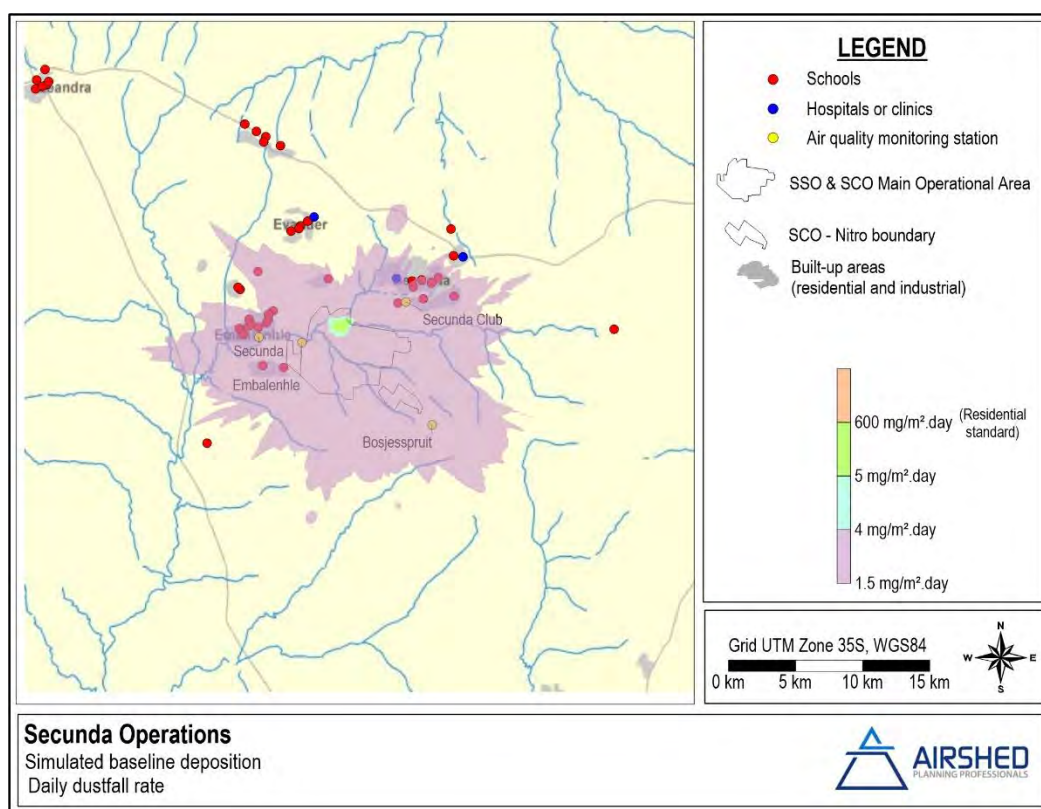


Figure 5-113: Simulated daily dustfall as a result of baseline emissions

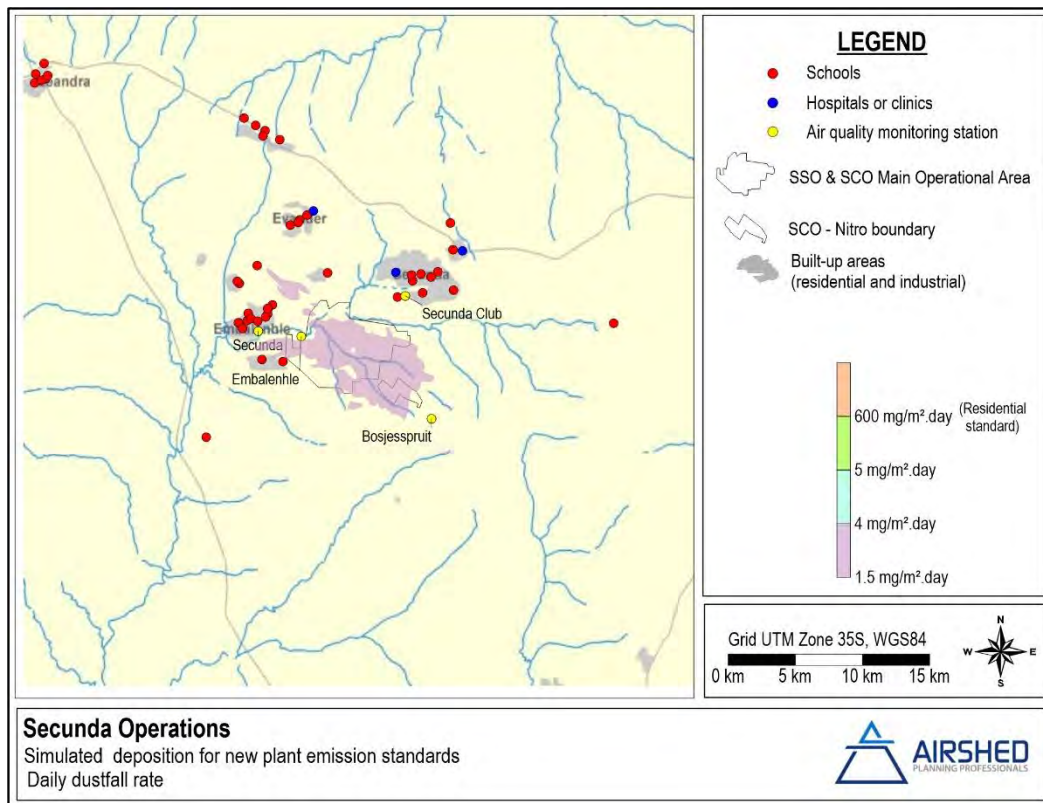


Figure 5-114: Simulated daily dustfall as a result of theoretical compliance with new plant standards

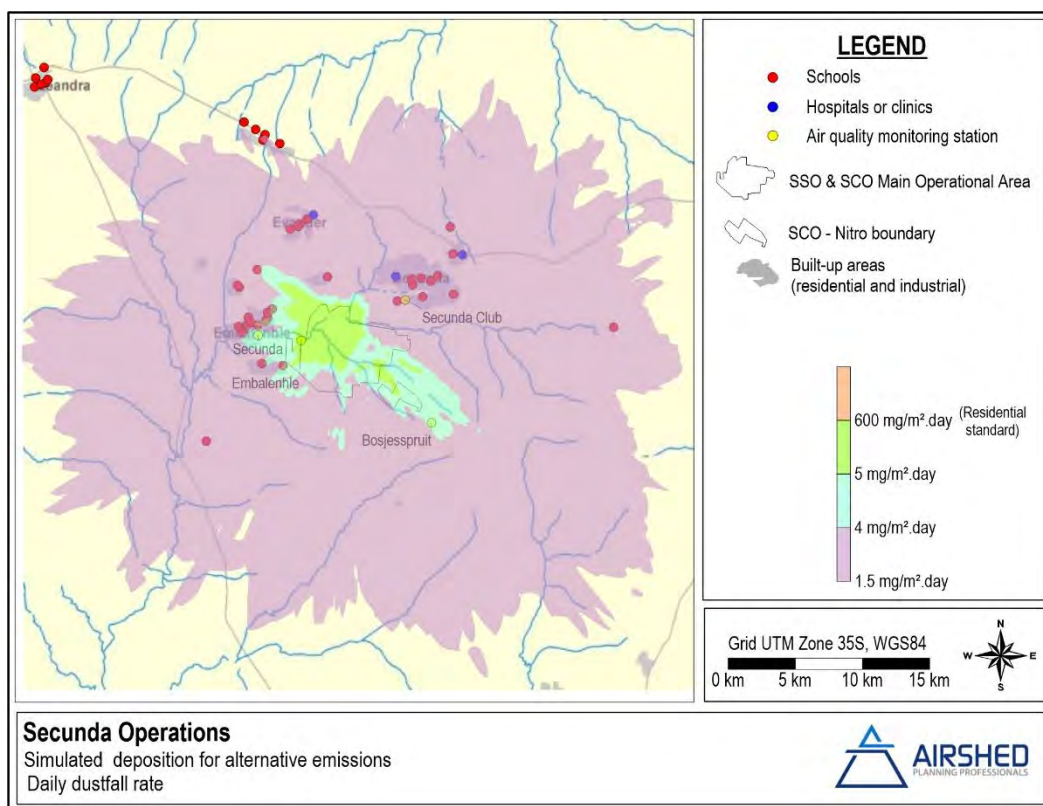


Figure 5-115: Simulated daily dustfall as a result of alternative emissions

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' exposure, showed steady-state corrosion with a linear increase in mass-loss with time.

The primary corrosion products found on iron were $\text{FeO}(\text{OH})$, Fe_3O_4 and FeCl_2 , whilst those found on zinc were $4\text{Zn}(\text{OH})_2$, ZnCl_2 , $\text{Zn}(\text{OH})_2$ 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 ($>0^\circ\text{C}$). 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 Embalenhle, Secunda Club and Secunda AQMS were used to calculate the TOW. The average TOW is 2868 hours for the period 2010 to 2017. According to the ISO 9233 classification (Table 5-40), the TOW class represented by these weather conditions is T4.

Table 5-40: ISO 9223 Classification of the Time of Wetness

Category	Time of Wetness	Example of Occurrence	Comment
	Hours per Year	Percentage	
T1	$T \leq 10$	$T \leq 0.1$	Indoor
T2	$10 < T \leq 250$	$0.1 < T \leq 3$	Indoor without climate control
T3	$250 < T \leq 2500$	$3 < T \leq 30$	Outdoor atmospheres in dry, cold climates and part of temperate climates
T4	$2\ 500 < T \leq 5\ 500$	$30 < T \leq 60$	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 SO₂ is classified according to the long-term (annual) deposition rate or air concentration of SO₂, as summarised in Table 5-38. Any concentration of SO₂ within category P₀ is considered to be the background concentration and is insignificant from the point of view of corrosive attack. Pollution by SO₂ within category P3 is considered extreme and is typical of operational microclimates beyond the scope of the International Standard. The ground-level SO₂ concentrations, as a result of emissions from Secunda Operations, fall into the P0 category for all scenarios (Table 5-42).

Table 5-41: ISO 9223 classification of pollution by sulfur-containing substances represented by SO₂

Category	Concentration of SO ₂	Deposition Rate of SO ₂
	µg/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 5-42: ISO 9223 classification of pollution by sulfur-containing substances represented by SO₂ as a result of Secunda Operations

Criterion	Scenario		
	Baseline	New Plant Emission Standards	Alternative Emissions
Maximum annual SO ₂ concentration (µg/m ³)	8.37	8.34	8.37
ISO corrosivity category for SO ₂	P0	P0	P0

Airborne Chloride

The ISO 9223 classification of pollution by chloride containing substances is provided in Table 5-43. Chloride deposition rates were estimated based HCl emissions from Secunda Operations sources (Table 5-44). 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 5-43: 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	$60 < S \leq 300$
S3	$300 < S \leq 1500$

Table 5-44: ISO 9223 classification of pollution by airborne chloride containing substances for SO

Criterion	Scenario		
	Baseline	New Plant Emission Standards	Alternative Emissions
Chloride deposition (mg/m ² .day)	0.01	0.04	0.11
ISO corrosivity category for Cl	S0	S0	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 5-45, and specific corrosivity categories associated with Secunda Operations are summarised for the three scenarios in Table 5-46. 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 5-47.

Table 5-45: 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 5-46: Estimated corrosivity categories of the atmosphere associated with SO

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

Table 5-47: 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 ($\mu\text{m/annum}$)				
	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 ($\mu\text{m/annum}$)				
	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 (SO_2) 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):

$$K = a + b_1[\text{SO}_2] + b_2[\text{Cl}^-] + b_3[\text{TOW}]$$

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 5-48 is a summary of constants for flat metal specimens. The deposition of SO_2 is expressed as an equivalent concentration, i.e. $\mu\text{g}/\text{m}^3$; the deposition of chloride pollutants $[\text{Cl}^-]$ is expressed in $\text{mg}/\text{m}^2\cdot\text{day}$, and time of wetness $[\text{TOW}]$ in hours per year.

Table 5-48: 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

Metal	Regression Constants for ISOCORRAG model			
	a	b ₁	b ₂	b ₃
Zinc	0.2098	0.0232	0.0059	0.00027
Copper	0.9556	0.0065	0.00393	0.0000538
Aluminium	0.0069	0.00638	0.000558	0.000065

Using simulated concentrations of SO₂ as a result of Secunda 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 5-49. 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 5-47 compared with Table 5-49).

Table 5-49: Corrosion rate of metals associated with Secunda Operations calculated according to the ISOCORRAG method

Scenario	Criteria	Corrosion rate (K) [µm/annum]			
		Steel	Zinc	Copper	Aluminium
Simulated Baseline Concentrations	Min	17.83	66.76	1.11	0.20
	Max	21.29	66.95	1.16	0.25
Simulated Concentrations for New Plant Emission Standards	Min	17.83	66.76	1.11	0.20
	Max	21.27	66.95	1.16	0.25
Simulated Concentrations for Alternative Emissions	Min	17.83	66.76	1.11	0.20
	Max	21.29	66.95	1.16	0.25
	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 ongoing 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, Mphepya *et al.* 2006, Scorgie and Kornelius 2009, Josipovic *et al.* 2010, Piketh *et al.* 2016, Galy-Lacaux *et al.* 2016) 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 SO₂ 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), 10 kg/ha/year (Galy-Lacaux *et al.* 2016) 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.

