



AIR QUALITY MANAGEMENT PLAN

CITY OF JOHANNESBURG, 2019

Table of Contents

Executive summary	5
List of Figures	11
List of Tables	13
List of Abbreviations, Acronyms and Chemical Compounds	15
1 Introduction: City of Johannesburg	17
1.1 Geographical setting	17
1.2 Demographics	17
1.2.1 Socio-economic status	18
1.3 Climate, topography and local meteorology	18
1.3.1 Potential impacts from climate change	20
2 Purpose of the AQMP	21
2.1 Policy Context of AQMP	21
2.1.1 NEMAQA	22
2.1.2 NDP	24
2.1.3 GDS.....	25
2.1.4 IDP 2016/2021	26
2.2 AQMP approach.....	30
2.3 2003 AQMP	31
3 Status Quo: Ambient air quality monitoring.....	31
3.1 Air quality monitoring network.....	31
3.2 State of ambient air quality in relation to NAAQS.....	36
3.2.1 Summary of the state of monitored ambient air quality.....	45
3.3 Ambient air quality monitoring gaps	45
3.4 Impact of air pollution in CoJ	46
3.5 Air quality complaints	47
4 Status Quo: Emissions inventory	48
4.1 Emissions inventory gaps.....	52
4.1.1 Waste Burning.....	52
4.2 Trends in emissions in CoJ	53
5 Status Quo: Air quality modelling	53
5.1 Model-measurement comparison	53

5.2	Hotspot analysis	53
5.3	Emission reduction scenario modelling	61
5.3.1	Wind-blown dust from TSF	61
5.3.2	On-road vehicles	62
6	Status Quo: Resource gap assessment	65
7	Conclusions from Status Quo Assessment.....	66
8	Approach to air quality management and improving air quality.....	67
8.1	Improvement and application of environmental governance cycle in the City of Johannesburg.....	70
8.2	Prioritised problem complexes	70
8.2.1	Improving air quality management.....	70
8.2.2	Emission reductions	70
8.3	Transboundary pollution and collaboration	71
8.3.1	Alignment with Gauteng Provincial AQMP	72
9	Air Quality Management Actions.....	73
9.1	AQMP vision, mission and AQMP Goals	73
9.1.1	Vision.....	73
9.1.2	Mission.....	73
9.1.3	AQMP Goals	74
9.2	AQMP Implementation	76
9.2.1	Goal 1: Cross-sectoral collaboration for improving air quality	76
9.2.2	Goal 2: Regulate emission sources	86
9.2.3	Goal 3: Air quality management system.....	88
9.2.4	Goal 4: Capacity Building	90
9.2.5	Goal 5: Empowerment of CoJ citizens about air quality.....	92
9.2.6	Goal 6: Innovation and research.....	95
9.3	Timeline.....	97
9.4	Budgetary needs	98
9.5	Technical tools budget considerations	99
9.6	Recapitalisation of monitoring instruments and expansion of stations.....	99
9.7	Reporting on implementation of AQMP	101
9.7.1	External Stakeholder Forum	102

10 Summary 102

11 References 103

Executive summary

While air quality management activities have been on-going in the City of Johannesburg (CoJ) since 2003, there has been a lack of a continuous effort to improve air quality. Currently, the air pollution in the City is not in compliance at many sites of the National Ambient Air Quality Standards (NAAQS) (Summary in Table E1). It is not possible, however, to estimate trends in either ambient air pollution or air pollutant emissions due to a lack of historical data.

Table E1. Summary of City of Johannesburg's ambient air pollutant concentrations

Pollutants	Summary of ambient concentrations
Sulphur dioxide (SO ₂)	Ambient concentrations of SO ₂ are relatively low in the CoJ, with occasional exceedances of the limit value of the ambient standards, but there are no exceedances of the allowed frequency of exceedances.
Nitrogen dioxide (NO ₂)	Concentrations are fairly high surrounding the major highways and traffic zones. The largest number of exceedances of the NO ₂ National Ambient Air Quality Standard is from the Buccleuch and Newtown monitoring stations.
Particulate Matter (PM ₁₀)	Concentrations of PM ₁₀ are generally highest at the stations located within low-income areas. Concentrations frequently exceed the daily and annual ambient standards at these stations.
Particulate Matter (PM _{2.5})	There are only data available from the Buccleuch station for the period 2004 to 2015. There are, however, exceedances of the daily and annual ambient standards during these years.
Carbon Monoxide (CO)	Ambient concentrations of CO are relatively low throughout the CoJ.
Ozone (O ₃)	Ambient concentrations are relatively high within the vicinity of the Delta Park station, with a number of exceedances of the 8-hour running average ambient air quality standard.
Benzene (C ₆ H ₆)	A limited amount of data for the ambient concentrations of benzene was only available from the Buccleuch monitoring station, and as such, was excluded from this analysis. Data recovery and the quality of data that was available were poor.
Lead (Pb)	Ambient concentrations of lead have decreased significantly throughout the country and are no longer monitored in most ambient monitoring networks.

The estimated share of emissions between sectors highlights that different sources are important for different pollutants, and thus management of specific sources may result in improvement of air quality, but only for certain pollutants (Figure E1). This means that source-specific management efforts need to be done in concert to effectively improve air quality.

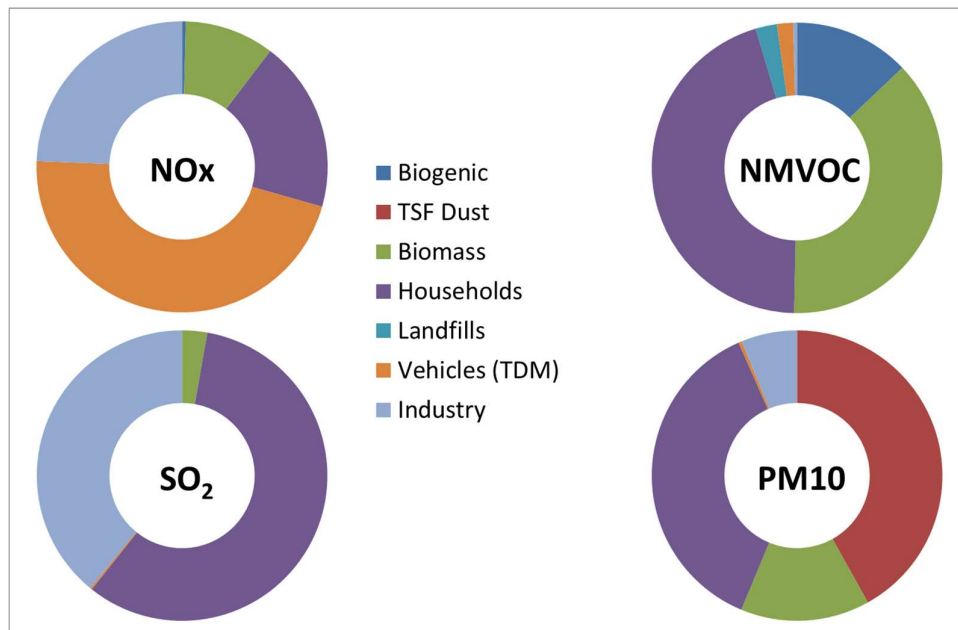


Figure E1. Summary of sector contribution to total annual criteria pollutant emissions within CoJ. In these estimates, the Travel Demand Model was used for the vehicle emissions estimates.

Air quality management is an on-going and continuous process performed in order to improve and then maintain good air quality that is in compliance with relevant national standards. This can be achieved through the necessary periodic review and update of Air Quality Management Plans (AQMP) every five years. However, air quality management is not just restricted to these periodic reviews, but rather it is an on-going and iterative process. An AQMP, apart from being a legislative requirement (Section 15(2) of the National Environmental Management Air Quality Act (NEMAQA) for a municipality such as CoJ, provides a valuable tool for the City to ensure a healthy living environment for its occupants. The last AQMP for the CoJ was completed in 2003, which leaves a gap that falls outside the recommended 5 year frequency for review. It was thus vitally important to develop an updated AQMP.

Approach to air quality management

This air quality management process can be illustrated through the environmental governance cycle, shown in Figure E2 (adapted from DEA, 2010). Enabling factors are those that support the governance cycle. The tools are those that are used in and across the governance cycle. These factors are not used in only one stage, but are used throughout the cycle.

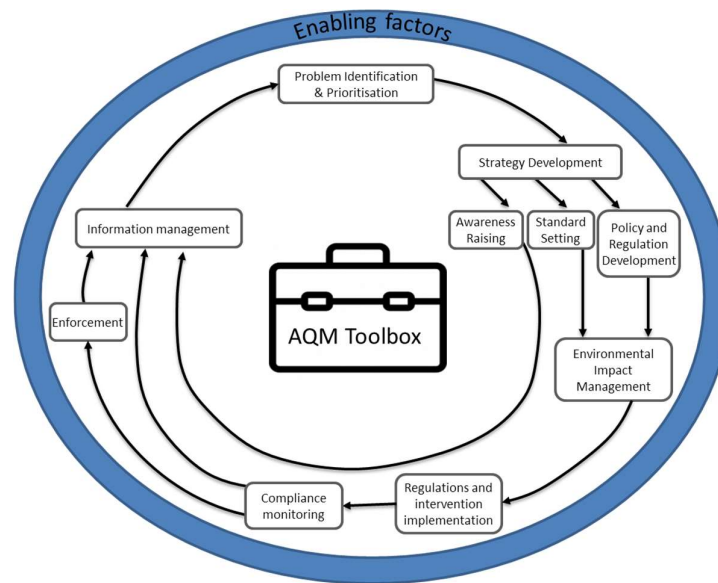


Figure E2: Environmental Governance Cycle (adapted from DEA, 2012). (AQM = Air quality management)

The problem complexes that were identified to be addressed in this AQMP included both enabling factors from the governance cycle, as well as key sectors that have been identified as priorities. It is envisioned that the City would be able to apply the governance cycle more effectively through improved enabling factors on the identified priority areas. Thus, in this AQMP, the governance cycle would be the means in which the City would implement its activities in order to reach its vision.

In order to improve air quality in the City of Johannesburg, it was identified that air quality management needed to improve, and emission reductions are needed in prioritised sectors.

The specific enabling factors identified and prioritised as areas to improve in this AQMP were,

- Effective and regular cross-sectoral collaboration of different CoJ government departments
- Improving the air quality management system
 - o Improving and having access to the necessary tools
- Strengthen and maintain capacity
- Communication internally and with CoJ citizens
- Innovation, research, and evidence based decision-making

Through improving these enabling factors, the environmental governance cycle will be more effective.

The specific sectors identified and prioritised as areas which need effort to reduce emissions are,

- Domestic fuel burning
- Industry

- Vehicles
- Dust from tailings storage facilities (TSF).

Developing and implementing such emission reductions would involve applying the environmental governance cycle.

Considering the environmental governance cycle and the highlighted problem complexes, a vision, mission, and goals for air quality in the City of Johannesburg were developed. These are developed with a five year time horizon.

Vision

The vision of the 2019 CoJ AQMP is

“To achieve acceptable air quality levels in the City of Johannesburg.”

Where, “acceptable air quality” is defined as that which,

- Complies with National Ambient Air Quality Standards (NAAQS),
- Supports liveable, sustainable and resilient communities,
- Is odourless, tasteless and looks clear.

Currently, there are stations that do not comply with NAAQS. Thus in order to meet this vision there are a number of measures that must be put into place. This plan is the first step to set-up the necessary systems and strategies to achieve this vision. The improvements identified include both improving the enabling factors that allow for effective air quality management as well as emission reductions in prioritised sectors. Together these improvements will work towards acceptable air quality in the City.

Mission

In order to improve air quality multiple stakeholders and sectors will have to work together; and the trajectory to improve air quality must be evidence-based. While the process to improve air quality follows the environmental governance cycle, enabling factors such as collaboration and scientific research, innovation and evidence-base are key areas of development for this process to be effective in CoJ. Thus in the mission of this AQMP the importance of the enabling factors is highlighted.

“The City of Johannesburg will work collaboratively with stakeholders to improve air quality in the City in order to minimise the impacts of air pollution on human health and the environment. The City will use evidence-based decision making and planning to achieve compliance with national ambient air quality standards.”

Goals

An important part of an AQMP is to set air quality goals, objectives and activities for the next five years to move the City of Johannesburg towards its mission of having acceptable air quality throughout the City. The goals for the AQMP are:

- 1. Collaborate with stakeholders in developing and implementing emission reduction strategies designed towards achieving ambient air quality standards and international and domestic greenhouse gas commitments and targets.**

This goal highlights the importance of working with collaborators to improve air quality. As emission sources are from a variety of sectors, any emission reduction plan would need to be multi-sectoral with numerous stakeholders. Thus collaboration is vital to improving air quality. The four sectors that were identified as key sectors for emission reductions will be the focus of these emission reduction strategies, however the impact of on-going and planned policies and projects of the city will be assessed across all applicable sectors. These emission reductions will focus on both air quality and climate change concerns. The two issues are strongly linked through their emissions sources, many of which can release pollutants that have air quality and climate change implications. Thus policies and interventions that impact greenhouse gas (GHG) emissions may many times also impact air pollutant emissions; however it is also true that not all policies provide win-win options for both. Due to these linkages, it is important to quantify the impacts of both (i.e. GHG and air quality) in these emission reduction strategies together.

- 2. Regulate emission sources within the City to achieve compliance with air quality requirements.**

In order to improve air pollution and in order to comply with national ambient air quality standards, the City must regulate scheduled point source emitters, and this goal highlights the importance of this regulation. Through this goal the City will develop and maintain an up-to-date and comprehensive list of regulated sources, quantify the emissions per source, as well as work to assess if localised standards are necessary.

- 3. Develop and maintain a comprehensive air quality management system.**

An air quality management system is the operational system that develops, improves and maintains the necessary air quality tools (e.g. ambient monitoring, development and improvement of emission estimates, etc.). These tools are used throughout the environmental governance cycle and provide the information necessary to understand the state of air quality, to support and measure the impact of decisions, and to prioritise problems. Thus through this goal the air quality management system will encompass the necessary tools, and will continually work to maintain, and as applicable, improve these tools.

4. Provide the appropriate capacity to deliver Air Quality Management services in a cost effective and efficient manner.

In order to implement this AQMP, appropriate capacity with the needed capabilities is required to fulfil the necessary positions as details in the resource gap assessment. This includes both attracting the needed capacity and capabilities, as well as capacity development of existing staff. The needed capabilities are a scarce skill, and Air Pollution Analyst is listed in the Department for Higher Education and Trainings 2015 list of occupations in high demand (DHET, 2016). Thus CoJ does need to ensure it is in a position to attract and retain specialists in the field of air quality.

5. Empower and inform CoJ citizens about air quality through education, awareness and communication programmes.

CoJ citizens play a role across the environmental governance cycle, and thus are a critical enabling factor in order to improve air quality. The communication is two-way, with the CoJ providing information to citizens on the state of air quality (e.g. through air quality information portal, real time air quality reporting, air quality indicator, emission reduction strategies and actions) and with citizens providing input to the CoJ (e.g. complaints, problem identification). This goal would work to continually develop and improve this two-way communication with the public, and would work to clearly identify and educate the public on their important role in improving air quality.

6. Support innovation and research that informs air quality improvement and decision making.

Improving air quality is not simple; while air quality management activities have been ongoing in CoJ since 2003, there are still areas out of compliance with NAAQS. Testing and implementing innovative ideas has the potential to greatly improve air quality management. In addition, research can assist to improve knowledge base and improve the air quality management tools. This goal would utilise the MOAs with universities and research organisations to engage with researchers and innovators in air quality. Through this engagement, the CoJ could then be a test bed to pilot these new ideas that could work towards improving air quality.

Through these goals, the trajectory to improve air quality and to meet the mission and vision is clear. As the AQMP is implemented, this trajectory and progress towards this mission and visions will continue to be quantified.

List of Figures

Figure 1. Location of the City of Johannesburg within Gauteng Province.....	17
Figure 2. Surface wind roses at Buccleuch, Alexandra, Jabavu and Orange Farm for July 2004 to June 2007. The legend details the colouring scheme for the wind speed in the individual wind roses (taken directly from CoJ, 2007).....	20
Figure 3. Location of the City of Johannesburg Ambient Air Quality Monitoring Stations.	33
Figure 4. Variability of data completeness of PM ₁₀ at all stations.....	36
Figure 5. Number of exceedances of the PM ₁₀ daily standard (120 µg/m ³) that was applicable 2009-2014. Four exceedances per year are allowed. Cells highlighted in grey are where the allowed FOE has been exceeded and where the data availability is greater than 90%.	37
Figure 6. Number of exceedances of the O ₃ 8-hourly standard (61ppb). Eleven exceedances per year are allowed. Cells highlighted in grey are where the allowed FOE has been exceeded and where the data availability is greater than 90%.....	38
Figure 7. Number of exceedances of the PM _{2.5} daily standard (65µg/m ³) that was applicable 2012-2015. Four exceedances per year are allowed. Cells highlighted in grey are where the allowed FOE has been exceeded and where the data availability is greater than 90%.	39
Figure 8. Number of exceedances of the NO ₂ hourly standard (106ppb). Eighty eight exceedances per year are allowed.	40
Figure 9. Number of exceedances of the SO ₂ hourly standard (134ppb). Eighty eight exceedances per year are allowed.	41
Figure 10. Trends in leading YLLs in City of Johannesburg between 2008 and 2012, rank (% of total YLLs), 2008-2013 (DHB, 2015). The meaning of the colour and thickness of the line are provided in the legend.	47
Figure 11. Number of air quality related complaints from provided complaint registers.	48
Figure 12. Emissions grid domains considered for the development of emissions inventories.	49
Figure 13. Summary of sector contribution to total annual criteria pollutant emissions within CoJ (using the TDM for the vehicle emissions estimates).....	50
Figure 14. Summary of sector contribution to total annual criteria pollutant emissions within CoJ (using top-down approach for vehicle emissions).....	51
Figure 15. 99th percentile of 24-hour average PM ₁₀ for 2014.	55

Figure 16. Monitoring stations in and near CoJ from City of Tshwane (CoT), Ekurhuleni (EKHL), West Rand (WRDM), and VTAPA networks.	56
Figure 17. 99th percentile of 8-hour (running average) ozone for 2014.....	58
Figure 18. 99th percentile of 24-hour average SO ₂ for 2014.....	60
Figure 19. Sector contributions to PM ₁₀ emissions assuming that TSF emissions meet medium-term goals and all other sectors are held constant at 2014 levels (as in Figure 13).	62
Figure 20. Simulated change in NO ₂ concentrations (1hr 99th and annual mean) for Do Nothing minus 2014 base.	64
Figure 21. Proposed organogram for the air quality management division of EISD.	66
Figure 22: Air Quality Management Cycle (adapted from The National Academies, 2004).....	68
Figure 23: Environmental Governance Cycle (adapted from DEA, 2012). (AQM = Air quality management).....	69
Figure 24: CoJ and Gauteng in relation to the three Air Quality Priority Areas.	72

List of Tables

Table 1. Climate data for the CoJ 1961-1990 (Adapted from CoJ, 2009; data sourced from SAWS). ..	19
Table 2. South Africa's National Ambient Air Quality Standards (NAAQS) per pollutant and averaging period, including allowed frequency of exceedance (FOE) (adapted from (RSA, 2009)).	23
Table 3. GDS, IDP and CoJ AQMP linkages.....	28
Table 4. Location and rational for the City of Johannesburg ambient air quality monitoring stations (CoJ, 2015).....	34
Table 5. Number of annual exceedances of the criteria pollutants NAAQS for all the CoJ stations.	Error! Bookmark not defined.
Table 6. Summary of City of Johannesburg's ambient air pollutant concentrations.....	45
Table 7. Total annual emissions of criteria pollutants in CoJ for 2014 (tons per annum).	50
Table 8. Summary of emissions inventory gap analysis.....	52
Table 9. Emission totals (tpa) for the Do Nothing case and ratio thereof to the 2014 base.	63
Table 10. Emission totals (tpa) for the Hi Diversion case and change (mass and percentage) from Do Nothing.	63
Table 11. Goal 1 objectives, activities, timing and indicators.....	77
Table 12. Projects per sector identified in the IDP that will be tracked under Goal 1.	81
Table 13. Goal 2 objectives, activities, timing and indicators.....	87
Table 14. Goal 3 objectives, activities, timing and indicators.....	89
Table 15. Goal 4 objectives, activities, timeline and indicators.....	91
Table 16. Goal 5 objectives, activities, timeline and indicators.....	93
Table 17. Goal 6 objectives, activities, timeline and indicators.....	96
Table 18. High-level timeline for implementation per goal (grey and blue striped cells indicate on-going activities).	97
Table 19. Budget assumptions as per the DEA Business Case Tool. HR costs reflected below are 20% higher than business case.	98

Table 20. Estimated operational costs per annum from DEA Business Case. 98

Table 21. Estimated budget to expand monitoring stations capabilities to cover all criteria pollutants.
..... 100

List of Abbreviations, Acronyms and Chemical Compounds

AQM	Air Quality Management
AQMP	Air Quality Management Plan
BTEX	Benzene, toluene, ethyl benzene, and xylene
BRT	Bus Rapid Transit
C ₆ H ₆	Benzene
CAMx	Comprehensive Air Quality Model with Extensions
CBD	Central Business District
CO	Carbon monoxide
CoJ	City of Johannesburg
COP	Conference of the Parties
CoT	City of Tshwane
CSIR	Council of Scientific and Industrial Research
DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs and Tourism
DHB	District Health Barometer
DHET	Department of Higher Education and Training
EISD	Environment, Infrastructure and Services Department
EKHL	Ekurhuleni
FOE	Frequency of exceedance
GDACE	Gauteng Department of Agriculture, Conservation and Environment
GDS	Growth and Development Strategy
GHG	Greenhouse gases
HPA	Highveld Priority Area
IDP	Integrated Development Plan
IWMP	Integrated Waste Management Plan
JMPD	Johannesburg Metropolitan Police Department
MoU	Memorandum of Understanding
NAAQS	National Ambient Air Quality Standards
NDP	National Development Plan
NEMAQA	National Environmental Management Air Quality Act
NH ₃	Ammonia
NMVOCS	Non-methane volatile organic compounds
NO	Nitrogen oxide
NO ₂	Nitrogen dioxide
NO _x	Nitrogen oxides
NPC	National Planning Commission
O ₃	Ozone
Pb	Lead
PM	Particulate matter
PM ₁₀	Particulate matter less than 10 micron in diameter

PM _{2.5}	Particulate matter less than 2.5 micron in diameter
RSA	Republic of South Africa
SAAQIS	South African Air Quality Information System
SAWS	South African Weather Service
SO ₂	Sulphur dioxide
TDM	Travel Demand Model
TSF	Tailings storage facility
VOC	Volatile Organic Compound
VTAPA	Vaal Triangle Airshed Priority Area
WRDM	West Rand District Municipality
WRF	Weather Research and Forecast model
YLL	Years of Life Lost

1 Introduction: City of Johannesburg

1.1 Geographical setting

The City of Johannesburg metropolitan municipality (CoJ or the City) is situated on the South African Highveld within the Gauteng Province (Figure 1). The City spans the Witwatersrand, which is an area that constitutes the watershed between the subcontinental drainage divide into the Indian and Atlantic Oceans. The city's elevation ranges from 1 500 m to 1 800 m.