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 Africa 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 Secunda Operations. Investigating deposition and its impacts on the Highveld grasslands as a result of Secunda Operations was beyond the time-frame of the accompanying postponement application especially since long-term impact studies are not yet available for South Africa.

5.2.5 Potential Environmental Impact of Benzene

Benzene (together with other VOCs) is a precursor pollutant involved in the formation of secondary atmospheric pollutants, such as smog (generally) and ozone (specifically).

As a secondary pollutant, O₃ is formed in the lower part of the atmosphere, from complex photochemical reactions following emissions of precursor gases such as NO_x and VOCs (Seinfeld and Pandis, 1998). O₃ is produced during the oxidation of CO and hydrocarbons by hydroxyls (OH) in the presence of NO_x and sunlight (Seinfeld and Pandis, 1998). The rate of ozone production can therefore be limited by CO, VOCs or NO_x. In densely populated regions with high emissions of NO_x and hydrocarbons, rapid O₃ production can take place and result in a surface air pollution problem. In these urban areas O₃ formation is often VOC-limited. O₃ is generally NO_x-limited in rural areas and downwind suburban areas.

O₃ concentration levels have the potential to become particularly high in areas where considerable O₃ precursor emissions combine with stagnant wind conditions during the summer, when high insolation and temperatures occur (Seinfeld and Pandis, 1998). The effects of sunlight on O₃ formation depend on its intensity and its spectral distribution.

The main sectors that emit ozone precursors are road transport, power and heat generation plants, household (heating), industry, and petrol storage and distribution. In many urban areas, O₃ nonattainment is not caused by emissions from the local area alone. Due to atmospheric transport, contributions of precursors from the surrounding region can also be important. The transport of O₃ is determined by meteorological and chemical processes which typically extend over spatial scales of several hundred kilometres. Thus, in an attempt to study O₃ concentrations in a local area, it is necessary to include regional emissions and transport. This requires a significantly larger study domain with the inclusion of a significantly more comprehensive emissions inventory of NO_x and VOCs sources (e.g. vehicle emissions in Gauteng). Such a collaborative study was not within the scope of this report.

Ozone is a strong oxidant known to cause injury and thereby reduce crop plant yield, especially above a threshold of 40 ppb. Recent assessments of ozone concentrations on the Highveld, to which the SSO benzene emissions would contribute, show ambient concentrations below the AOT40 (WHO Ambient Ozone Threshold of 40 ppb):

- Ambient monthly ozone concentrations measured at Amersfoort during the 3-year period 2000 to 2002 ranged between 15 and 45 ppb (Zunckel 2004) where the highest concentrations were measured between July and November 2001.
- Ambient monthly ozone concentrations measured during a campaign between September 2005 and August 2007 showed across the Highveld rarely exceeded 20 ppb. The maximum monthly average (43 ppb) was measured near Thabazimbi (Josipovic *et al.* 2010)

Lourens *et al.* (2011) note that in the South African context, carbon monoxide is probably a more important precursor to ozone formation than benzene (or BTEX more broadly), where ozone concentrations and CO concentrations peak simultaneously during late winter and early spring when biomass burning (veld fires) regularly occur.

Benzene is also a primary pollutant (slightly soluble in water (1.79 g/L at 15°C)) that is toxic to aquatic systems, primarily by altering redox potentials which in turn limits the biological communities which can function under the altered redox potentials (Fahy *et al.* 2005). The toxicity for aquatic organisms is considered to be low to moderate, but this is only likely to be apparent when high concentrations arise from significant spills. Benzene quickly reacts with other chemicals in the air and is thus removed within a few days of release. In soils and water bodies it breaks down more slowly and can pass into groundwater where it can persist for weeks. Benzene does not accumulate in animals or plants and is unlikely to have any environmental effects at a global level (Scottish Environmental Protection Agency (SEPA)).

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
2017	No complaints received			
2016	One external Sasol related complaint was received. The following complaint was received: The complaint related to unpleasant odour from the factory experienced in Secunda town. The last odour related complaint related to a sulphur / H₂S smell	Analyses of measured meteorological data at the time of the incident were undertaken and low winds speeds were identified as an exacerbating factor. Analyses of measured ambient data was also undertaken to observe the concentrations at the time of the incident to identify the pollutants causing the smells.	Process conditions on the factory and H ₂ S emissions from sulphur plants during low wind conditions	An investigation form is sent to the relevant BU's environmental manager who launches a full investigation. Measures implemented to prevent a similar incident from reoccurring need to be specified and implemented. This is tracked from the Environmental group
2015	A total of 3 external Sasol related complaints were received during 2015. The following complaints were received: The complaint related to a nuisance smell coming from the water recovery effluent dams, which was being experienced in the Secunda residential area. The second complaint related to unpleasant odour from the factory experienced in Secunda town. The last odour related complaint related to a sulphur / H₂S smell.	Regarding the first complaint, feedback was given to the complainant which included an explanation on how the process dams operate and the possible contributing factors that results in odour. A commitment to inform and discuss the matter further with the senior manager of that plant was also undertaken and further feedback requested. For both odour related complaints, analyses of measured meteorological data at the time of the incidents was undertaken and low winds speeds was identified as an exacerbating factor. Analyses of measured ambient data was also undertaken to observe the concentrations at the times of the incidents to identify the pollutants causing the smells.	Process conditions on the factory and Sasol emissions (from process dams and H ₂ S from sulphur plants) during low wind conditions	An investigation form is sent to the relevant BU's environmental manager who launches a full investigation. Measures implemented to prevent a similar incident from reoccurring need to be specified and implemented. This is tracked from the Environmental group
2014	Only 1 external Sasol related complaints was received during 2014. The following complaint was received:	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	Process conditions on the factory. Generally higher than normal ambient concentrations of ambient pollutants (H ₂ S, SO ₂ and NO _x) and low wind	An investigation form is sent to the relevant BU's environmental manager who launches a full investigation. Measures implemented to prevent a similar incident from reoccurring need to be

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
	The complaint related to a 'chemical smell' within the Secunda residential area.	are taken to reduce and manage the impact and to reduce the time of the incident. An analyses of ambient data that could have contributed to the problem was undertaken.	conditions at the time. Looking at the plant operations over this time period there were no abnormal conditions	specified and implemented. This is tracked from the Environmental group

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 the Secunda Operations 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 existing and 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 two 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 NO₂ 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 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 PM₁₀ concentrations reflected in Section 5.1.8.1.3 include direct emissions of PM plus secondary particulates formed from Sasol's emissions.

10 ANNEXURE A

DECLARATION OF ACCURACY OF INFORMATION – APPLICANT

Name of Enterprise:

Declaration of accuracy of information provided:

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

I, W Groenewald [*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 Secunda on this 3th day of December 2018



SIGNATURE

Senior manager air quality, Secunda Synfuels Operations

CAPACITY OF SIGNATORY

DECLARATION OF ACCURACY OF INFORMATION – APPLICANT

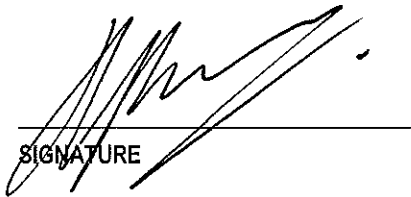
Name of Enterprise: Secunda Chemical Operations.

Declaration of accuracy of information provided:

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

I, J. Hyman [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 Secunda on this 3rd day of December 2018


SIGNATURE

Acting VP SCO SHE
CAPACITY OF SIGNATORY

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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 30 day of November 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 ◦ Understanding of their interaction ◦ 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 regard 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
	Ability to review reports to ensure accuracy, clarity and completeness

Competency	Task, Knowledge and Experience
	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 0.

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 0).
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	Included

Chapter	Name	AIR regulations requirement	Status in AIR
		directives, compliance notices, interdicts, prosecution, fines	
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 (O₃), 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 NO₂ 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 0).

AIR Regulations	Compliance with Regulations	Comment
Data period Geographical Information Topography and land-use	Yes	3 years (2015 to 2017) Required for CALMET 3D meteorological file preparation (Section 5.1.4.6.2)
Domain and co-ordinate system	Yes	- Dispersion modelling domain: 50 x 50 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 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 Land-use classification Surface roughness Albedo Temporal and spatial resolution Receptors and spatial resolutions Building downwash Chemical transformations	Yes Yes Yes Yes Yes Yes Yes Yes	Section 5.1.5.4, Section 5.1.6, and Appendix G Model predicted, 99 th 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) Section 5.1.4.2 and Section 5.1.4.6.2 Computed from Land-use categories in the CALMET pre-processing step (Section 5.1.4.6.2). Computed from Land-use categories in the CALMET pre-processing step (Section 5.1.4.6.2). Sections 5.1.8 and 5.1.4.6.4 Section 5.1.4.6.5 Sections 5.1.4.3, Section 5.1.4.4 and Appendix E and Appendix F.
General Reporting Requirements Model accuracy and uncertainty Plan of study Air Dispersion Modelling Study Reporting Requirements Plotted dispersion contours	Yes Yes Yes Yes	Section 5.1.6, Section 5.1.9, Appendix I and Appendix J Section 5.1.1.1 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). Section 5.1.8

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

C1: Raw Materials

Table C-1: Raw materials used at Sasol Secunda

Raw Material Type	Maximum Permitted Consumption Rate ^(a)	Units (quantity/period)
<u>Utilities</u>		
<u>Boilers</u>		
Coal		tonnes/h per boiler
Boiler feed water		tonnes/h per boiler
Fuel oil		m ³ /cold start up
Tar sludge East		tonnes/h per boiler
Tar sludge West		tonnes/h per boiler
Ammonia		kg/precipitator/h (90%NH ₃ East and 99% NH ₃ West)
Air (total)		kNm ³ /h per boiler
Low pressure (LP) steam (400kPag)		tonnes/h per boiler
<u>Gas Turbines</u>		
Natural Gas or Methane Rich Gas (MRG)		kJ/kWh (per gas turbine)
		kg/h per gas turbine
Boiler feed water (condensate)		tonnes/h per HRSG
Low pressure (LP) steam (400kPag @ 174°C)		tonnes/h per boiler (de-aerator)
<u>Gas Production</u>		
<u>Coal Processing</u>		
Run-of-mine coal		tonnes/day (per unit)
<u>Gasification and Raw Gas Cooling</u>		
Coarse coal		tonnes/day (per unit)
98.6+ vol% pure oxygen		kNm ³ /h
HP superheated steam		tonnes/h
<u>Rectisol</u>		
Raw Gas		kNm ³ /h per unit
<u>Gas Circuit</u>		
<u>Benfield</u>		
Tail Gas into Benfield		kNm ³ /h
Potassium carbonate recirculation rate		m ³ /h
Carbonate system steam consumption		tonnes/h
DEA solution recirculation rate		m ³ /h
DEA system steam consumption		tonnes/h
<u>Catalyst Manufacturing & Catalyst Reduction</u>		
IP sensitivities		
<u>Refining</u>		
<u>Tar Distillation (Unit 14 / 214)</u>		
Crude Tar/ Depitched Tar (all 4 trains combined)		m ³ /h
<u>Unit 27A</u>		

Raw Material Type	Maximum Permitted Consumption Rate ^(a)	Units (quantity/period)
HNO-DTA		m³/h
Unit 74		
Phenolic pitch		m³/h
Coal Tar Naphtha Hydrogenation (Unit 15 / 215)		
Rectisol, Light and Heavy (containing coker naphtha and raffinate from Merisol) naphtha		m³/h
Naphtha (containing coker naphtha and raffinate from Merisol) from Tar Distillation		m³/h
Naphtha from Tar Distillation		m³/h
Creosote Hydrogenation (Unit 228)		
Creosote from Tar Distillation including coker gas oil		m³/h
Naphtha Hydrotreater, Platformer and CCR (Unit 30/230, 31/231)		
NHT hydrotreater		m³/h
Platformer		m³/h
CCR		
Catalytic Distillation Hydrotreater (Unit 78)		
C5/C6 Hydrocarbons (From Co-monomers)		m³/h
C5 Hydrocarbons from U229/29		m³/h
C6/C7 Hydrocarbons		m³/h
CD Tame (Unit 79)		
C5/C6 Hydrocarbons from Co-monomers		m³/h
Methanol		m³/h
C5 Isomerisation (Unit 90)		
C5 Hydrocarbons from Co-monomers		m³/h
Vacuum Distillation (Unit 34 / 234)		
Decanted Oil		m³/h
Distillate Hydrotreater (Unit 35 / 235)		
DHT feed from U29/229/34/234		m³/h
Distillate Selective Cracker (Unit 35DSC)		
DHT distillate feed from U35 / 235		m³/h
Light Oil Fractionation (Unit 29 / 229)		
Synthol light oil		m³/h
Catalytic polymerisation and LPG recovery (Unit 32 / 232)		
Condensates		m³/h