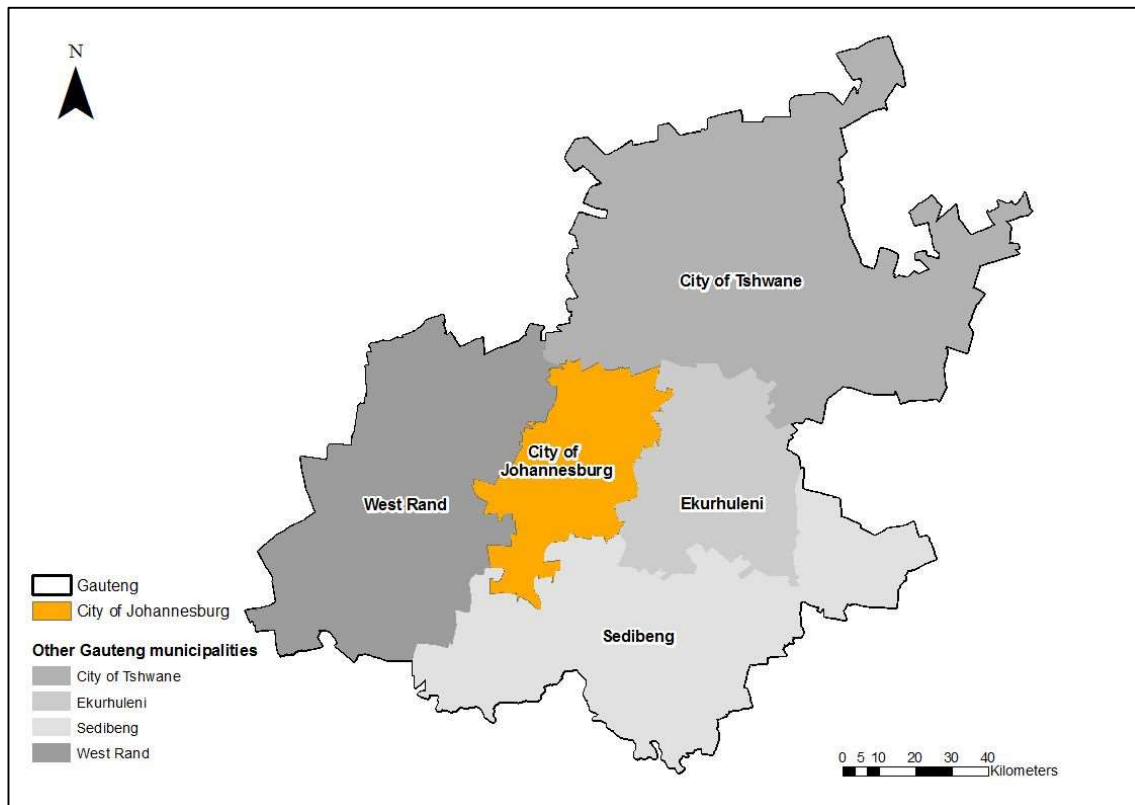


Figure 1. Location of the City of Johannesburg within Gauteng Province.

1.2 Demographics

The CoJ is the city with the highest population in South Africa, with a population of over 5.05 million people according to Statistics South Africa in 2018. The metropolitan municipality is divided into seven sub-districts, named Johannesburg Sub-district A to Johannesburg Sub-district G.

The population density of the City is 2 900 persons per km². It has been estimated that the CoJ will experience population growth of about 66% in the next 30 years, with a growth projection of 6.5 million by 2040 (World Population Review, 2019).

1.2.1 Socio-economic status

Even though both the employment rate and average disposable household income in Johannesburg are high in comparison to the rest of the country, income inequality in the City is extremely severe, with the City's Gini index (a measure of inequality) being among the highest globally (Euromonitor International, 2016).

Key findings from the Poverty and Livelihoods study (De Wet et al., 2008) indicated that;

- Most of the respondents (77 %) indicated that they have secondary level qualifications, or matric.
- Overall, 40 % of households did not make provision for unexpected events. In addition, 66% of all households were either moderately or severely food insecure, in terms of the categories of the Household Food Insecurity.
- Relatively high levels of chronic illness, such as high blood pressure (42% in Doornkop), diabetes (10% in Orange Farm and Riviera) and tuberculosis (10% in Doornkop) were indicated. Tobacco (69% of households in Riviera have at least one user) and alcohol usage (44% of households in Ivory Park) was generally high. The incidences of mental disorder symptoms were 40%. Although these varied between the surveyed areas, these indicators signify that poor households experience significant levels of stress.
- Although most households indicated limited access to community support, less than 50% indicated that they felt unsafe in their neighbourhoods. About 33% of households participated actively in community organisations.

In summary, the CoJ has the highest population of all cities in South Africa. In the City, Ward 5 (primarily Lenasia) has the largest proportion (32%) of the population below the age of 15 years and ward 97 (encompassing Struben's Valley, Wilgeheuwel, Little Falls, Roodekrans and Roodepoort Farms) with the largest proportion (5%) that is older than 64 years of age. CoJ falls within the wealthiest districts in the country, probably because it has a higher employment rate (54%) than the national figure (43%). This contributes to the fact that the City has an average household disposable income double that of the country's average.

However there are some areas where poverty is a reality in terms of income (De Wet et al., 2008). For example, the suburb of Tswelapele has an average household income of only R 581 per month and 42% of households in this area have no income at all. Also Meadowlands East (Zone 1) has a 47% unemployment rate and 41% of households with no income. Alexandra, with an unemployment rate of 39%, and 36% of households without any income, was ranked number one of the "poverty" areas, due to the large population of 154 327 (De Wet et al., 2008).

1.3 Climate, topography and local meteorology

Climate and local meteorology can impact air pollution levels from the emission of pollutants, to the transformation, dispersion and removal. The CoJ has a temperate climate with rainfall predominantly occurring in the summer months from October to March, frequently in late-

afternoon thunderstorms (CoJ, 2008). On average, the City receives 802 mm of rainfall per annum. Extreme temperatures in the summer months can exceed 30°C and can fall below 0°C in winter (Table 1).

Table 1. Climate data for the CoJ 1961-1990 (Adapted from CoJ, 2009; data sourced from SAWS).

Season 1	Temperature (°C)				Precipitation		
	Highest Recorded	Average Daily Maximum	Average Daily Minimum	Lowest Record	Average Monthly (mm)	Average number of days/month with ≥ 1 mm	Highest 24 Hour Rainfall (mm)
Summer	35	25	14	4	107	14	188
Autumn	32	21	10	-3	53	8	92
Winter	26	17	5	4	6	2	31
Spring	33	24	11	-3	72	10	110
Year	35	22	10	-8	713	99	188

Note: This climatological information represents the normalised values, and according to World Meteorological Organization (WMO) prescripts is based on monthly averages for the 30-year period 1961-1990.

Wind is an important component to consider when determining air pollution levels because air pollutants can be blown by wind or formed by chemical or physical reactions that occur in the atmosphere (CoJ, 2007). Wind roses are shown for four areas (Buckleuch, Alexandra, Jabavu and Orange Farm) which fall within the CoJ boundary (Figure 2). Buckleuch is situated in the north-east, Alexandra is in the east, Orange Farm is in the south and Jabavu is in the south-west of the CoJ. Wind roses are used to summarise the occurrence of winds, representing strength, direction and frequency (CoJ, 2007). According to CoJ (2007), there was a substantial variation between wind observations at the four areas (Figure 2). For example, the prevailing wind direction during the period of measurement was west-north-westerly at Buckleuch, east-north-east and west at Alexandra, west-south-west, west and north-east at Orange Farm and depending on the time of year, winds varied at Jabavu (CoJ, 2007). In the north, winds are generally light but it was found that areas further south experience stronger winds, particularly in Orange Farm, where winds were much stronger on average than at Buckleuch during the day and at night.

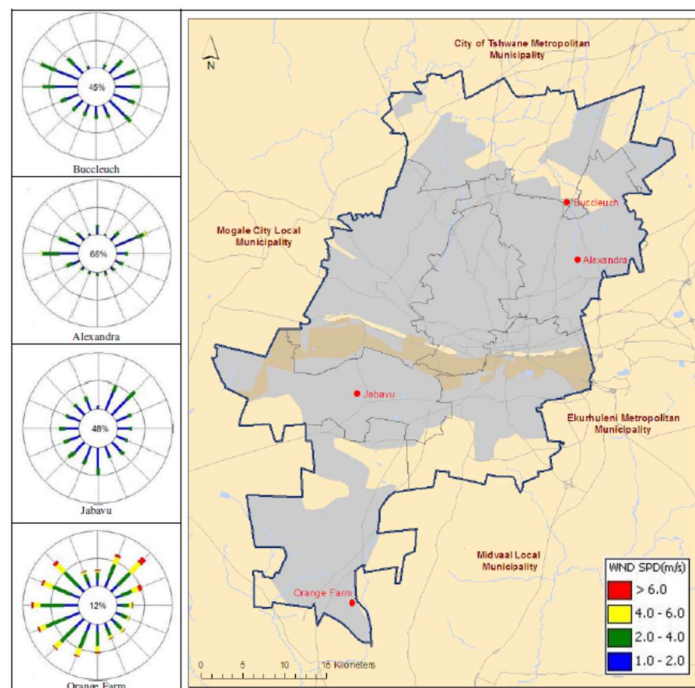


Figure 2. Surface wind roses at Buccleuch, Alexandra, Jabavu and Orange Farm for July 2004 to June 2007. The legend details the colouring scheme for the wind speed in the individual wind roses (taken directly from CoJ, 2007).

1.3.1 Potential impacts from climate change

In terms of climate change, a warmer future with an increase in extreme weather events is predicted for Gauteng province; under a business-as-usual global CO₂ emissions scenario, temperatures are projected to increase by 3 – 4 °C by the second half of the 21st century (DEA, 2016). Future climate change may therefore pose a significant threat to the CoJ in many ways. Climate change does have the potential to impact air quality. For example, it is projected that there will be intensification of the subtropical high pressure belt, particularly during winter months, which is characterised by temperature inversions. This impact on inversions will result in the increased potential for pollutants to become trapped under the temperature inversion, which will reduce the dispersion capacity of pollutants in the City (CoJ, 2008). According to CoJ (2014), climate model projections for the CoJ indicate that local climate is likely to become significantly hotter and more humid. The CoJ is likely to experience an increase in annual rainfall characterised by an increased frequency of storm events and prolonged rainy seasons (CoJ, 2014). Temperatures are predicted to increase by as much as approximately 2.3°C by 2056 – 2065 and 4.4°C by 2081 – 2100. Increased temperatures can impact the emission and transformation of pollutants. Additionally, exposure to air pollution can exacerbate the potential negative health impacts from exposure to high temperatures, as exposure to high temperatures can have many of the same negative health effects as those from exposure to air pollution.

2 Purpose of the AQMP

CoJ is one of the most active commercial cities on the African continent and is the hub of the South African economy; making Gauteng the wealthiest province in South Africa (CoJ, 2014). The City of Johannesburg Metropolitan Municipality is considered to be the “economic powerhouse of South Africa”, contributing 17% of the country’s gross domestic product (CoJ, 2016). Located centrally in the province of Gauteng, the CoJ covers 60 km from north to south and 30 km from west to east, covering a surface area of 1645 km². With a population of over 4.7 million people, the CoJ is characterised as the largest city in the Gauteng province in terms of population size (DHB, 2015).

This large amount of activity within the CoJ leads to an impact on air quality; be it from light industry, on-road vehicles or residential fuel combustion. An Air Quality Management Plan (AQMP), apart from being a legislative requirement (Section 15(2) of the National Environmental Management Air Quality Act (NEMAQA) for a municipality such as CoJ, provides a valuable tool for the City to ensure a healthy living environment for its occupants. The last AQMP for the CoJ was completed in 2003, which leaves a gap that falls outside the recommended 5 year frequency for review. It was thus vitally important to develop an updated AQMP.

The CSIR Climate Studies, Modelling and Environmental Health group were appointed by the City of Johannesburg to develop an AQMP for the City’s Environmental and Infrastructure Services Department (EISD). Airshed Planning Professionals (Pty) Ltd were sub-contracted to develop the emissions inventory for industrial sources and mine tailings facilities.

Even though the timeline for the AQMP implementation range from short to medium-term, all aim to meet the current vision. An AQMP is seen as a progressive advancement towards improved air quality for the region in question, and thus the plan itself sets the stage for activities to occur within the next 5 years.

2.1 Policy Context of AQMP

The City of Johannesburg’s first AQMP was developed in 2003, prior to any regulatory advances in air quality management. There have since been a number of legislative mandates and policy documents put in place to facilitate the implementation of the overarching principles of air quality management. The process of developing and implementing an AQMP is supported by these key pieces of legislation, which include the National Environmental Management: Air Quality Act (Act 39 of 2004) (RSA, 2005), the National Framework for Air Quality Management (DEAT, 2007), the Air Quality Management Planning Manual (DEAT, 2008) and the Municipal Systems Act (Act 32 of 2000) (RSA, 2000). Although these policies deal directly with air quality management on a national level, South Africa’s National Development Plan (NDP) Vision 2030 provides a holistic view of what the country is trying to achieve for its future by addressing issues of poverty and inequality that are impacted on by several factors, such as air quality (NPC, 2011). Municipalities are obliged to develop AQMPs to facilitate the mitigation of the negative impacts of air quality on the environment and human health.

The City of Johannesburg's Growth and Development Strategy (GDS) 2040 and Integrated Development Plan (IDP) 2016/21, were drafted in 2011 and 2016, respectively. These documents pertain directly to the future development aspirations of the City (CoJ, 2011; CoJ, 2016). The City of Johannesburg's IDPs and IDP reviews are aligned with the long-term strategy outlined in the GDS and for this reason, these policies share similar outcomes. The development of an AQMP, and its inclusion in the IDP, is a mandatory requirement of all municipal authorities, as listed in Section 15(2) of the NEMAQA (RSA, 2005).

In line with these development goals, the City aims to make improvements and provide effective governance to the citizens of Johannesburg through ten mayoral priorities. These priorities were released in 2016 and are as follows:

- The city has to adjust under the leader coalition;
- To be responsive and pro-poor;
- To grow Johannesburg's economy by 5%;
- Professional civil service where city employees act with regard to service and economic goals;
- Corruption is public enemy number one;
- Compile a list of semi-completed housing units in the inner city that can be completed for housing;
- Compile an official housing list that can be accessed on the city website and by employees in the city's offices;
- Speed up delivery of title deeds to beneficiaries of housing projects;
- Initiate a pilot project for clinics to open for extended hours;
- Revitalise the Johannesburg inner city.

2.1.1 NEMAQA

The objectives of the National Environmental Management: Air Quality Act 39 of 2004 (NEMAQA) are to protect the environment by providing reasonable measures for - (i) the protection and enhancement of the quality of air in the Republic; (ii) the prevention of air pollution and ecological degradation; and (iii) securing ecologically sustainable development while promoting justifiable economic and social development. These objectives are stated in line with Section 24 of the Constitution, which guarantees an environment that is not harmful to the health and well-being of people (RSA, 2005: 10).

Under the NEMAQA, local municipalities are required to develop an Air Quality Management Plan to ensure that the national ambient air quality standards set in this act are adhered to. In order to fulfil the requirements of section 15(2) of NEMAQA and the role of local government as enshrined in Chapter 5 of the Municipal Systems Act, municipalities are obliged to include an air quality management plan in their Integrated Development Plan (RSA, 2000; RSA, 2005).

2.1.1.1 National Ambient Air Quality Standards

The NEMAQA allows for the setting of National Ambient Air Quality Standards (NAAQS) and emission limits, as effective tools to assess air quality in South Africa (RSA, 2009). To ensure compliance with these regulatory obligations, the NEMAQA also specifies that a National Framework for Air Quality Management be developed, which provides National Norms and Standards for ambient air quality monitoring (RSA, 2005).

Criteria pollutants are regulated under NEMAQA (Act No. 39 of 2004). National ambient air quality standards have been stipulated for all criteria pollutants (Table 2). In this table, regulatory concentrations or limit values are quoted in line with their averaging periods, the frequency of exceedance (FOE) and the compliance date. The averaging period refers to the period of time over which an average is calculated. The FOE refers to the number of times the limit value can be exceeded within one calendar year. If the limit value is exceeded on more occasions than specified by the FOE value, then there is no longer compliance with that standard. The compliance date refers to the dates that the standard was promulgated and period over which compliance of the standard is required (RSA, 2005). Air quality standards are essential for effective air quality management as they provide the indicators to safe exposure levels with respect to human health (RSA, 2009).

Table 2. South Africa's National Ambient Air Quality Standards (NAAQS) per pollutant and averaging period, including allowed frequency of exceedance (FOE) (adapted from (RSA, 2009)).

Pollutant		Averaging Period				
		10 minute	1 hour	8 hour (running)	24 hour	1 year
Sulphur Dioxide (SO ₂)	Limit Value	500 µg/m ³	350 µg/m ³		125 µg/m ³	50 µg/m ³
	FOE	526	88		4	0
	Compliance Date	Immediate	Immediate		Immediate	Immediate
Nitrogen Dioxide (NO ₂)	Limit Value		200 µg/m ³			40 µg/m ³
	FOE		88			0
	Compliance Date		Immediate			Immediate
Particulate Matter (PM ₁₀) <i>Original</i>	Limit Value				120 µg/m ³	50 µg/m ³
	FOE				4	0
	Compliance Date				Immediate – 31/12/2014	01/01/2015
Particulate Matter (PM ₁₀) <i>Revised</i>	Limit Value				75 µg/m ³	40 µg/m ³
	FOE				4	0
	Compliance Date				Immediate – 31/12/2014	01/01/2015
Particulate Matter (PM _{2.5}) <i>Original</i>	Limit Value				65 µg/m ³	25 µg/m ³
	FOE				4	0
	Compliance Date				Immediate – 31/12/2015	Immediate – 31/12/2015
Particulate Matter (PM _{2.5}) <i>Revised</i>	Limit Value				40 µg/m ³	20 µg/m ³
	FOE				4	0
	Compliance Date				01/01/2016 – 31/12/2029	01/01/2016 – 31/12/2029

Pollutant	Averaging Period					
		10 minute	1 hour	8 hour (running)	24 hour	1 year
Particulate Matter (PM _{2.5}) <i>Revised</i>	Limit Value				25 µg/m ³	15 µg/m ³
	FOE				4	0
	Compliance Date				01/01/2030	01/01/2030
Ozone (O ₃)	Limit Value			120 µg/m ³		
	FOE			11		
	Compliance Date			Immediate		
Benzene (C ₆ H ₆)	Limit Value					10 µg/m ³
	FOE					0
	Compliance Date					Immediate – 31/12/2014
Benzene (C ₆ H ₆) <i>Revised</i>	Limit Value					5 µg/m ³
	FOE					0
	Compliance Date					01/01/2015
Lead (Pb)	Limit Value					0.5 µg/m ³
	FOE					0
	Compliance Date					Immediate
Carbon Monoxide (CO)	Limit Value		30000 µg/m ³	10000 µg/m ³		
	FOE		88	11		
	Compliance Date		Immediate	Immediate		

2.1.2 NDP

South Africa's National Development Plan (NDP) was developed in 2011 and its aim is to eliminate poverty and reduce inequality by the year 2030. Changes in South Africa's political state, with its transition into a democratic country, created disparities within society that are still being overcome. The NDP aims to address the high levels of inequality, poverty and unemployment that exist as an outcome of this political landscape. In attempting to address these developmental challenges, the NDP promotes environmental sustainability and the transition to a low-carbon economy, guided by principles such as ecosystems protection that acknowledges that the health and wellbeing of humans is linked to the protection of the environment. The plan has outlined a multidimensional framework and key priority areas to address the complexity of national development (NPC, 2011).

The six priorities are (NPC, 2011: 26):

- Priority 1: Uniting all South Africans around a common programme to achieve prosperity and equity.
- Priority 2: Promoting active citizenry to strengthen development, democracy and accountability.
- Priority 3: Bringing about faster economic growth, higher investment and great labour absorption.

- Priority 4: Focusing on key capabilities of people and the state.
- Priority 5: Building a capable and developmental state.
- Priority 6: Encouraging strong leadership throughout society to work together to solve problems.

The plan envisions development and transformation, through these six priority areas, to address the key challenges facing the country. A planned trajectory of sustainable livelihoods and job-creating growth will need to accommodate these priority areas and the objectives set out in the NDP in order for progress to be made and transformation to occur (NPC, 2011).

2.1.3 GDS

The City of Johannesburg's Growth and Development Strategy (GDS), Joburg 2040, was developed in 2011. This strategy was put in place to address the social, economic and environmental challenges that the city is faced with and defines the type of society the City aspires to achieve by 2040 (CoJ, 2011).