Raw Material Type	Maximum Permitted Consumption Rate ^(a)	Units (quantity/period)
<u>Polymer Hydrotreater (Unit 33 / 233)</u>		
Unhydrogenated petrol / diesel feed from unit 32/232		m ³ /h
<u>Total Refinery West</u>		
Hydrogen		Nm ³ /h
<u>Total Refinery East</u>		
Hydrogen		Nm ³ /h
<u>Sasol Catalytic Converter</u>		
Fresh C6/C7 Feed		tonnes/h
C2 Rich Gas		tonnes/h
U24 Cracked Gas		tonnes/h
FT Feed to VL7001		tonnes/h
Rerun Gasoline		tonnes/h
99% Hydrogen to reactor		tonnes/h
Hydrogen to CD Hydro Columns		Nm ³ /h
PPU3 Vent Gas		tonnes/h
PP2 Carrier Gas		tonnes/h
HVGO		m ³ /h
Caustic		tonnes/h
Tar, Phenosolvan and sulfur		
<u>Gas Liquor Separation</u>		
Dusty Gas Liquor		kg/h per factory
Tarry Gas Liquor		kg/h per factory
Oily Gas Liquor		kg/h per factory
Trim and Final Cooler Return		kg/h per factory
Rectisol Return		kg/h per factory
<u>Phenosolvan</u>		
Gas Liquor		m ³ /h per factory
<u>Sulfur Recovery</u>		
Offgas from Rectisol & Phenosolvan		kNm ³ /h per absorber (8 absorbers)
Caustic soda		m ³ /day per phase
SAV		tonnes/week (only when required)
ADA		tonnes/week (only when required)
NaSCN		tonnes/day (only when required)
<u>Wet Sulfuric Acid</u>		
Off gas from Rectisol & Phenosolvan		kNm ³ /h
Potable water (Rand Water)		m ³ /h supply to Proxa
Ammonia		Nm ³ /h
<u>Carbo Tar and Coal Tar Filtration</u>		
Unit 039 MTP		m ³ /h
Unit 039 Waxy Oil		m ³ /h
Unit 039 FCC Slurry		m ³ /h

Raw Material Type	Maximum Permitted Consumption Rate ^(a)	Units (quantity/period)
Unit 075 Green coke		tonnes/year
Unit 075 Green coke Hybrid		tonnes/year
Unit 076 Green Coke		tonnes/year
Unit 096 Coal Tar		m ³ /day
Unit 096 Oil		m ³ /day
Unit 086 Waxy Oil Train 1 API Oil		m ³ /h per train
Unit 086 Train 1 Waxy Oil API Oil		m ³ /h per train
Unit 086 Tar Train 2 Dam Tar		m ³ /h per train
Unit 086 Tar Train 2 Raw Tar		m ³ /h per train
Unit 086 Tar Train 2 Tank Sludge's		m ³ /h per train
Unit 086 OBF Waxy Oil 12		m ³ /h per train
Unit 086 OBF HFO 150		m ³ /h per train
Water and Ash		
<u>Multi hearth sludge incinerator</u>		
Thickened waste activated sludge	508	m ³ /day
<u>HOW Incinerator</u>		
High organic waste	48	m ³ /day
<u>Sewage Incinerator</u>		
Raw sewage and Domestic waste Screenings	440	kg/day
<u>WRF TO</u>		
Vent gas, Nitrogen and Air	1578	Nm ³ /h
Market and Process Integration		
<u>Central Corridor Flares</u>		
The flares are safety devices that need to flare gasses to protect equipment during process upset conditions		
Solvents		
<u>Solvents West</u>		
Reaction water ex Synthol		tonnes/h
Propanol plus		tonnes/h
Heavy aldehydes (C3 aldehydes)		tonnes/h
Ethanol 95%		tonnes/h
93 % ethanol for HPE (from EA)		tonnes/h
<u>Solvents East</u>		
Reaction water		tonnes/h
Aldehydes ex West		tonnes/h
Ethanol Effluent		tonnes/h
<u>Ethyl acetate</u>		
Ethanol 95 (E/A)		tonnes/h
<u>Hexene</u>		
Feed (C5- C7)		tonnes/h
NMP		tonnes/year
Methanol		tonnes/h
<u>Octene</u>		
Sweetened feed (total)		tonnes/h
Ethanol		m ³ /year

Raw Material Type	Maximum Permitted Consumption Rate ^(a)	Units (quantity/period)
NMP		tonnes/year
Potassium Carbonate		tonnes/year
<u>Regenerator</u>		
Potassium salt		kg/h
Stripper off gases		kg/h
Fuel gas		kg/h
Atomising steam		kg/h
<u>Safol</u>		
29VL106 Overheads		kg/h
229VL104 Sidedraw		kg/h
Acetonitrile		
HP Hydrogen		kg/h
Pure Gas		kg/h
Instrument air		kg/h
<u>Octene Train 3</u>		
1-Heptene feed from Hexene and Octene 1 (acid free)		
1-Heptene feed from Octene 2 (acidic)		
Syngas		
Hydrogen		
Polymers		
<u>Polypropylene</u>		
<u>PP1</u>		
Propylene		tonnes/year
Ethylene		tonnes/year
Hydrogen		tonnes/year
Nitrogen		tonnes/year
Heptane		tonnes/year
Catalyst		tonnes/year
Co- catalyst		tonnes/year
Silane		tonnes/year
Iso propanol		tonnes/year
1-Pentene		tonnes/year
<u>PP2</u>		
Propylene		tonnes/year
Ethylene		tonnes/year
Hydrogen		tonnes/year
Gas bleed from reactors and propylene recovery unit		kg/h
20 Caustic solution		kg – once per year
<u>Monomers</u>		
<u>Monomers West</u>		
C ₂ Rich Gas (from Synfuels)		tonnes/h
60% C ₂ H ₄		tonnes/h
40% C ₂ H ₆		tonnes/h

Raw Material Type	Maximum Permitted Consumption Rate ^(a)	Units (quantity/period)
Propane		kNm ³ /h
Low Pressure Gas		m ³ /h
C ₃ Condensate		m ³ /h
Carrier gas		kNm ³ /h
Ethane from SCC		tonnes/h
Ethane from U280		tonnes/h
<u>Monomers East</u>		
Condensate 2 to U288		tonnes/year
Condensate 3 to U288		tonnes/year
Condensate 3 to U285		tonnes/year
C2's to U280		tonnes/year
<u>Oil</u>		
<u>Main flares</u>		
Feed gas (off-gases, off specification gases and emergency venting)		tonnes/h
<u>Ground level flares</u>		
<u>First flare burner</u>		
Alcohols or off spec products		m ³ /h
<u>Ammonia flares</u>		
Ammonia		kg/h
Propane		kg/h
Ethane		kg/h
<u>Storage of hydrocarbons</u>		
Various intermediate liquid material		
<u>LOC</u>		
Various products in road loading (Central road loading facility)	VOC containing products loaded in quantities exceeding 50 000 m ³ /a	m ³ /year
Various products in rail loading (Central rail loading facility)	VOC containing products loaded in quantities less than 50 000 m ³ /a	m ³ /year
<u>Nitro</u>		
<u>Fertilisers</u>		
<u>Granulation Plant</u>		
Ammonia		tonnes/year
Ammonium nitrate		tonnes/year
Ammonium sulfate		tonnes/year
Limestone		tonnes/year
<u>Nitric Acid Plant</u>		

Raw Material Type	Maximum Permitted Consumption Rate ^(a)	Units (quantity/period)
Ammonia		tonnes/day
Air		Nm ³ /day
Water		m ³ /day
<u>Ammonium Nitrate Plant</u>		
Ammonia		tonnes/year
Nitric Acid		tonnes/year
<u>Liquid Fertilizer Plant</u>		
Water		tonnes/year
Ammonia		tonnes/year
Potassium Chloride		tonnes/year
Urea		tonnes/year
Phosphoric Acid		tonnes/year
Ammonium Nitrate		tonnes/year
Zinc		tonnes/year
<u>Ammonium Sulfate Plant</u>		
Ammonia		kg/h
Sulfuric Acid		tonnes/year
<u>Explosives (open burning grounds)</u>		
Waste		kg/day
Note: Raw material and/or consumption rates were excluded for proprietary or competition law sensitivities.		

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

Appliance name	Appliance type/description	Appliance function/purpose
Not available	Electrostatic Precipitators	Reduce particulate emissions
Not available	Stainless Steel Filters	Reduce particulate emissions
Venturi Scrubber	Venturi Scrubber	Reduce particulate and gaseous emissions
Electrostatic precipitator	Wet Electrostatic precipitator	Reduce particulate and gaseous emissions
Reactor	DeNOx converter	Reduce NOx emissions
Flares	Flares	Combust organic gasses to CO ₂ and H ₂ O
Bag house	Bag filters	Reduce particulate emissions
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)	Emission Hours	Type of Emission (Continuous / Batch / Intermittent)
Utilities											
B1	West stack	26.5575	29.14993	250	230	13.6	185	10 025 400	23-27	24	Continuous
B2	East stack	26.56014	29.16841	301	281	14.4	185	11 278 580	23-27	24	Continuous
GT1	Gas Turbine stack	26.564167	29.165	40	37	5.3	548	3 176 904	40	24	Continuous
GT2	Gas Turbine stack	26.564167	29.164444	40	37	5.3	548	3 176 904	40	24	Continuous
Gas Production											
Rectisol East	Off gas to main stack	26.56014	29.16841	301	281	13.6	20 - 25	830 370	20-30	24	Continuous
Rectisol West	Off gas to main stack	26.5575	29.14993	250	230	14.4	20 – 25	830 370	20-30	24	Continuous
Gas Circuit											
<u>Catalyst Manufacturing</u>											
CM1	West Kiln Stack	26.55496	29.15655	25	-5	0.91	170	81 163	28.7	24	Batch
CM2	West Arc Furnace Stack	26.55509	29.15655	25	-5	1.6	35	190 211	34.3	24	Batch
CM3	East A Kiln Stack	26.55735	29.17548	25	-5	0.76	205	33 917	12	24	Batch
CM4	East Arc Furnace Stack	26.55773	29.17531	25	-5	1.6	73	43 720	5.35	24	Batch
CM5	East B Kiln Stack	26.55692	29.17537	25	-5	0.77	192	19 970	11.9	24	Batch
Refining											
<u>Tar Distillation</u>											
R1 (14HT101)	Tar Distillation Reboiler Stack Outlet	-26.54917	29.18306	51.876	46.876	0.894	440	7 390	3.27	24	Continuous
R2 (14HT201)	Tar Distillation Reboiler Stack Outlet	-26.54917	29.15083	51.876	46.876	0.894	440	7 390	3.27	24	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)	Emission Hours	Type of Emission (Continuous / Batch / Intermittent)
R3 (214HT101)	Tar Distillation Reboiler Stack Outlet	-26.54917	29.13417	51.876	46.876	0.894	440	7 390	3.27	24	Continuous
R4 (214HT201)	Tar Distillation Reboiler Stack Outlet	-26.54917	29.11750	51.876	46.876	0.894	440	7 390	3.27	24	Continuous
<u>Creosote Hydrogenation</u>											
R5 (228HT101)	Heater stack outlet	-26.91972	29.28278	41.274	36.274	0.914	318	9 220	3.9	24	Continuous
<u>Naphtha Hydrotreater, Platformer and CCR</u>											
R6 (30HT101)	NHT charge heater stack outlet	-26.55028	29.14972	51.876	46.876	1.22	298	6216	1.48	24	Continuous
R7 (30HT102)	Stripper Reboiler heater stack outlet	-26.55028	29.14972	38.4	33.4	0.99	304	11527	4.16	24	Continuous
R8 (30HT103)	Platformer charge heater stack outlet	-26.55028	29.14972	51.7	46.7	2.362	177	37722	2.39	24	Continuous
R9 (30HT104)	Debutanizer Reboiler heater stack outlet	-26.55028	29.14972	43	38	1.28	360	8313	1.79	24	Continuous
R10 (30HT105)	Splitter Reboiler heater stack outlet	-26.55028	29.14972	38.4	33.4	0.99	313	6856	2.47	24	Continuous
R11 (230HT101)	NHT charge heater stack outlet	-26.92417	29.28278	51.9	46.9	1.22	298	9696	2.3	24	Continuous
R12 (230HT102)	Stripper reboiler stack outlet	-26.92361	29.28278	38.4	33.4	0.99	304	8576	3.09	24	Continuous
R13 (230HT103)	Platformer Charge Heater stack outlet	-26.92222	29.28306	51.7	46.7	2.362	177	40816	2.59	24	Continuous
R14 (230HT104)	Debutanizer reboiler stack outlet	-26.92306	29.28306	43	38	1.28	360	3312	0.79	24	Continuous
R15 (230HT105)	Splitter reboiler stack outlet	-26.92361	29.28306	38.4	33.4	0.99	313	7115	2.57	24	Continuous
<u>Vacuum Distillation</u>											
R17 (34HT101)	Vacuum heater stack outlet	-26.55056	29.15028	32	27	1.27	321	10727	2.35	24	Continuous
R18 (234HT101)	Vacuum heater stack outlet	-26.92472	29.28306	32	27	1.27	321	10727	2.35	24	Continuous