The GDS is defined by four key outcomes that have associated outputs, through which the City plans to achieve the outcomes, as well as indicators for success to assess the progress that has been achieved. These outcomes are as follows (CoJ, 2011: 9):

Outcome 1: Improved quality of life and development-driven resilience for all

The City envisages a future that presents significantly improved human and social development realities, through targeted focus on poverty reduction, food security, development initiatives that enable self-sustainability, improved health and life expectancy, and real social inclusivity. By 2040, the City aims to achieve substantially enhanced quality of life for all, with this outcome supported by the establishment of development-driven resilience.

Outcome 2: Provide a resilient, liveable, sustainable urban environment – underpinned by infrastructure supportive of a low-carbon economy

The City plans to lead in the establishment of sustainable and eco-efficient infrastructure solutions (e.g. housing, eco-mobility, energy, water, waste, sanitation and information and communications technology), to create a landscape that is liveable, environmentally resilient, sustainable, and supportive of low-carbon economy initiatives.

Outcome 3: An inclusive, job-intensive, resilient and competitive economy that harnesses the potential of citizens

The City of Johannesburg will focus on supporting the creation an even more competitive, 'smart' and resilient city economy, when measured in relation to national, continent and global performance. The City will promote economic growth and sustainability through the meaningful

mobilisation of all who work and live here, and through collaborating with others to build job-intensive long-term growth and prosperity, from which all can benefit.

Outcome 4: A high performing metropolitan government that pro-actively contributes to and builds a sustainable, socially inclusive, locally integrated and globally competitive Gauteng City Region (GCR)

The City envisages a future where it will focus on driving a caring, responsive, efficient and progressive service delivery and developmental approach within the GCR and within its own metropolitan space, to enable both to reach their full potential as integrated and vibrant spaces.

Through an extensive public outreach process, the City gained valuable insight into developing strategies that covered the requirements of the different groups of stakeholders and a way in which the City could be held accountable for implementing these strategies. A list of principles that govern how the City moves towards a sustainable future and achieves the outcomes stated above were developed from this process. These principles are as follows (CoJ, 2011: 33-35):

- Principle 1: Eradicating poverty
- Principle 2: Building and growing an inclusive economy
- Principle 3: Building sustainable human settlements
- Principle 4: Ensuring resource security and environmental sustainability
- Principle 5: Achieving social inclusion through support – and enablement
- Principle 6: Promoting good governance

As highlighted in the Johannesburg GDS 2040, the City strives towards a transition to a more resilient, sustainable and inclusive future through the nurturing of partnerships, engaging honestly with its citizens, management of the environment and services, economic growth, good governance and human and social development (CoJ, 2011).

2.1.4 IDP 2016/2021

The City of Johannesburg's GDS 2040 was developed to address the major challenges that the City faces with regards to high unemployment, high poverty rates and its increasing levels of income inequality. The IDP 2016/21 represents the initial steps of implementing the long-term strategies set out in the GDS 2040 and realising its future vision, by setting up medium-term programmes for implementation. In doing so, the City has translated the four outcomes detailed in the GDS 2040, into eleven strategic focus areas in the IDP, that align with the GDS principles, the National Development Plan and the Sustainable Development Goals (CoJ, 2016). These strategic priorities are (CoJ, 2016: 34):

- Priority 1: Economic growth, job creation, investment attraction and poverty reduction
- Priority 2: Informal Economy and SMME support
- Priority 3: Green and Blue economy
- Priority 4: Transforming sustainable human settlements
- Priority 5: Smart City and innovation
- Priority 6: Financial Sustainability
- Priority 7: Environmental sustainability and climate change
- Priority 8: Building safer communities
- Priority 9: Social cohesion, community building and engaged citizenry
- Priority 10: Repositioning Johannesburg in the global arena
- Priority 11: Good governance

The GDS served as a conceptual foundation for the five-year IDP, and the City adopts the same four key outcomes stated in the GDS in their 2016/21 IDP. A high-level mapping exercise was conducted that links the overarching GDS principles to the strategic priorities of the IDP together with the major focus areas of the CoJ AQMP (Table 3).

Table 3. GDS, IDP and CoJ AQMP linkages.

GDS Principle	Link to IDP Strategic Priority	Link to CoJ AQMP	Links to Supporting documentation
1. Eradicating poverty	1. Economic growth, job creation, investment attraction and poverty reduction	Domestic burning,	Draft Strategy to Address Air Pollution in Dense Low-Income Settlements
2. Building and growing an inclusive economy	1. Economic growth, job creation, investment attraction and poverty reduction 2. Informal Economy and SMME support 3. Blue and Green Economy	Industrial, human and financial capacity	
3. Building sustainable human settlements	4. Transforming sustainable human settlements 5. Smart City and Innovation	Domestic burning, Awareness, education and communication, transport, monitoring	CoJ's Environmental Education and Awareness Strategy
4. Ensuring resource security and environmental sustainability	7. Environmental sustainability and climate change	Monitoring and modelling, transport, emission reductions, dust - tailings dams	Energy and Climate Change Strategy & Action Plan, Integrated Strategy for the Control of Motor Vehicle Emissions

GDS Principle	Link to IDP Strategic Priority	Link to CoJ AQMP	Links to Supporting documentation
5. Achieving social inclusion through support – and enablement	8. Building safer communities 9. Social cohesion, community building and engaged citizenry	Awareness, education and communication, public transport,	Corridors of Freedom, Strategic Integrated Transport Plan Framework for the City of Joburg
6. Promoting good governance	5. Smart City and Innovation 6. Financial sustainability 10. Repositioning Joburg in the global arena 11. Good governance	Regulations and Licensing, Enforcement, monitoring, emission reductions, M&E	CoJ's Air Pollution Control By-Laws

The 2003 CoJ AQMP has guided air quality management in the CoJ since its development. A review of the past air quality management interventions and an update of the AQMP is now necessary to fulfil the legal requirements as stipulated in the NEMAQA. Aligning the City of Johannesburg's AQMP with the overarching development goals and mayoral priorities provides a way forward that is not just focused on the aspects of air quality management, but also includes the broader focus of environmental sustainability and further developing measures that support sustainable development.

2.2 AQMP approach

The approach to developing this AQMP is delineated into two broad areas of focus, i.e. the Status Quo Assessment (commonly referred to as a baseline assessment, looking at past activities and the current air quality status) and the Management Plan itself (charting a way forward in order to meet the vision, mission and goals set).

The Status Quo Assessment dealt with the current situation of air quality and air quality management in the City. This included:

- An assessment of air quality (and associated health risks) via monitoring data
- Development of a city wide emissions inventory as well as a regional inventory for air quality modelling purposes
- Investigation of the impact of two emissions policy scenarios
- A review of the 2003 AQMP
- Gap assessments for the CoJ monitoring network, emissions inventory, modelling capacity and government resources
- Public participation and stakeholder engagement; utilising experts in the air quality management sphere through Technical Advisory Stakeholder forums as well as internal and public stakeholders through Public Stakeholder Forums.

The findings from the Status Quo Assessment formed the basis for the 2016 City of Johannesburg AQMP in that the vision, mission, goals, objectives and specific activities were driven by gaps and limitations within the current air quality management situation.

An updated set of goals were developed through consultation with EISD that focus on short to long-term strategies to achieve improved air quality through activities that enable the City to manage emission sources in an informed manner. Such activities aim to improve emission inventories (by accessing the City's internal data holders), build and maintain a functioning monitoring network, build internal capacity around dispersion modelling and actively seek cross-sectoral engagement in order to inform City-wide policy with regard to air quality impacts from future developments or current activities.

2.3 2003 AQMP

The initial AQMP was completed by CoJ in 2003, which was before the NEMAQA was promulgated. However, the 2003 AQMP did strive to the same goals as listed in Section 16 of NEMAQA, such as to improve air quality, to identify and reduce the negative impact of air quality on human health and the environment, to addresses the effects of emissions from a range of sources, and to strive to give effect to best practices in air quality management. This is evident in the vision statement as indicated below.

“Clean air is essential to a healthy population, a healthy environment, and, in turn, a healthy economy. The City of Johannesburg is committed to making the air in every community healthy to breathe, to reducing ecosystem damage from air pollution, and to doing its share to address global air quality problems. Air quality will be managed through the implementation of a coordinated approach to the control of air pollution and through the sustainable development of the built environment and transportation within the City. It is intended, in the long-term, that the air be rendered odourless, tasteless, look clear and have no measurable short- or long-term adverse effects on people, animals or the environment.” (CoJ, 2003)

Alongside this, four goals were set for the AQMP and their implementation was designed to:

1. *“Achieve acceptable air quality levels throughout Johannesburg.*
2. *Promote a clean and healthy environment for all citizens within Johannesburg.*
3. *Minimize the negative impacts of air pollution on health and the environment.*
4. *Promote the reduction of greenhouse gases so as to support the council's climate change protection programme” (CoJ, 2003; 10).*

Air quality management activities have been on-going in the CoJ under this AQMP. Since 2003, the City of Johannesburg has undertaken many air quality management activities towards the goals of the 2003 AQMP. However, while there have been successes, there have also been challenges in the continuity of air quality management efforts in the City. Sections 3 - 7 highlight the status quo of air quality and air quality management in the CoJ, and sections 8 - 9 presents the management plan for the next five years.

3 Status Quo: Ambient air quality monitoring

3.1 Air quality monitoring network

The City of Johannesburg’s ambient air quality monitoring network was first established in 2004. Six monitoring stations were initially set up in Alexandra, Buccleuch, Delta Park, Jabavu, Newtown and Orange Farm. Expansions of the network occurred in 2009 with the inclusion of the Diepsloot and Ivory Park stations, and then in 2015 with the mobile station in Davidsonville. The monitoring network now consists of a total of nine stations (Figure 3). There is a representative spatial distribution of monitoring stations across the City, although the focus is weighted towards low

income communities with a strong reliance on domestic combustion, these are therefore likely to represent the worst areas in the City related to air pollution.

The City of Johannesburg's Air Quality Monitoring Plan states that the purpose of the monitoring (CoJ, 2015) is as follows;

"to determine the ambient concentrations of criteria pollutants within the city, in comparison with the National Ambient Air Quality Standards in order to assist the city with the following:

- *Making informed decisions regarding the measures required to protect human health and the environment*
- *Provide air quality information for strategic and policy development by the city and municipal owned entities and*
- *To assess the effectiveness of policy and strategic interventions on trends in air quality"*

From the overall monitoring objectives for the monitoring program (CoJ, 2015), objectives for each of the monitoring stations are specified that captures the main reason for monitoring in those sites and the types of pollutants that are expected to be of concern. The details regarding the monitoring stations in the City of Johannesburg's air quality monitoring network are presented in Table 4, including the location and the monitoring objectives for each of the stations, as well as its status during sites visits in May and June 2016.

In this assessment, ambient air quality monitoring data from the City of Johannesburg monitoring network were acquired from the South African Air Quality Information System (SAAQIS) database for the period 2004 - 2015. In the analysis, data from the Alexandra, Buccleuch, Delta Park, Diepsloot, Ivory Park, Jabavu, Newtown and Orange Farm monitoring stations were utilised. These data included all available pollutant and meteorological parameters in hourly averages.

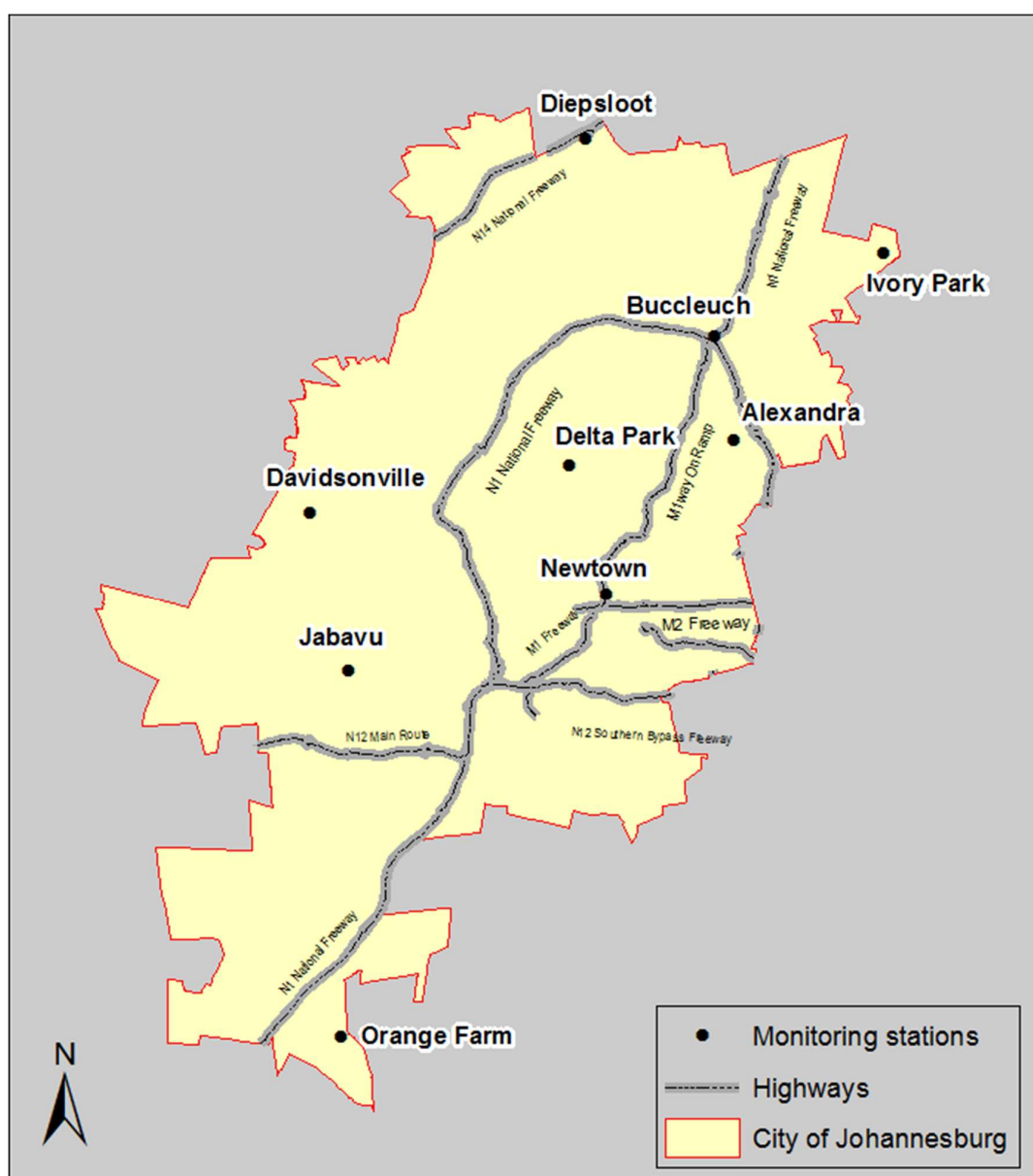


Figure 3. Location of the City of Johannesburg Ambient Air Quality Monitoring Stations.

Table 4. Location and rationale for the City of Johannesburg ambient air quality monitoring stations (CoJ, 2015).

Monitoring station	Co-ordinates	Location Rationale	Parameters Measured	Status (as of May - June 2016)
Buccleuch	Latitude: 26°02'42.7"S Longitude: 28°05'56.6"E Altitude: 1513m	The station is located at the intersection of N1, N3, and M1. It is meant to measure the effects of vehicle emissions on ambient air quality in the area.	PM ₁₀ , PM _{2.5} , SO ₂ , NO _x , O ₃ , Meteorology	Not operational due to power problems at the time of the visit
Alexandra	Latitude: 26°06'24.5"S Longitude: 28°06'36.8"E Altitude: 1522m	The station was sited to measure the effect of emissions from domestic fuel burning on ambient air quality in the area. A significant proportion of households in the area use coal and biomass for space heating and cooking purposes.	PM ₁₀ , SO ₂ (Open path analyser), Meteorology	Not operational - station has been shut down since 2010
Delta Park	Latitude: 26°07'30.0"S Longitude: 28°00'31.0"E Altitude: 1587m	This station was intended to be used as a background urban station and is located within the Delta Park Environmental Centre. This station is not exposed to any direct emissions from air pollution sources, however, measured concentrations at this station compare well with the rest of the stations. The station is therefore no longer representative of the urban background concentrations.	All instruments have been removed, previously measurements of O ₃ , NO _x , PM ₁₀ , Meteorology	Not operational - station has been shut down
Newtown	Latitude: 26°12'18.7"S Longitude: 28°01'55.6"E Altitude: 1725m	The station is located in the CBD to measure urban, commercial and industrial emissions, and is located close to the M1 Highway.	CO, NO _x , PM ₁₀ , BTEX, Meteorology	Not Operational

Monitoring station	Co-ordinates	Location Rationale	Parameters Measured	Status (as of May - June 2016)
Orange Farm	Latitude: 26°28'48.0"S Longitude: 27°52'01.2"E Altitude: 1571m	The station was sited to measure the effect of emissions from domestic fuel burning and other sources on ambient air quality in the area. A significant proportion of households in the area use coal and biomass for space heating and cooking purposes.	PM ₁₀ , SO ₂ , O ₃ Meteorology	Operational
Jabavu	Latitude: 26°15'10.8"S Longitude: 27°52'19.2"E Altitude: 1624m	The station is located in Soweto and was sited to measure the effect of emissions from domestic fuel burning and other sources on ambient air quality in the area. A significant proportion of households in the area use coal and biomass for space heating and cooking purposes.	PM ₁₀ , SO ₂ , O ₃ Meteorology	Operational
Diepsloot	Latitude: 25°55'19.2"S Longitude: 28°01'08.4"E Altitude: 1439m	The station was sited to measure the effect of emissions from domestic fuel burning and other sources on ambient air quality in the area. A significant proportion of households in the area use coal and biomass for heating and cooking purposes.	PM ₁₀ , SO ₂ , Meteorology	Operational
Ivory Park	Latitude: 25°59'34.8"S Longitude: 28°12'14.4"E Altitude: 1566m	The station was sited to measure emissions from domestic fuel burning. A significant proportion of households in the area use coal for heating and cooking purposes.	PM ₁₀ , SO ₂ , Meteorology	Operational
Davidsonville	Latitude: 26°09'16.13"S Longitude: 27°50'52.7"E Altitude: 1697m	This is a mobile station that is located in Davidsonville, Roodepoort. The station is located to assess community exposure to dust from mine tailings.	PM ₁₀ , Meteorology	Operational

3.2 State of ambient air quality in relation to NAAQS

An analysis of the monitoring data from the City of Johannesburg's ambient air quality monitoring stations provided insight into the overall performance of the monitoring network with regards to data completeness and exceedances of the National Ambient Air Quality Standards (NAAQS). The data availability per station, per year was highly variable, and has decreased substantially over the analysis period (Figure 4); no trend analysis was performed due to this high variability in data availability. Due to the low data availability percentages for Ivory Park and Diepsloot, they were not included in the assessment.

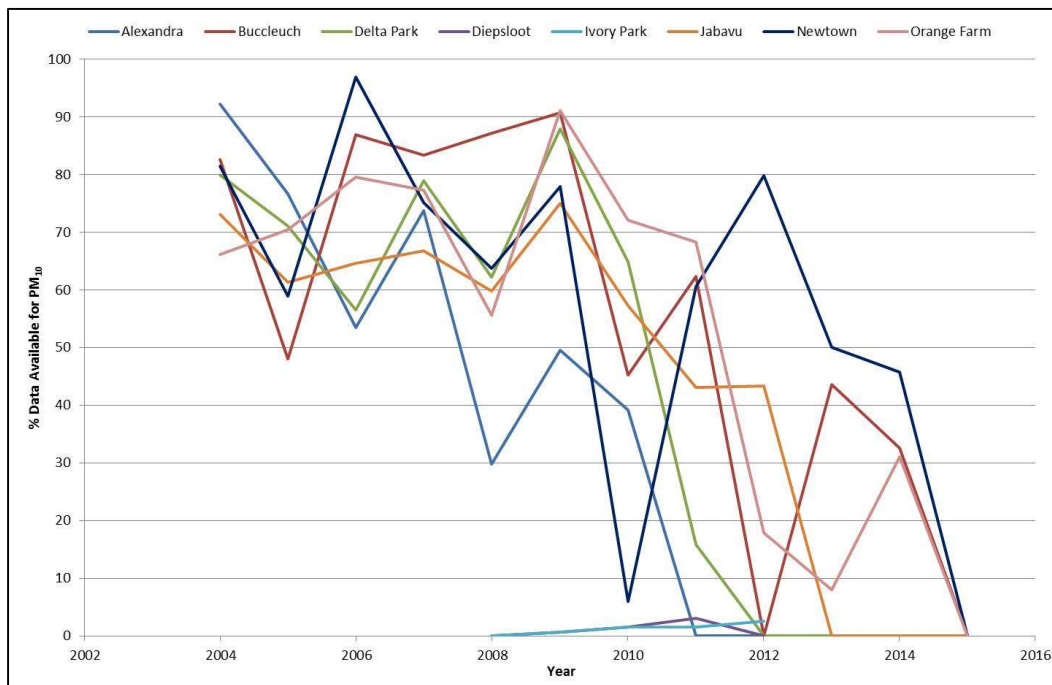


Figure 4. Variability of data completeness of PM₁₀ at all stations.

Exceedances of the NAAQS (Table 2) at the monitoring stations were calculated for each criteria pollutant for all applicable averaging periods, together with the number of missing data points for each year under investigation. The full assessment is in the Status Quo report, and the key findings are highlighted here.

Exceedances of at least one parameter have been recorded at all of the monitoring stations within the CoJ network that were considered. Exceedances of the PM₁₀ daily NAAQS (Figure 5), the O₃ 8-hourly NAAQS (Figure 6), the PM_{2.5} daily NAAQS (Figure 7), the NO₂ hourly NAAQS (Figure 8), and the SO₂ hourly NAAQS (Figure 9) have been graphed to highlight the areas that are in non-compliance with the NAAQS most often. A large proportion of these exceedances correspond with years where the data recovery was less than 90%; in this situation, the number of exceedances should be considered the lower limit. In the figures below, values highlighted in grey refer to instances where

the allowed frequency of exceedance (FOE) has been exceeded (Table 2) and where the data availability is greater than 90%. The greatest number of exceedances, across all of the stations, has been recorded for PM₁₀ and O₃.