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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)	Emission Hours	Type of Emission (Continuous / Batch / Intermittent)
<u>Distillate Hydrotreater</u>											
R19 (35HT101)	Reactor Charge Heater stack outlet	-26.38250	29.14306	41.3	36.3	0.99	299	7865	1.916	24	Continuous
R20 (35HT102)	Fractionator Charge Heater stack outlet	-26.38250	29.14306	44.2	39.2	1.35	345	11112	1.76	24	Continuous
R22 (235HT101)	Reactor Charge Heater stack outlet	-26.92111	29.28278	41.3	36.3	1.308	299	6806	1.31	24	Continuous
R23 (235HT102)	Fractionator Charge Heater stack outlet	-26.92111	29.28278	44.2	39.2	1.35	310	12641	2.45	24	Continuous
<u>Distillate Selective Cracker</u>											
R24 (35HT103)	Reactor Charge Heater stack outlet	-26.38250	29.14306	31.4	26.4	0.87	388	3495	1.63	24	Continuous
R25 (35HT104)	Fractionator Charge Heater stack outlet	-26.38250	29.14306	35	30	0.99	221	3135	1.13	24	Continuous
R26 (35HT105)	Vacuum Charge Heater stack outlet	-26.38250	29.14306	31	26	0.684	340	3728	2.82	24	Continuous
<u>Light Oil Fractionation</u>											
R27 (29HT101)	Light Oil Splitter Reboiler stack outlet	-26.55083	29.15056	48	43	1.808	280	21349	2.31	24	Continuous
R28 (29HT102)	Diesel Splitter Reboiler stack outlet	-26.55139	29.15111	42.6	37.6	1.2	267	13708	3.37	24	Continuous
R29 (229HT101)	Light Oil Splitter Reboiler stack outlet	-26.92472	29.28306	47.7	42.7	1.727	367	36129	4.28	24	Continuous
<u>Polymer Hydrotreating</u>											
R30 (33HT101)	Stripper Reboiler stack outlet	-26.55111	29.14972	34.9	29.9	1.53	300	15260	8300	24	Continuous
R31 (33HT102)	Charge Heater stack outlet	-26.55083	29.14972	38.68	33.68	1.4	274	16055	10429	24	Continuous
R32 (33HT105)	Splitter Reboiler stack outlet	-26.55083	29.14972	46	41	1.37	320	26830	18200	24	Continuous
R33 (233HT101)	Stripper Reboiler stack outlet	-26.92556	29.28250	34.9	29.9	1.53	300	15260	8300	24	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)	Emission Hours	Type of Emission (Continuous / Batch / Intermittent)
R34 (233HT102)	Charge Heater stack outlet	-26.92556	29.28250	38.68	33.68	1.4	274	16055	10429	24	Continuous
R35 (233HT105)	Splitter Reboiler stack outlet	-26.92556	29.28250	46	41	1.37	320	26830	18200	24	Continuous
<u>Catalytic Polymerisation and LPG recovery</u>											
R36 (32HT101)	Poly Debutanizer Reboiler stack outlet.	-26.92556	29.15028	37.2	32.2	1.24	267	16520	13679	24	Continuous
R37 (32HT201)	Poly Debutanizer Reboiler stack outlet.	-26.55167	29.15028	37.2	32.2	1.24	226	15266	12641	24	Continuous
R38 (32HT102)	Recycle Column Reboiler stack outlet.	-26.55167	29.15028	51.5	46.5	2.13	309	86588	24300	24	Continuous
R39 (232HT101)	Poly Debutanizer Reboiler stack outlet.	-26.92806	29.28167	37.2	32.2	1.24	267	17530	14516	24	Continuous
R40 (232HT201)	Poly Debutanizer Reboiler stack outlet.	-26.92806	29.28167	37.2	32.2	1.24	226	18754	15529	24	Continuous
R41 (232HT102)	Recycle Column Reboiler stack outlet.	-26.92806	29.28167	51.5	46.5	2.13	309	84654	23757	24	Continuous
<u>Sasol Catalytic Converter</u>											
SCC1 Stack	Main stack	26.55599	29.1639	80	76	1.067	232	410 000	12.5	24	Continuous
SCC2 (TK 1001)	Slurry Storage Tank – N ₂ blanketing	26.55599	29.1639	11	N/A	N/A	N/A	N/A	N/A	24	Intermittent
SCC3 (TK 1002)	Fuel Oil Storage Tank – N ₂ blanketing	26.55599	29.1639	11	N/A	N/A	N/A	N/A	N/A	24	Intermittent
SCC4 (TK 1003)	Fuel Oil Make-up Tank – N ₂ blanketing	26.55599	29.1639	7	N/A	N/A	N/A	N/A	N/A	24	Intermittent
SCC5 (TK 3201)	DEA – Storage Tank – N ₂ blanketing	26.55599	29.1639	9	N/A	N/A	N/A	N/A	N/A	24	Intermittent
SCC6 (TK 3202)	Slop Oil tank – N ₂ blanketing	26.55599	29.1639	5.7	N/A	N/A	N/A	N/A	N/A	24	Intermittent
SCC7 (TK 3401)	Caustic Storage Tank – N ₂ blanketing	26.55599	29.1639	5.5	N/A	N/A	N/A	N/A	N/A	24	Intermittent

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)	Emission Hours	Type of Emission (Continuous / Batch / Intermittent)
SCC8 (TK 3402)	Spent Caustic Tank – N ₂ blanketing	26.55599	29.1639	5.5	N/A	N/A	N/A	N/A	N/A	24	Intermittent
Tar, Phenosolvan and Sulfur:											
<u>Phenosolvan</u>											
P1	Ammonia vent line at west stack	26.5575	29.14993	250	230	0.6	33	30	0.114		Intermittent
P2	Ammonia vent line at east stack	26.56014	29.16841	301	281	0.6	31	30	0.114		Intermittent
<u>Wet Sulfuric Acid</u>											
WSA1 (518ME-1003)	Wet Sulfuric Acid stack	26.559278	29.167642	75	65	2.75	41	206 600	9.73	24	Continuous
<u>Carbo Tar and Coal Tar Filtration</u>											
FPP1 (U86 TK201)	Storage and mixing Tank	26.54895	29.14649	18	12	N/A	N/A	N/A	N/A	24	Batch
FPP2 (U86 TK202)	Storage and mixing Tank	26.54887	29.14697	18	12	N/A	N/A	N/A	N/A	24	Batch
FPP3 (U86 TK203)	Storage and mixing Tank	26.54882	29.14697	18	12	N/A	N/A	N/A	N/A	24	Batch
FPP4 (U86 TK204)	Storage and mixing Tank	26.54876	29.14697	18	12	N/A	N/A	N/A	N/A	24	Batch
FPP5 (U86 ME514)	Stack	26.5487	29.14879	18	14	0.609	17.86	20 000	24	24	Batch
CT1 (39 TK101)	Waxy Oil 30 tank	26.54887	29.1483	10	6	N/A	N/A	N/A	N/A	24	Continuous
CT 2 (39 TK102)	Waxy Oil 30 tank	26.54896	29.14816	10	6	N/A	N/A	N/A	N/A	24	Continuous
CT3 (39 TK103)	Pitch tank	26.54899	29.14762	10	6	N/A	N/A	N/A	N/A	24	Continuous
CT4 (39 TK104)	Pitch tank	26.54887	29.14746	10	6	N/A	N/A	N/A	N/A	24	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)	Emission Hours	Type of Emission (Continuous / Batch / Intermittent)
CT5 (39 TK105)	Pitch tank	26.54875	29.14714	10	6	N/A	N/A	N/A	N/A	24	Continuous
CT6 (39 TK112)	FCC Slurry tank	26.54887	29.14746	10	6	N/A	N/A	N/A	N/A	24	Continuous
CT7 (39 TK 113)	FCC Slurry tank	26.54875	29.14714	10	6	N/A	N/A	N/A	N/A	24	Continuous
CT8 (39 TK 114)	FCC Slurry tank	26.54904	29.1472	10	6	N/A	N/A	N/A	N/A	24	Continuous
CT9 (39 TK 115)	FCC Slurry tank	26.54907	29.14731	10	6	N/A	N/A	N/A	N/A	24	Continuous
CT10 (39TK 201)	Fuel Oil 10	26.5487	29.14711	8	N/A	N/A	N/A	N/A	N/A	24	Continuous
CT11 (39TK 202)	Low Sulfur Heavy Fuel Oil	26.54877	29.14711	8	N/A	N/A	N/A	N/A	N/A	24	Continuous
CT12 (39TK 203)	Low Sulfur Heavy Fuel Oil	26.54884	29.14709	8	N/A	N/A	N/A	N/A	N/A	24	Continuous
CT13 (39TK 204)	Heavy Tar Oil	26.54891	29.14709	8	N/A	N/A	N/A	N/A	N/A	24	Continuous
CT14 (39 H101)	Stack	26.55026	29.14843	60	56	1.53	320	5.74	3.1	24	Continuous
Water and Ash:											
<u>Multi Hearth Sludge Incinerators</u>											
WA1 (52WK-2102)	Stack	26.54617	29.1422	30	10	1.2	80	41 063	10.08	24	Continuous
WA2 (52WK-2202)	Stack	26.54598	29.14155	30	10	1.2	80	41 063	10.08	24	Continuous
WA3 (252WK-2102)	Stack	26.54096	29.14283	30	10	1.2	80	40 298	9.89	24	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)	Emission Hours	Type of Emission (Continuous / Batch / Intermittent)
WA4 (252WK-2202)	Stack	26.54111	29.14226	30	10	1.2	80	40 298	9.89	24	Continuous
<u>HOW Incinerators</u>											
HOW1 (052CI-101)	Chimney	26.5481	29.14257	15	7	1.8	600 (max)	74 731	8.15	24	Continuous
HOW2 (252CI-101)	Chimney	26.5432	29.14331	15	7	1.8	600 (max)	60 055	6.55	24	Continuous
<u>Sewage Incinerator</u>											
SW1 (353IN101)	Chimney	26.53883	29.14611	10	5	0.8	231	4485	4.4	24	Batch
<u>WRF RTO</u>											
WRF	Thermal oxidiser	26.55089	29.1434	20	15	1.25	815	1940	0.44	24	Continuous
<u>Solvents</u>											
1	Regenerator Stack (Octene)	26.5534028	29.1788083	66	63	Approx 1.2m	88.04	66654	16.93	24	Continuous
2	Stack for heater and	26.554425	29.180619	58	52	1	350	27000	9.6	24	Continuous
<u>Polymers</u>											
<u>Monomers West</u>											
1	Furnace A stack	26.54283	29.154	34	30	0.7	300	43000	31	24	Continuous
2	Furnace B stack	26.54283	29.154	34	30	0.7	300	43000	31	24	Continuous
3	Furnace C stack	26.54283	29.154	34	30	0.7	300	43000	31	24	Continuous
4	Furnace D stack	26.54283	29.154	34	30	0.7	300	43000	31	24	Continuous
5	Furnace E stack	26.54283	29.154	34	30	0.7	300	43000	31	24	Continuous
<u>LOC</u>											
1	Central road loading	-29.1648	26.5487	2 -3 m	Not Applicable	Not Applicable	Fugitive emissions				
2	Central road loading	29.1608	26.5488	2 -3 m	Not Applicable	Not Applicable	Fugitive emissions				

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)	Emission Hours	Type of Emission (Continuous / Batch / Intermittent)
Nitro											
1	Nitric Acid Stack	26.5918	29.18227	61	20.5	1.52	100	120 000	18.36	24	Continuous
2	Ammonium Nitrate Production Plant Stack	26.58996	29.18286	45.3	38.8	0.8	76.5	20413	11.28	24	Continuous
3	Granular Fertilizer Production Plant Stack (LAN)	26.9775	29.4086	64	42	3	40	420000	12.38	24	Continuous
4	Ammonium Sulfate Stack	26.7142	29.4147	21		0.91	22.1	40 401	17.25	24	Continuous

Table C-5: Point source emission rates during normal operating conditions

Point Source Code	Pollutant Name	Maximum Release Rate (mg/Nm ³) ^(a)	Average Period	Duration of Emissions
Utilities				
B1 (U43)	Particulate matter	120	Daily	Continuous
	SO ₂	2 000	Daily	Continuous
	NO _x	1 100	Daily	Continuous
B2 (2U43)	Particulate matter	120	Daily	Continuous
	SO ₂	2 000	Daily	Continuous
	NO _x	1 100	Daily	Continuous
GT1	Particulate matter	10	Daily	Continuous
	SO ₂	500	Daily	Continuous
	NO _x	300	Daily	Continuous
GT2	Particulate matter	10	Daily	Continuous
	SO ₂	500	Daily	Continuous
	NO _x	300	Daily	Continuous
Gas Production				
Rectisol East (Off gas to main stack)	H ₂ S (measured as S)	13.5 t/hr (combined with West)	Daily	Continuous
	Total VOC's	300	Hourly	Continuous
	H ₂ S	8 400	Daily	Continuous
Rectisol West (Off gas to main stack)	H ₂ S (measured as S)	13.5 t/hr (combined with East)	Daily	Continuous
	Total VOC's	300	Hourly	Continuous
	H ₂ S	8 400	Daily	Continuous
Gas Circuit				
CM1 (West Kiln Stack)	Particulate matter	100	Hourly	Continuous
	SO ₂	500	Hourly	Continuous
	NO _x expressed as NO ₂	2000	Hourly	Continuous
CM2 (West Arc Furnace stack)	Particulate matter	100	Hourly	Continuous
	SO ₂	500	Hourly	Continuous
	NO _x expressed as NO ₂	500	Hourly	Continuous
CM3 (East Kiln A Stack)	Particulate matter	100	Hourly	Continuous
	SO ₂	500	Hourly	Continuous
	NO _x expressed as NO ₂	2000	Hourly	Continuous
CM4 (East Arc Furnace stack)	Particulate matter	100	Hourly	Continuous
	SO ₂	500	Hourly	Continuous
	NO _x expressed as NO ₂	500	Hourly	Continuous
CM5 (East Kiln B Stack)	Particulate matter	100	Hourly	Continuous
	SO ₂	500	Hourly	Continuous
	NO _x expressed as NO ₂	2000	Hourly	Continuous
Refining				
R1 (14HT101)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R2 (14HT201)	Particulate matter	120	Hourly	Continuous