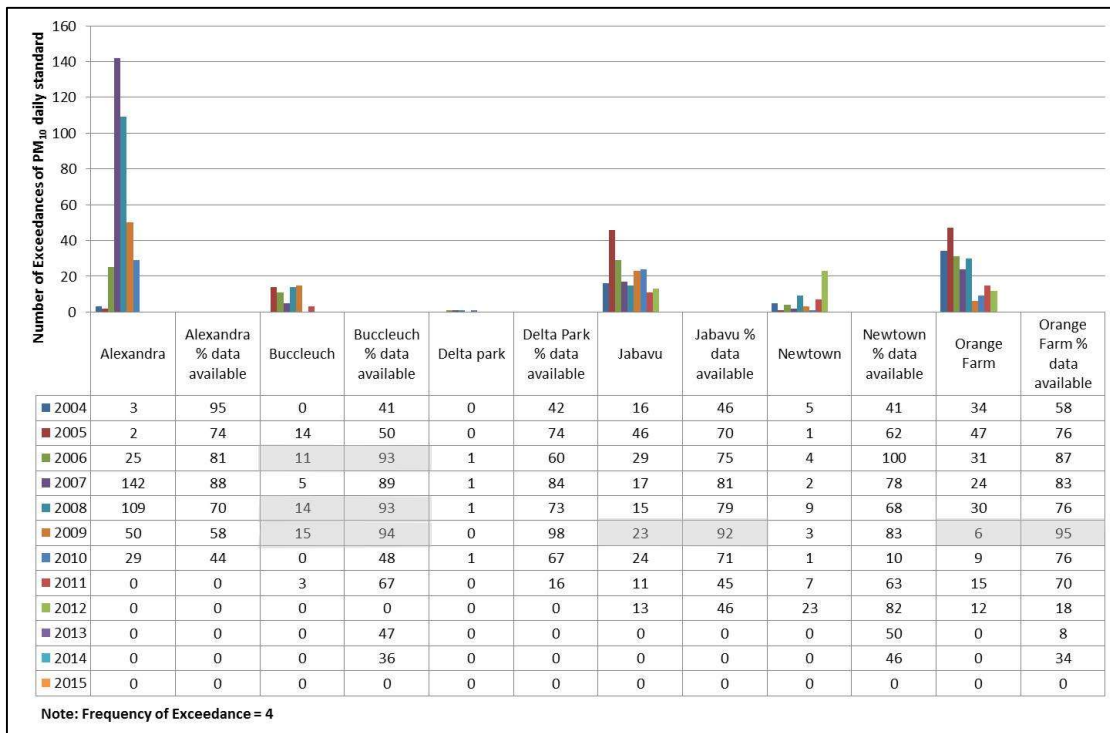


Figure 5. Number of exceedances of the PM₁₀ daily standard (120 µg/m³) that was applicable 2009-2014. Four exceedances per year are allowed. Cells highlighted in grey are where the allowed FOE has been exceeded and where the data availability is greater than 90%.

Exceedances of the daily limit value of the PM₁₀ NAAQS, from 2004 to 2015 for the stations within the City of Johannesburg's air quality monitoring network are shown in Figure 5. The PM₁₀ standard that ended on 31 December 2014, with a limit value of 120µg/m³, was used to calculate the exceedances of PM₁₀ during this analysis, as the available data of the period under investigation coincided with this NAAQS. The revised limit value only came into effect at the beginning of 2015, when no data were available at any of the monitoring stations within the network. Four exceedances per year are allowed in the NAAQS.

It is evident in Figure 5 that the largest number of exceedances of the PM₁₀ daily NAAQS occurred in Alexandra, Jabavu and Orange Farm. There were 142 exceedances of this daily standard recorded at the station in Alexandra in 2007, and in that year, the percentage of PM₁₀ data available for the Alexandra station was 88%. The PM₁₀ levels in these sites, for the periods when data were available, were almost always out of compliance with the daily NAAQS. There were also numerous exceedances of the annual PM₁₀ NAAQS (**Error! Reference source not found.**), where instances of

non-compliance occurred for a good portion of the period under investigation, at all of the monitoring station, except Delta Park.

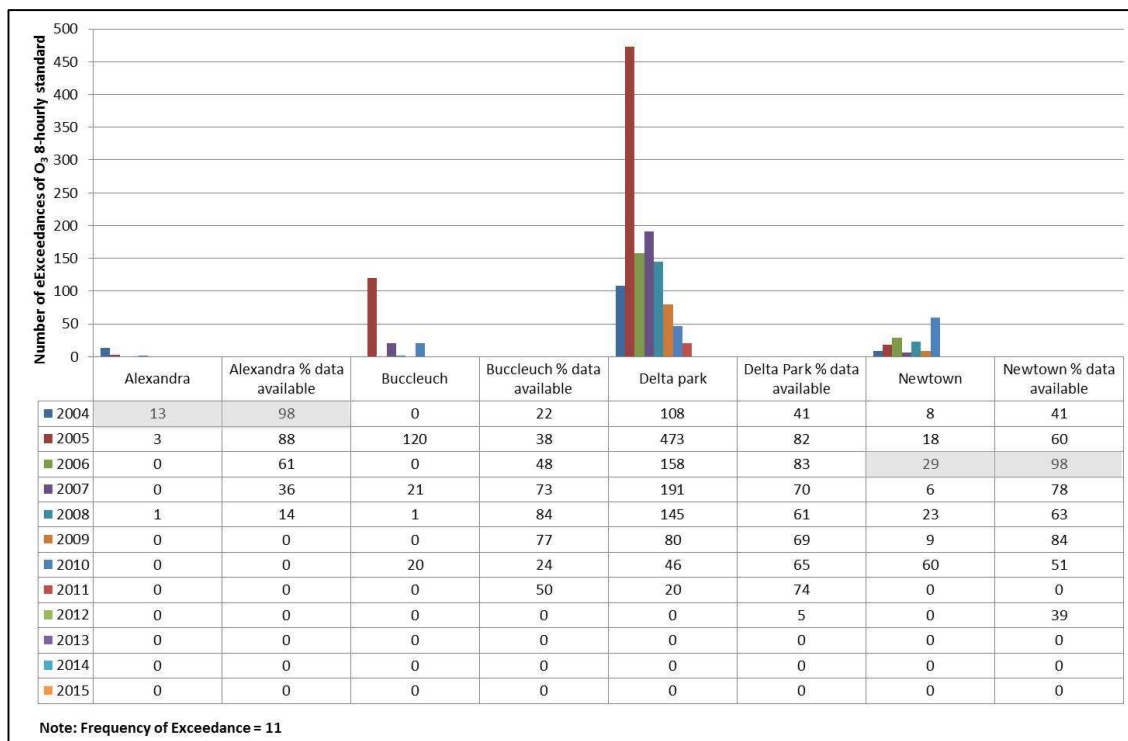


Figure 6. Number of exceedances of the O₃ 8-hourly standard (61ppb). Eleven exceedances per year are allowed. Cells highlighted in grey are where the allowed FOE has been exceeded and where the data availability is greater than 90%.

The largest number of exceedances of the O₃ 8-hourly NAAQS has been recorded at Delta Park. (Figure 6). From 2004 to 2011, the allowable number of exceedances of 11 for the O₃ 8-hourly NAAQS limit value has been exceeded, indicating that there has been non-compliance at this station for this entire period. It must be noted however that none of the years of the period under investigation have data completeness above 90% (i.e. no cells are grey even though FOE>11); in this situation, the number of exceedances should be considered the lower limit.

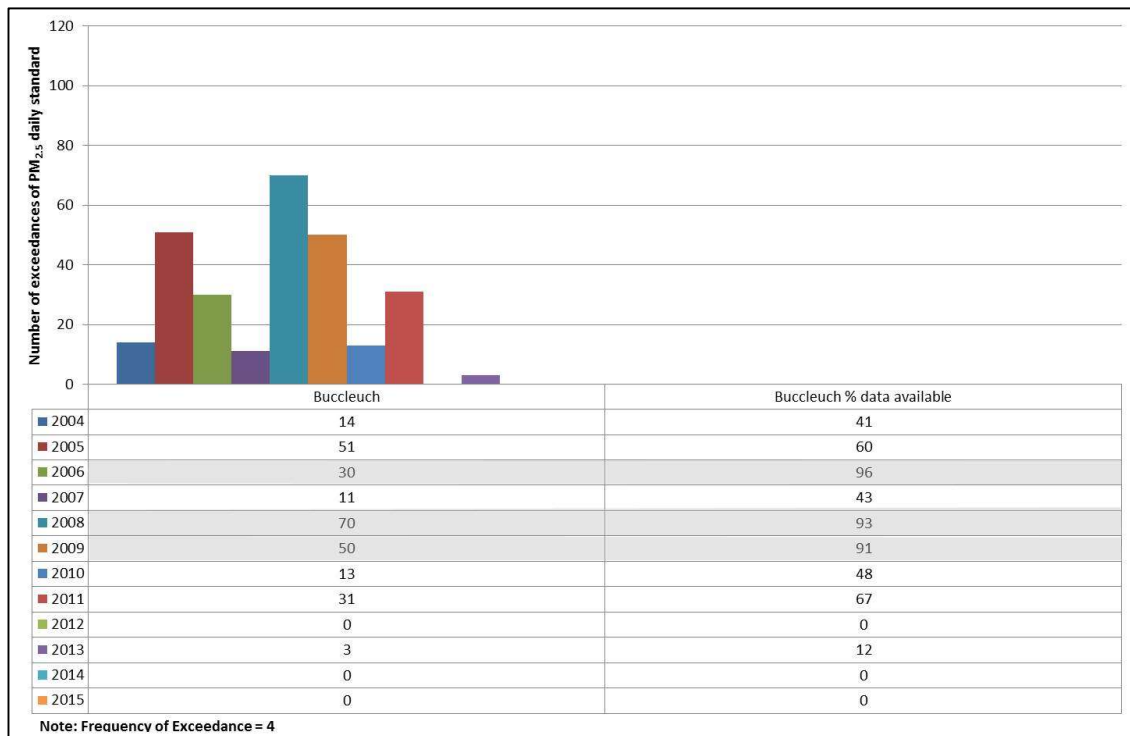


Figure 7. Number of exceedances of the PM_{2.5} daily standard (65µg/m³) that was applicable 2012-2015. Four exceedances per year are allowed. Cells highlighted in grey are where the allowed FOE has been exceeded and where the data availability is greater than 90%.

PM_{2.5} data was only available for the CoJ's Buccleuch ambient air quality monitoring station. It is evident in Figure 7 that the FOE was exceeded every year from 2004 to 2011, however, only years 2006, 2008, and 2009 recorded data availability of above 90%. The PM_{2.5} standard that ended on 31 December 2015, with a limit value of 65µg/m³, was used to calculate the exceedances of PM_{2.5} during this analysis. There were no data for 2015. The revised limit value only came into effect at the beginning of 2016. Four exceedances per year are allowed in the NAAQS.