Point Source Code	Pollutant Name	Maximum Release Rate (mg/Nm ³) ^(a)	Average Period	Duration of Emissions
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R3 (214HT101)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R4 (214HT201)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R5 (228HT101)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R6 (30HT101)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R7 (30HT102)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R8 (30HT103)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R9 (30HT104)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R10 (30HT105)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R11 (230HT101)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R12 (230HT102)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R13 (230HT103)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R14 (230HT104)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R15 (230HT105)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R17 (34HT101)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous

Point Source Code	Pollutant Name	Maximum Release Rate (mg/Nm ³) ^(a)	Average Period	Duration of Emissions
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R18 (234HT101)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R19 (35HT101)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R20 (35HT102)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R22 (235HT101)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R23 (235HT102)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R24 (35HT103)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R25 (35HT104)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R26 (35HT105)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R27 (29HT101)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R28 (29HT102)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R29 (229HT101)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R30 (33HT101)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R31 (33HT102)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R32 (33HT105)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous

Point Source Code	Pollutant Name	Maximum Release Rate (mg/Nm ³) ^(a)	Average Period	Duration of Emissions
R33 (233HT101)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R34 (233HT102)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R35 (233HT105)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R36 (32HT101)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R37 (32HT201)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R38 (32HT102)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R39 (232HT101)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R40 (232HT201)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
R41 (232HT102)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
SCC5 Stack	Particulate matter	330	Hourly	Continuous
	SO ₂	3000	Hourly	Continuous
	NO _x expressed as NO ₂	550	Hourly	Continuous
Tar, Phenosolvan and Sulfur (TPS)				
WSA1 (518-ME-1003)	SO ₂	2800	Hourly	Continuous
	SO ₃	100	Hourly	Continuous
	NO _x	2000	Hourly	Continuous
Water and Ash ^(a) emission limits in line with the alternative emission limit applied for ^(b) Average concentrations measured quarterly for preceeding 2 years. Incinerator will be decommissioned in first quarter of 2017.				
WA1 (052WK-2102) ^(a)	Particulate matter	600	Hourly	Continuous
	CO	4 422	Hourly	Continuous
	SO ₂	205	Hourly	Continuous
	NO _x expressed as NO ₂	714	Hourly	Continuous
	HCl	29	Hourly	Continuous
	HF	20	Hourly	Continuous

Point Source Code	Pollutant Name	Maximum Release Rate (mg/Nm ³) ^(a)	Average Period	Duration of Emissions
	Pb+As+Sb+Cr+Co+Cu+Mn+Ni+V	2.6	Hourly	Continuous
	Hg	0.95	Hourly	Continuous
	Cd+Tl	0.12	Hourly	Continuous
	TOC	4 216	Hourly	Continuous
	NH ₃	52	Hourly	Continuous
	Dioxins and furans	0.31 (ng I-TEQ/Nm ³)	Hourly	Continuous
WA2 (052WK-2202) ^(a)	Particulate matter	600	Hourly	Continuous
	CO	4 422	Hourly	Continuous
	SO ₂	205	Hourly	Continuous
	NO _x expressed as NO ₂	714	Hourly	Continuous
	HCl	29	Hourly	Continuous
	HF	20	Hourly	Continuous
	Pb+As+Sb+Cr+Co+Cu+Mn+Ni+V	2.6	Hourly	Continuous
	Hg	0.95	Hourly	Continuous
	Cd+Tl	0.12	Hourly	Continuous
	TOC	4 216	Hourly	Continuous
	NH ₃	52	Hourly	Continuous
	Dioxins and furans	0.31 (ng I-TEQ/Nm ³)	Hourly	Continuous
WA3 (252WK-2102) ^(a)	Particulate matter	600	Hourly	Continuous
	CO	4 422	Hourly	Continuous
	SO ₂	205	Hourly	Continuous
	NO _x expressed as NO ₂	714	Hourly	Continuous
	HCl	29	Hourly	Continuous
	HF	20	Hourly	Continuous
	Pb+As+Sb+Cr+Co+Cu+Mn+Ni+V	2.6	Hourly	Continuous
	Hg	0.95	Hourly	Continuous
	Cd+Tl	0.12	Hourly	Continuous
	TOC	4 216	Hourly	Continuous
	NH ₃	52	Hourly	Continuous
	Dioxins and furans	0.31 (ng I-TEQ/Nm ³)	Hourly	Continuous
WA4 (252WK-2202) ^(a)	Particulate matter	600	Hourly	Continuous
	CO	4 422	Hourly	Continuous
	SO ₂	205	Hourly	Continuous
	NO _x expressed as NO ₂	714	Hourly	Continuous
	HCl	29	Hourly	Continuous
	HF	20	Hourly	Continuous
	Pb+As+Sb+Cr+Co+Cu+Mn+Ni+V	2.6	Hourly	Continuous
	Hg	0.95	Hourly	Continuous
	Cd+Tl	0.12	Hourly	Continuous
	TOC	4 216	Hourly	Continuous
	NH ₃	52	Hourly	Continuous
	Dioxins and furans	0.31 (ng I-TEQ/Nm ³)	Hourly	Continuous
SW1 (353IN101) ^(b)	Particulate matter	26	Hourly	Continuous

Point Source Code	Pollutant Name	Maximum Release Rate (mg/Nm ³) ^(a)	Average Period	Duration of Emissions
	CO	193	Hourly	Continuous
	SO ₂	20	Hourly	Continuous
	NO _x expressed as NO ₂	200	Hourly	Continuous
	HCl	10	Hourly	Continuous
	HF	1.6	Hourly	Continuous
	Pb+As+Sb+Cr+Co+Cu+Mn+Ni+V	1.3	Hourly	Continuous
	Hg	0.7	Hourly	Continuous
	Cd+Tl	0.05	Hourly	Continuous
	TOC	92	Hourly	Continuous
	NH ₃	10	Hourly	Continuous
	Dioxins and furans	0.19 (ng I-TEQ/Nm ³)	Hourly	Continuous
HOW1 (052CI-101) ^(a)	Particulate matter	1 354	Hourly	Continuous
	CO	1 400	Hourly	Continuous
	SO ₂	546	Hourly	Continuous
	NO _x expressed as NO ₂	3 800	Hourly	Continuous
	HCl	55	Hourly	Continuous
	HF	10	Hourly	Continuous
	Pb+As+Sb+Cr+Co+Cu+Mn+Ni+V	21	Hourly	Continuous
	Hg	0.27	Hourly	Continuous
	Cd+Tl	0.12	Hourly	Continuous
	TOC	38	Hourly	Continuous
	NH ₃	12	Hourly	Continuous
	Dioxins and furans	4.2 (ng I-TEQ/Nm ³)	Hourly	Continuous
HOW2 (252CI-101) ^(a)	Particulate matter	1 354	Hourly	Continuous
	CO	1 400	Hourly	Continuous
	SO ₂	546	Hourly	Continuous
	NO _x expressed as NO ₂	3 800	Hourly	Continuous
	HCl	55	Hourly	Continuous
	HF	10	Hourly	Continuous
	Pb+As+Sb+Cr+Co+Cu+Mn+Ni+V	21	Hourly	Continuous
	Hg	0.27	Hourly	Continuous
	Cd+Tl	0.12	Hourly	Continuous
	TOC	38	Hourly	Continuous
	NH ₃	12	Hourly	Continuous
	Dioxins and furans	4.2 (ng I-TEQ/Nm ³)	Hourly	Continuous
Solvents				
1 (Regenerator Stack, Octene)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	200	Hourly	Continuous
2 (HT 1901/HT1902)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	200	Hourly	Continuous
Polymers				

Point Source Code	Pollutant Name	Maximum Release Rate (mg/Nm ³) ^(a)	Average Period	Duration of Emissions
1 (Furnace A stack)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
2 (Furnace B stack)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
3 (Furnace C stack)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
4 (Furnace D stack)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
5 (Furnace E stack)	Particulate matter	120	Hourly	Continuous
	SO ₂	1700	Hourly	Continuous
	NO _x expressed as NO ₂	1700	Hourly	Continuous
Oil				
All sources	VOCs (non-thermal)	40000	24 hours	Continuous
Nitro				
1 Nitric Acid Stack	NO _x expressed as NO ₂	2000	Hourly	Continuous
	NH ₃	100	Hourly	Continuous
2 Ammonium Nitrate Stack	NH ₃	180 mg/Nm ³ on a wet basis	Hourly	Continuous
	Particulate matter	50 mg/Nm ³ on a wet basis	Hourly	Continuous
3 Granular Fertilizer (LAN) stack	NH ₃	300	Hourly	Continuous
	Particulate matter	100	Hourly	Continuous
4 (Ammonium Sulfate Stack	NH ₃	100	Hourly	Continuous
	Particulate matter	100	Hourly	Continuous

(a) units are mg/Nm³ unless otherwise specified

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 Sasolburg⁴ and 3 Secunda⁵)	•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.	•Sasol operated surface meteorological weather stations (3 Sasolburg and 3 Secunda) •Closest upper air monitoring station is at OR Tambo	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

⁴ AJ Jacobs (WS, WD, SO₂, NO₂, PM₁₀, PM_{2.5}); Leitrim (WS, WD, TEMP, AMB PRESS, RH, SO₂, NO₂, PM₁₀, PM_{2.5}) and Eco Park (WS, WD, TEMP, RH, AMB PRESS, SOL RAD, RAIN, SO₂, O₃, NO₂, PM₁₀, PM_{2.5})

⁵ Sasol Club (WS, WD, TEMP, NO₂, SO₂, O₃, PM₁₀, PM_{2.5}, CO); Bosjesspruit (WS, WD, TEMP, NO₂, SO₂, H₂S, PM₁₀, PM_{2.5}) and Embalenhle (WS, WD, TEMP, NO₂, SO₂, PM₁₀, PM_{2.5}, Benzene)

Run Type	Description of Run Type	Ease of Use and Representativeness	Data availability	Advantages	Disadvantages
		•Considered representative if sufficient observation stations and site-specific choice of parameters by the modeller.	International Airport (twice-daily soundings only)		•Soundings at incorrect time of 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 SO₂, SO₄²⁻, NO, NO₂, HNO₃, and NO₃ - (RIVAD/ARM3 method)	- RIVAD is a 6-species scheme wherein NO and NO₂ are treated separately. - In the RIVAD scheme the conversion of SO₂ 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 NO₂ for each source. - Two options are specified for the ozone concentrations: (1) hourly ozone concentrations from a network of stations, or (2)	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 NO₂ 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
			a single user defined ozone value. • The background ammonia concentrations required for the $\text{HNO}_3/\text{NH}_4\text{NO}_3$ 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 $\text{HNO}_3/\text{NH}_4\text{NO}_3$ 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/NO_x CONVERSION RATIOS FOR NO₂ FORMATION

Scire and Borissova (2011) analysed hourly monitored NO₂ 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) NO₂/NO_x ratios were developed on bin-maximum data, whereas the long-term (annual average) NO₂/NO_x ratios were based on bin-averaged data. The method was subsequently tested using the NO₂/NO_x ratios applied to the observed NO_x at selected stations to predict NO₂, and then compared to observed NO₂ 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 NO₂ can be obtained, albeit mostly more conservative. In Figure F-3, the method is compared to the assumption of 100% conversion over the short-term, which clearly illustrates the extreme conservatism, especially at elevated concentrations.

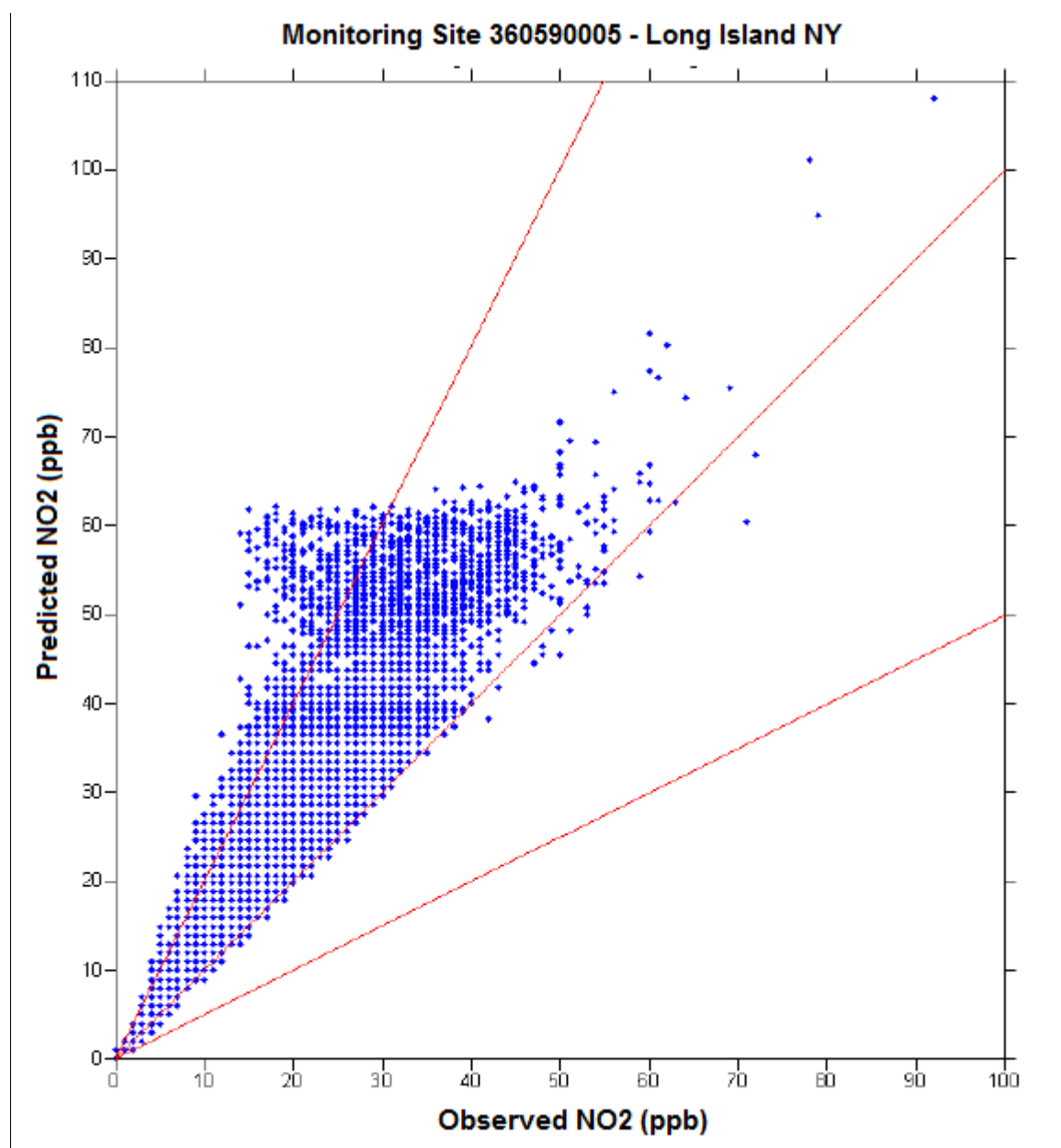


Figure F-1: Comparison of observed with predicted NO₂ concentrations (Long Island, NY) using the derived short-term NO₂/NO_x ratios (Scire and Borissova, 2011)

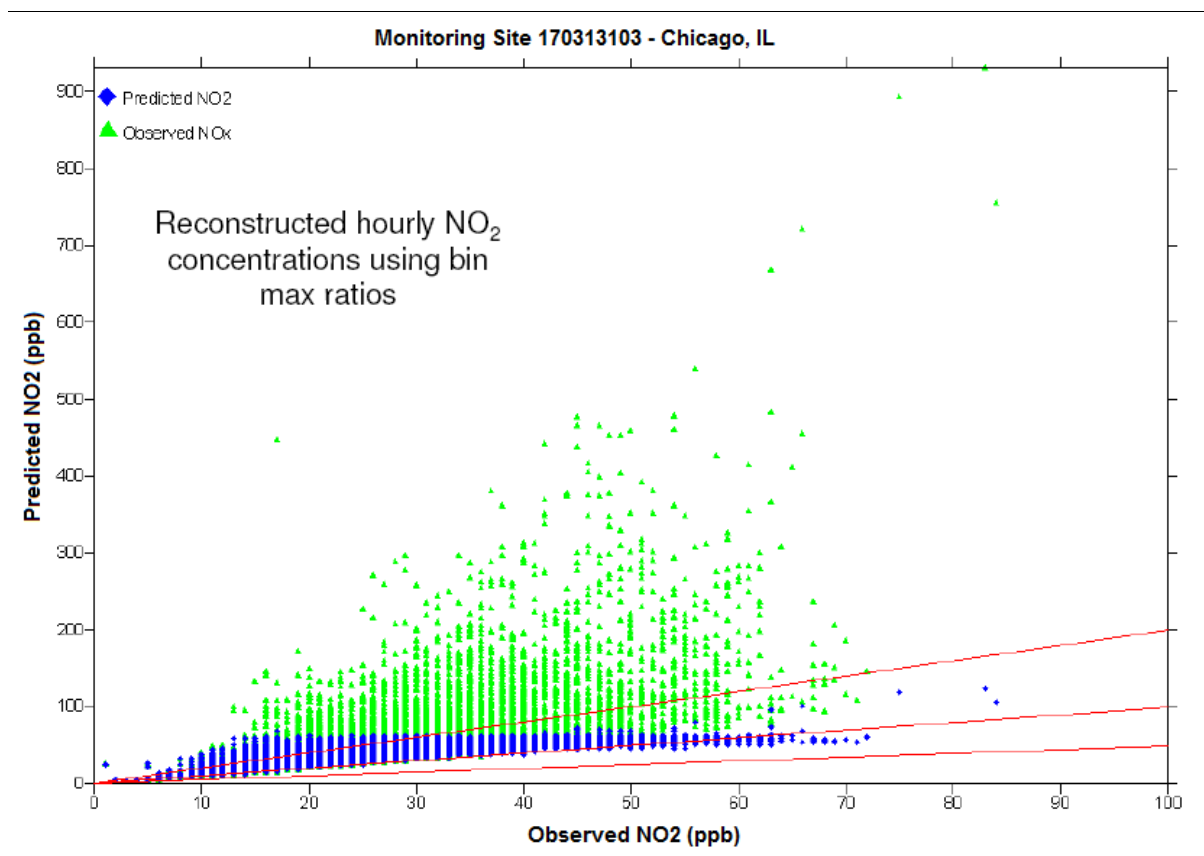


Figure F-2: Comparison of observed with predicted NO₂ concentrations (Chicago, IL) using the derived short-term NO₂/NO_x ratios (Scire and Borissova, 2011)

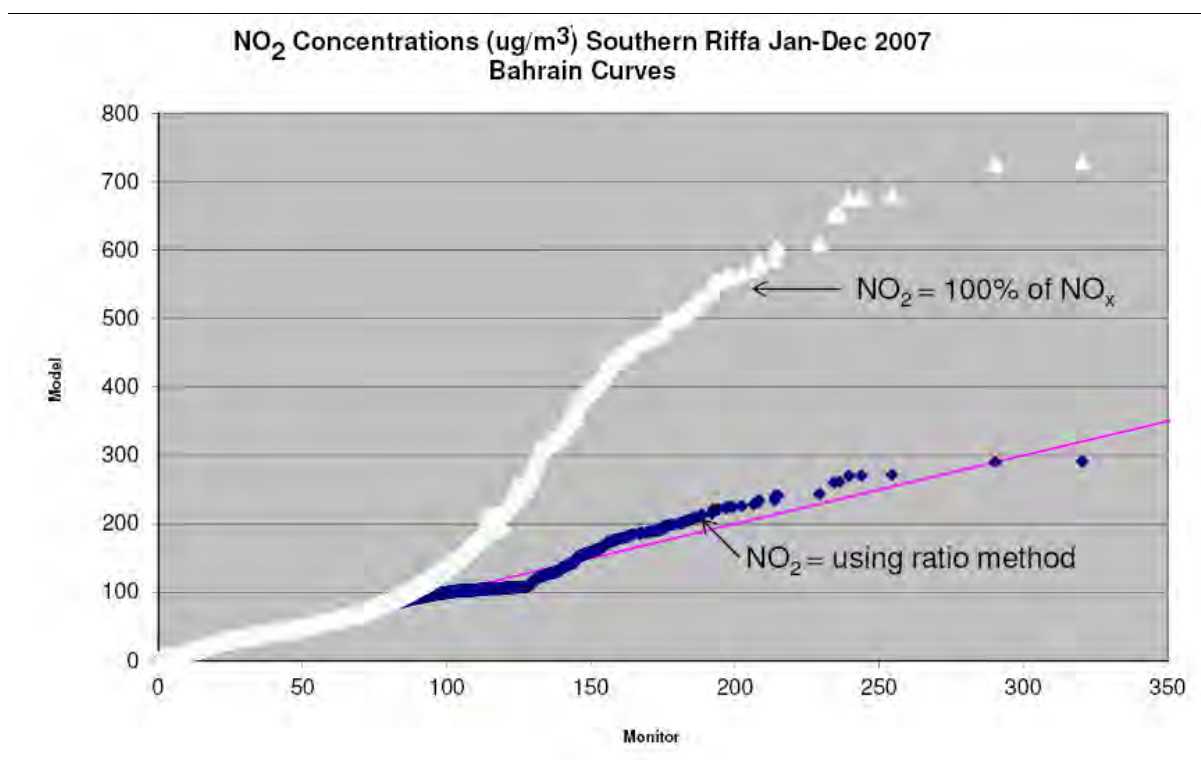


Figure F-3: Observed versus predicted NO₂ concentrations (Bahrain) using the derived short-term NO₂/NO_x ratios (Scire and Borissova, 2011)

It was decided that the NO₂/NO_x conversion factors described by Scire and Borissova (2011) and as given in Table F-1, will be employed in this study. Observed NO₂/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 NO₂/NO_x ratios at the site would have been used instead.

Table F-1: NO₂/NO_x conversion ratios for NO₂ formation

Bin	Concentration (ug/m ³)			NO ₂ /NO _x 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

Bin	Concentration ($\mu\text{g}/\text{m}^3$)			NO ₂ /NO _x Ratios			
				Sasolburg		Scire and Borissova 2011	
	Min	Max	Centre	AJ Jacobs 2010-2012	Ecopark 2012	Bin Average	1-Hour Max
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

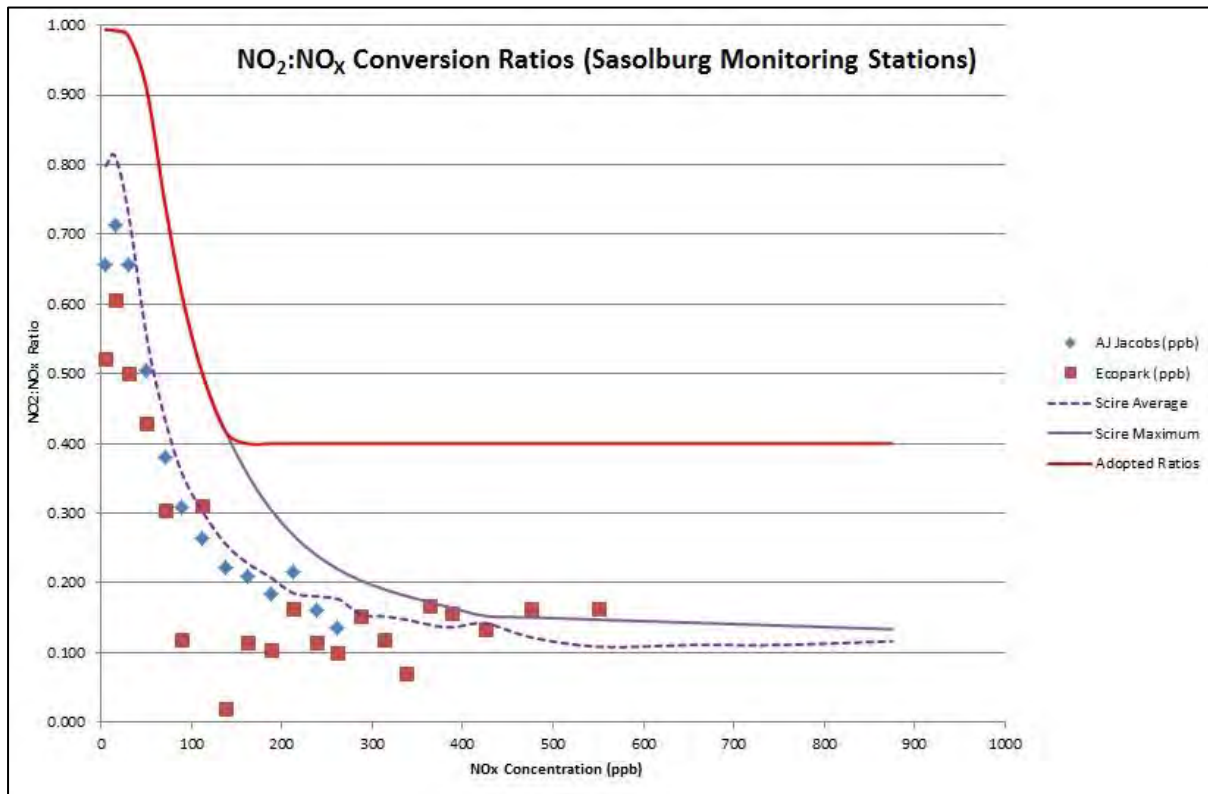


Figure F-4: NO₂/NO_x conversion ratios for Sasol's Sasolburg monitoring stations

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.

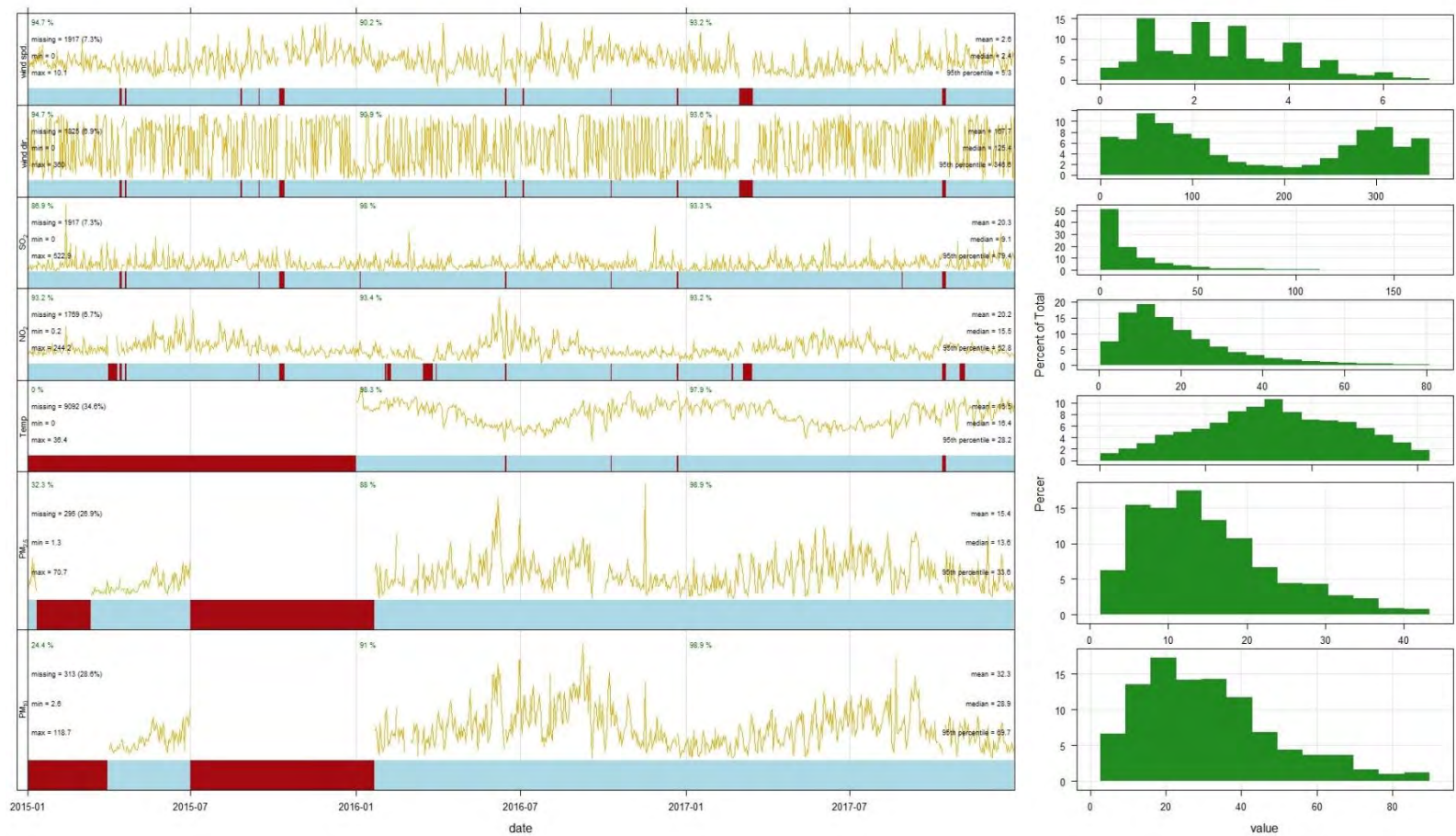


Figure G-1: Data available from the Secunda Club ambient air quality monitoring station (2015-2017)

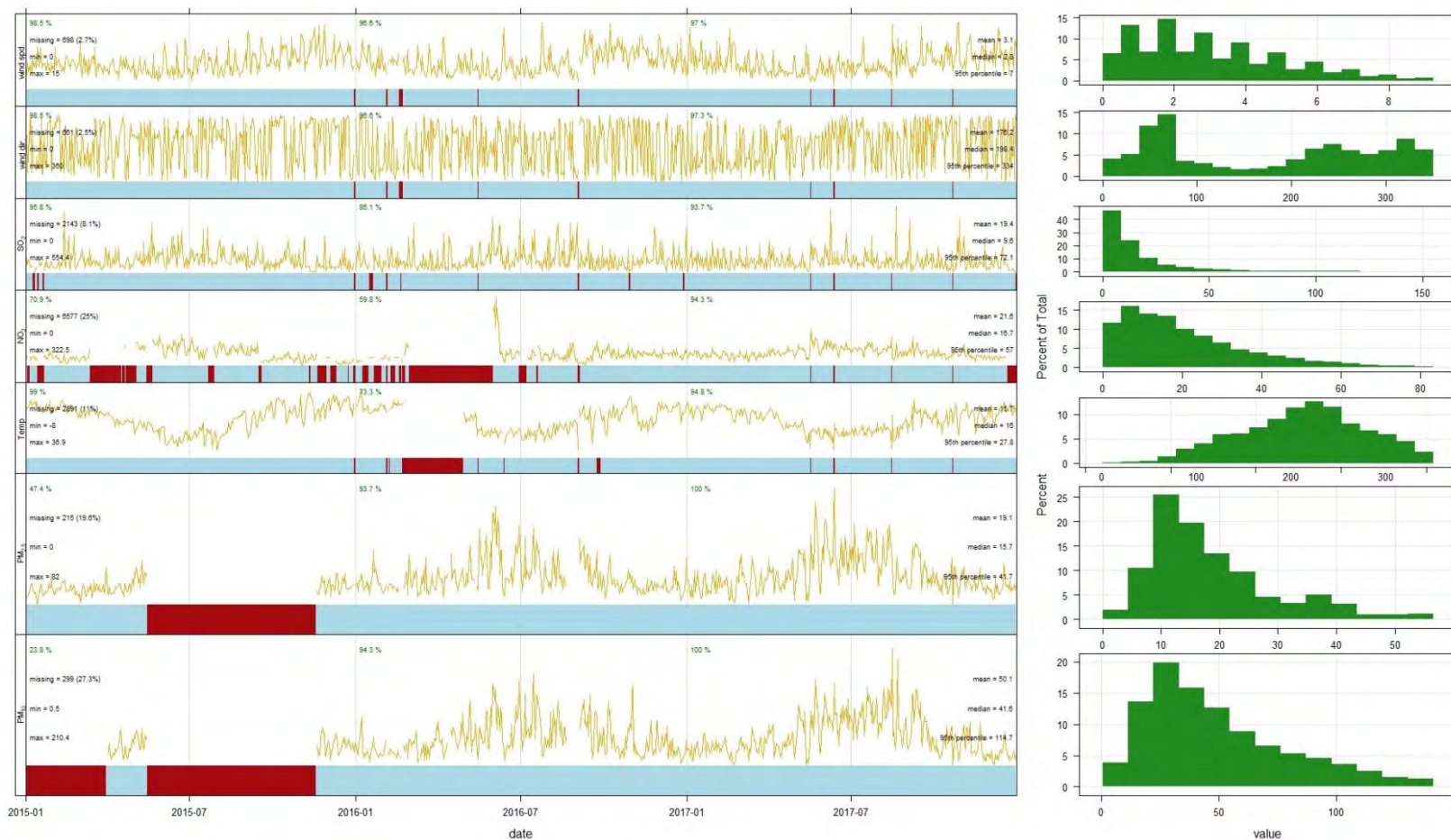


Figure G-2: Data available from the Sasol Embalenhle ambient air quality monitoring station (2015-2017)

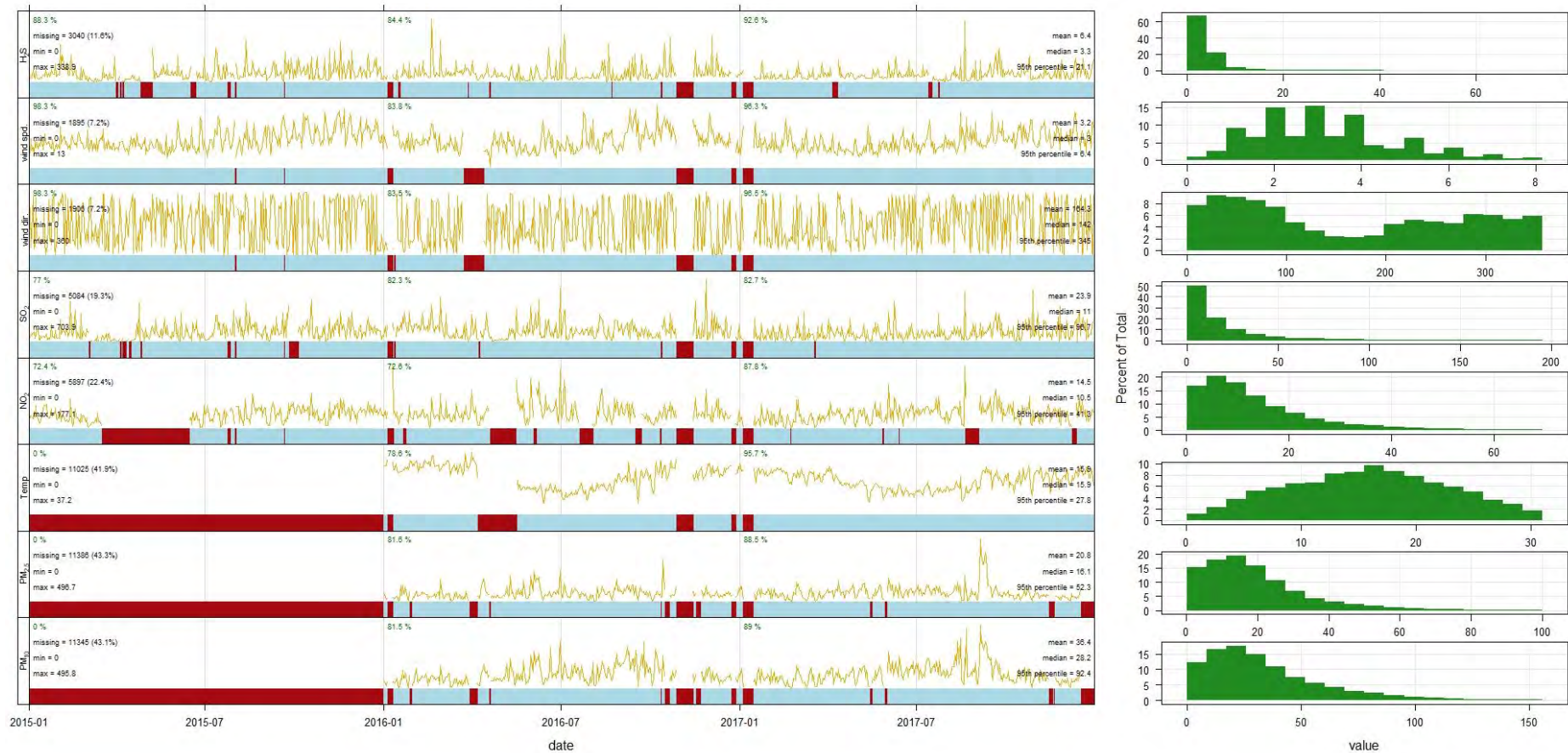


Figure G-3: Data available from the Bosjesspruit ambient air quality monitoring station (2015-2017)

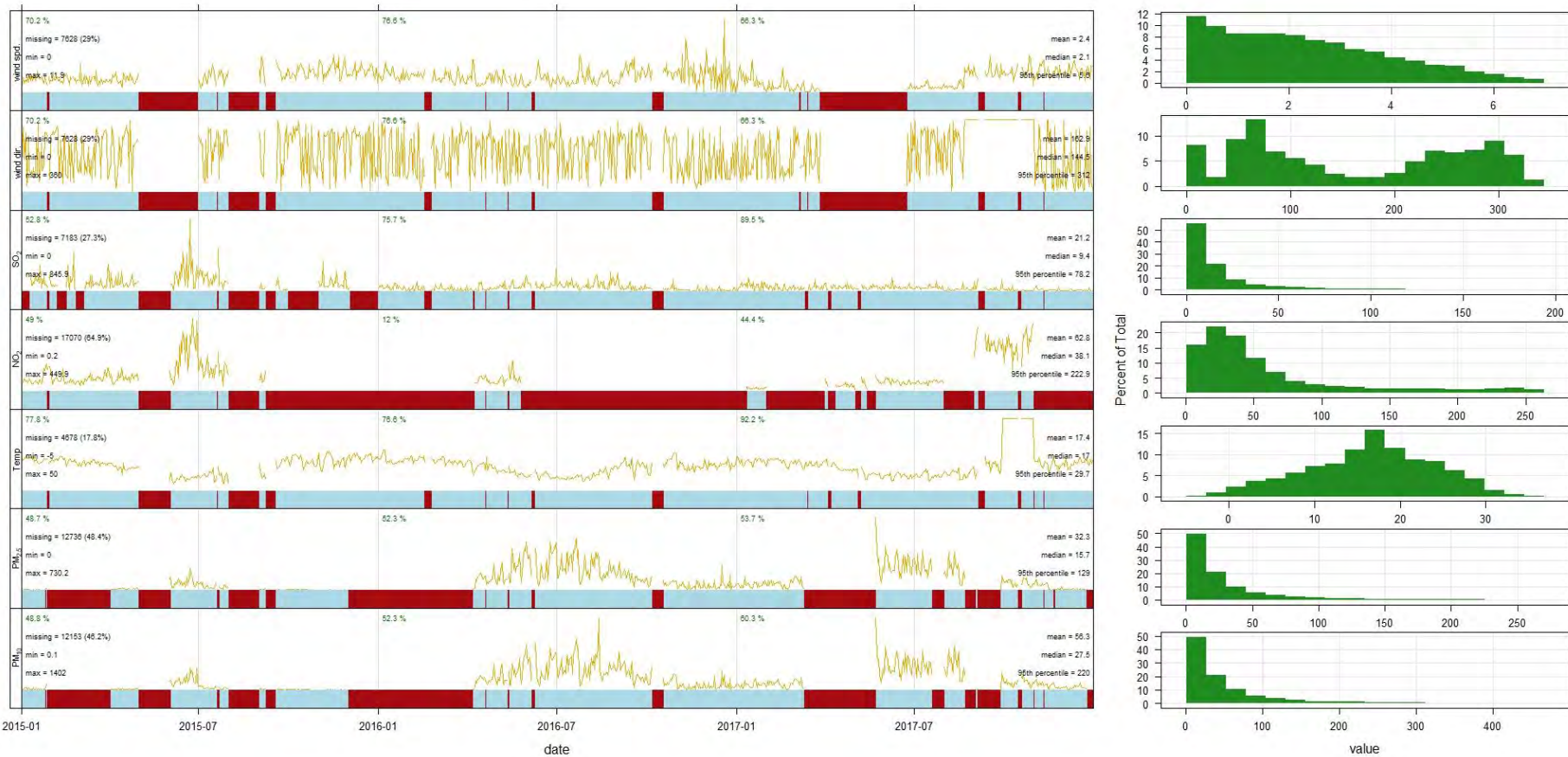


Figure G-4: Data available from the DEA Secunda ambient air quality monitoring station (2015-2017)

APPENDIX H: PREDICTED BASELINE AND OBSERVED AIR CONCENTRATIONS

The following tables summarise the predicted baseline SO₂ and NO₂ 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 (Secunda Operations) 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 SO₂ concentration from routine emissions and observed SO₂ concentration statistics

Description	Year	Bosjesspruit		Secunda Club		Embalenhle		Secunda	
		Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed
Maximum	2015	376.97	442.65	686.73	506.98	484.68	397.46	626.10	845.95
	2016	457.10	703.86	663.76	522.90	849.33	536.26	347.90	502.73
	2017	487.28	389.15	704.97	510.74	740.36	554.42	760.83	802.24
	Average	440.45	511.89	685.15	513.54	691.46	496.05	578.28	716.97
99 th Percentile	2015	164.06	203.22	162.31	176.19	98.44	142.91	89.06	330.09
	2016	161.60	190.43	122.91	158.19	107.70	176.21	82.48	144.26
	2017	172.57	177.50	136.65	170.09	134.42	145.74	139.15	98.40
	Average	166.08	190.38	140.63	168.16	113.52	154.95	103.56	190.92
90 th Percentile	2015	8.32	48.51	4.64	51.21	1.48	43.84	0.97	96.66
	2016	6.67	61.54	2.20	47.03	1.53	50.54	1.04	39.95
	2017	6.95	55.69	3.39	50.50	2.02	41.42	1.39	27.77
	Average	7.31	55.25	3.41	49.58	1.68	45.27	1.13	54.79
50 th Percentile	2015	0.00	7.43	0.00	9.61	0.00	10.39	0.00	17.73
	2016	0.00	14.36	0.00	8.20	0.00	9.67	0.00	8.91
	2017	0.00	8.20	0.00	9.83	0.00	8.46	0.00	6.55
	Average	0.00	9.99	0.00	9.21	0.00	9.51	0.00	11.06
Annual Average	2015	7.53	19.90	6.57	21.13	3.18	19.48	2.92	39.83
	2016	7.30	26.40	4.42	19.17	3.65	20.65	2.64	17.91
	2017	7.80	21.19	5.34	20.86	4.31	17.90	4.32	12.94

Description	Year	Bosjesspruit		Secunda Club		Embalenhle		Secunda	
		Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed
	<i>Average</i>	7.54	22.50	5.44	20.39	3.71	19.34	3.30	23.56
Background (observed value when simulation indicated little contribution (0.1 µg/m³))	2015		15.89		22.29		23.48		54.12
	2016		25.47		23.71		20.03		23.22
	2017		18.16		24.37		16.98		14.41
	<i>Average</i>		19.84		23.46		20.16		30.58

Table H-2: Simulated NO₂ concentration from routine emissions and observed NO₂ concentration statistics

Description	Year	Bosjesspruit		Secunda Club		Embalenhle		Secunda	
		Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed
Maximum	2015	119.88	129.75	221.93	185.76	143.60	118.90	189.22	449.87
	2016	138.93	177.11	209.11	244.25	244.44	322.51	104.07	323.53
	2017	150.15	150.79	211.05	154.67	215.02	113.36	236.86	289.52
	<i>Average</i>	136.32	152.55	214.03	194.89	201.02	184.93	176.72	354.31
99 th Percentile	2015	58.88	61.53	58.85	83.44	52.04	80.46	50.28	289.57
	2016	58.96	74.70	54.43	84.12	53.33	106.88	49.90	113.92
	2017	59.93	72.02	56.34	72.95	55.76	75.94	56.86	257.56
	<i>Average</i>	59.25	69.42	56.54	80.17	53.71	87.76	52.35	220.35
90 th Percentile	2015	9.17	28.39	5.40	41.71	3.95	47.36	2.10	140.11
	2016	8.03	32.61	3.47	39.44	4.93	43.38	2.59	59.28
	2017	8.92	31.92	4.38	39.05	5.74	44.87	3.30	212.44
	<i>Average</i>	8.71	30.97	4.42	40.07	4.87	45.20	2.66	137.27

Description	Year	Bosjesspruit		Secunda Club		Embalenhle		Secunda	
		Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed
50th Percentile	2015	0.00	10.69	0.00	17.06	0.00	14.53	0.00	44.83
	2016	0.00	11.30	0.00	12.30	0.00	15.40	0.00	26.35
	2017	0.00	9.59	0.00	16.04	0.00	18.89	0.00	31.96
	Average	0.00	10.52	0.00	15.13	0.00	16.27	0.00	34.38
Annual Average	2015	4.12	13.95	3.43	22.00	2.08	20.32	1.73	64.38
	2016	4.01	15.53	2.58	17.48	2.40	21.23	1.76	31.18
	2017	4.17	14.21	3.01	19.91	2.72	22.65	2.35	66.40
	Average	4.10	14.56	3.00	19.80	2.40	21.40	1.95	53.98
Background (observed value when simulation indicated little contribution (0.1 µg/m³))	2015		14.47		25.49		29.23		92.14
	2016		15.32		22.47		24.16		43.24
	2017		14.72		24.78		26.52		65.80
	Average		14.84		24.25		26.63		67.06

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 ± 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 NO₂).

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 2015, 2016 and 2017 to the Sasol monitoring data collected over the same time period. In particular, the simulated SO₂ and NO₂ concentrations arising from the Secunda operations were included 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). Fractional biases were computed for SO₂ and NO₂ as simulated and observed at the four monitoring stations; Bosjesspruit, Secunda Club, Embalenhle and Secunda. 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 three ambient air quality monitoring stations in and around Secunda, namely at Bosjesspruit, Secunda Club and Embalenhle. Data for 2015 to 2017 from the monitoring stations were included in this investigation.

All of the abovementioned 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 Secunda Operations 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 PM₁₀ Air Emissions

All particulate matter was assumed to be PM_{2.5} since it was not possible to establish the PM_{2.5}/PM₁₀ 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.

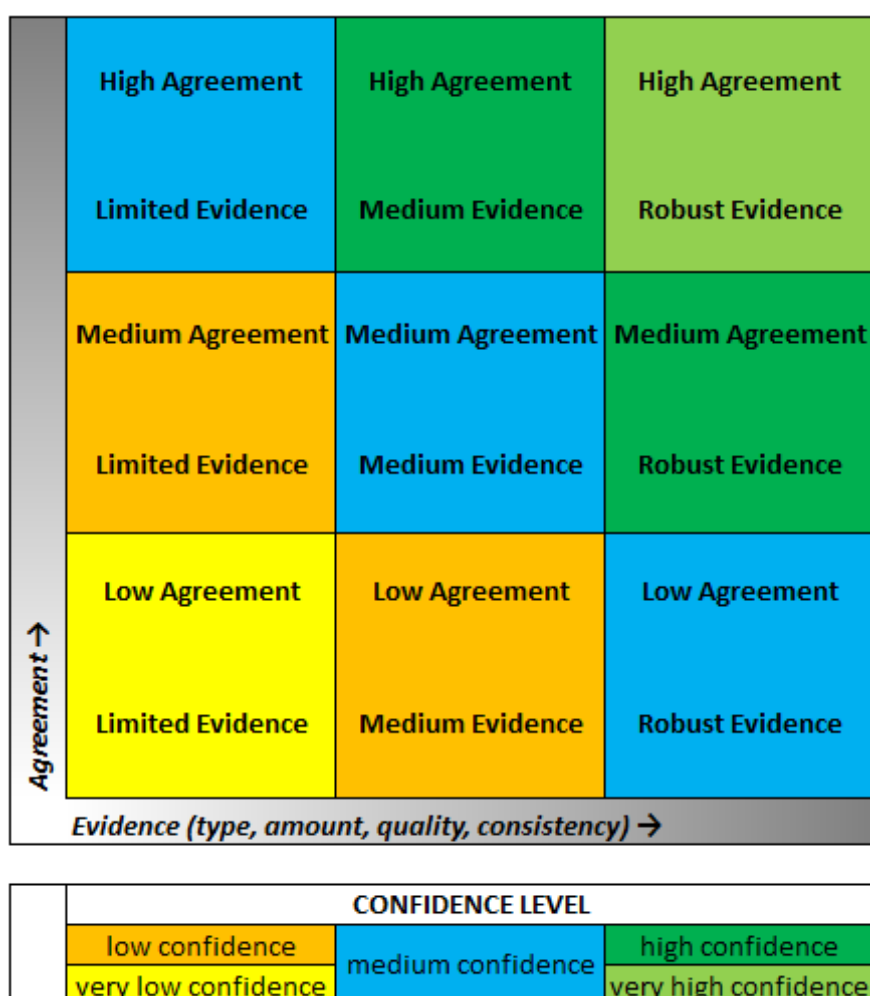


Figure J-1: A depiction of evidence and agreement statements and their relationship to confidence. Confidence increases towards the top-right corner as suggested by the increasing strength of shading. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality 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 $\geq 66\%$ (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)
Embalenhle	Sasol Embalenhle Monitoring Station (previously Langverwacht)	3.3
Secunda Club	Sasol Secunda Club Monitoring Station	6.3
Secunda	HPA Secunda/ Embalenhle Monitoring Station	6.0
Bosjesspruit	Sasol Bosjesspruit Monitoring Station	8.3
42	Roodebank Combined School	4.5
60	Zamokuthle Primary School	5.8
46	Osizweni Secondary School	6.1
55	Isibanisesizwe Primary School	6.3
41	Maphala-Gulube Primary School	6.3
56	Kiriyatswane Secondary School	6.3
48	Osizweni Primary School	6.4
57	Kusasaletu Secondary School	6.5
58	Laerskool Oranjegloed	6.7
62	Highveld Medi Clinic/Hydromed	7.2
53	Tholukwazi Primary School	7.3
30	TP Stratten Primary School	7.3
59	School	7.5
33	Laerskool Goedehoop	7.5
38	Laerskool Kruinpark	7.5
52	Lifalethu Primary School	7.6
61	Secunda Mediclinic	7.7
50	Embalenhle Primary School	7.8
51	Buyani Primary School	8.0
54	Allan Makhunga Primary School	8.1
36	Highveld Park Secondary School	8.3
37	Hoërskool Secunda	8.7
45	Muzimuhle Primary School	9.1
47	KT Twala Secondary School	9.3
34	Laerskool Trichard	9.3
49	Laerskool Secunda	9.5
39	Trichardsfontein School	9.5
31	Hoërskool Evander	10.3
32	Thomas Nhlabathi Secondary School	10.3
28	Laerskool Hoëveld	10.4
29	Thorisong Primary School	10.6
64	Vukuzithathe Primary School	10.8
35	Highveld Ridge Primary School	11.3
63	Evander Hospital	11.8
43	Qinile Primary School	11.9
40	Shapeve Primary School	12.6
25	Thistle Grove Combined School	16.6
27	Inganawe Primary School	17.2
23	Kinross Primary School	17.5
26	Sasolia Primary School	18.2
24	Laerskool Kinross	19.0
44	Adullam Combined School	20.3
17	Chief Ampie Mayisa Secondary School	30.1
22	Highveld Muslim Combined School	30.2
21	Wildebesspruit Primary School	30.3
16	Vukuqhakaze Secondary school	30.5
18	Sidingulwazi Primary School	30.9
19	Laerskool Leandra	31.0
20	Mpumelelo Primary School	33.5

LAKES ENVIRONMENTAL WRF MODELING

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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.



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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).

Table 1 presents the grid dimensions and number of grid points 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

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



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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



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#	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 / m ²)
5	Long wave radiation at the top	(W / m ²)
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>



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