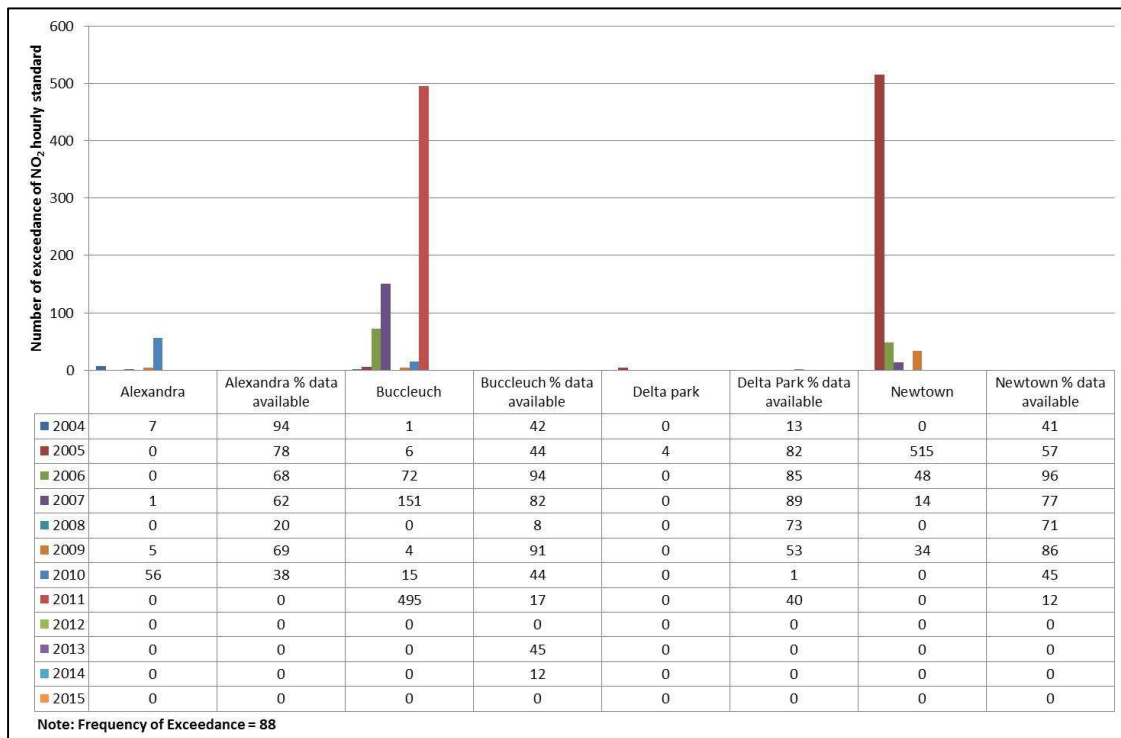


Figure 8. Number of exceedances of the NO₂ hourly standard (106ppb). Eighty eight exceedances per year are allowed.

There are instances across years when the NO₂ hourly limit value is exceeded at all stations, though the FOE is exceeded only at Buccleuch and Newtown from the data available. However, in these instances, none of the stations have data availability above 90%; and thus the number of exceedances should be considered only a lower limit. Over certain years, Alexandra, Buccleuch and Newtown all obtained a percentage data availability of above 90%, but in those years, the number of exceedances of the NO₂ limit value did not exceed the FOE.

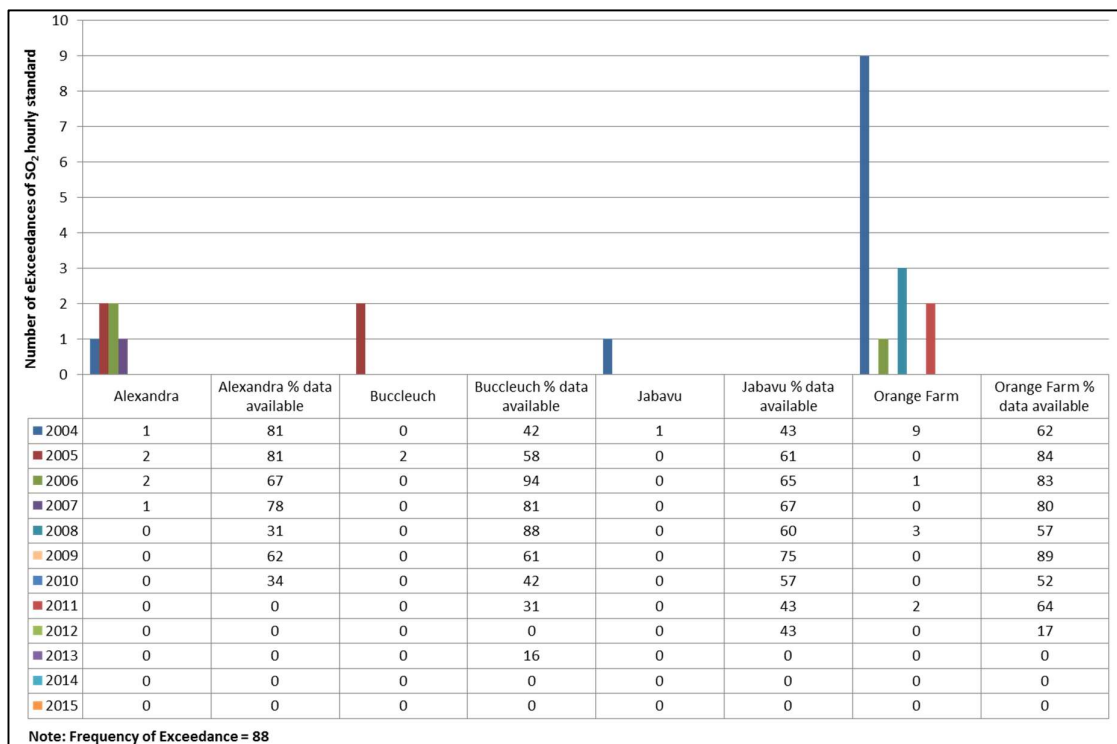


Figure 9. Number of exceedances of the SO₂ hourly standard (134ppb). Eighty eight exceedances per year are allowed.

Exceedances of the SO₂ hourly limit value were recorded at the Alexandra, Buccleuch, Jabavu and Orange Farm stations but there were however, none that exceeded the frequency of exceedance for the SO₂ hourly NAAQS, which is 88. All instances of exceedance of the SO₂ hourly NAAQS limit value do not correspond with 90% or above data availability. There has only been one occurrence of data availability above 90% across all of the stations and over the period under investigation, and that was in 2006 at the Buccleuch station.

Error! Reference source not found. presents the number of annual exceedances for each criteria pollutant per year, for each monitoring station. Cells containing “1” and highlighted in red show instances where there is non-compliance with the NAAQS and data availability of 90% or above. Again, as noted throughout this section, the data availability for many years is low; thus the number of exceedances should be considered as a lower limit. There are exceedances of the annual NAAQS for PM₁₀, PM_{2.5}, and NO₂ across multiple stations.

Table 5. Number of annual exceedances of the criteria pollutants NAAQS for all the CoJ stations.

		Alexandra		Buccleuch		Delta Park		Jabavu		Newtown		Orange Farm	
		Exceedance	% Data Availability	Exceedance	% Data Availability	Exceedance	% Data Availability	Exceedance	% Data Availability	Exceedance	% Data Availability	Exceedance	% Data Availability
PM ₁₀ Annual	2004	0	92	1	83	0	80	1	73	0	82	1	66
	2005	0	77	1	48	0	71	1	61	0	59	1	70
	2006	1	54	1	87	0	57	1	65	0	97	1	80
	2007	1	74	1	83	0	79	1	67	0	75	1	77
	2008	1	30	1	87	0	62	1	60	1	64	1	56
	2009	1	50	1	91	0	88	1	75	0	78	1	91
	2010	1	39	1	45	0	65	1	57	0	6	1	72
	2011		0	0	62	0	16	1	43	1	61	1	68
	2012		0		0		0	1	43	1	80	1	18
	2013		0	1	44		0		0	0	50	0	8
	2014		0	1	33		0		0	0	46	1	31
	2015		0		0		0		0		0		0
	2016	0	20	1	41		-	0	57		-	0	55
	2017	1	45	1	29		-	1	66		-	0	73
	2018	0	11		-		-	1	84		-	0	63
PM _{2.5} Annual	2004		-	1	83		-		-		-		-
	2005		-	1	58		-		-		-		-

	2006		-	1	95		-		-		-		-
	2007		-	1	41		-		-		-		-
	2008		-	1	88		-		-		-		-
	2009		-	1	87		-		-		-		-
	2010		-	1	45		-		-		-		-
	2011		-	1	62		-		-		-		-
	2012		-		0		-		-		-		-
	2013		-	1	11		-		-		-		-
	2014		-		0		-		-		-		-
	2015		-		0		-		-		-		-
	2016	0	20	1	43		-		0		-		
	2017	1	51	1	29		-		0		-		
	2018	0	12		-		-	1	26		-		
SO ₂ Annual	2004	0	81	0	83		-	0	77		-	0	74
	2005	0	81	0	58		-	0	60		-	0	84
	2006	0	68	0	94		-	0	71		-	0	84
	2007	0	78	0	81		-	0	77		-	0	80
	2008	0	31	0	88		-	0	74		-	0	57
	2009	0	62	0	61		-	0	89		-	0	89
	2010	0	34	0	42		-	0	68		-	0	52
	2011		0	0	31		-	0	43		-	0	64
	2012		0		0		-	0	45		-	0	17
	2013		0	0	16		-		0		-		0

	2014		0		0		-		0		-		0
	2015		0		0		-		0		-		0
	2016		0	0	28		-	0	36		-	0	49
	2017	0	56	0	28		-	0	87		-	0	80
	2018	0	90		-		-	0	86		-	0	79
NO ₂ Annual	2004	1	94	1	83	0	27		-	1	82		-
	2005	1	78	1	44	0	82		-	1	57		-
	2006	1	68	1	94	0	86		-	1	96		-
	2007	1	62	1	83	0	89		-	1	77		-
	2008	0	20	0	8	0	73		-	1	71		-
	2009	1	69	1	91	0	53		-	1	86		-
	2010	1	38	1	44	0	1		-	0	45		-
	2011		0	1	17	0	40		-	0	12		-
	2012		0		0		0		-		0		-
	2013		0	0	45		0		-		0		-
	2014		0	0	12		0		-		0		-
	2015		0		0		0		-		0		-
	2016		0	1	45		-		-		-		-
	2017	1	15	1	22		-		-		-		-
	2018		0		-		-		-		-		-

3.2.1 Summary of the state of monitored ambient air quality

Table 6 below summarises the state of air in the CoJ per pollutant. In general, PM and ozone concentrations are above standards at most sites within the City. In addition, at the sites impacted heavily by traffic, NO₂ concentrations are above the standards. The largest number of exceedances of the PM₁₀, NO₂ and O₃ NAAQS occur at Alexandra, Buccleuch and Delta Park, respectively. The limitations due to low data recovery across many years should be kept in mind when interpreting the number of exceedances.

Table 6. Summary of City of Johannesburg's ambient air pollutant concentrations.

Pollutants	Summary of ambient concentrations
Sulphur dioxide (SO ₂)	Ambient concentrations of SO ₂ are relatively low in the CoJ, with occasional exceedances of the limit value of the ambient standards, but there are no exceedances of the allowed frequency of exceedances.
Nitrogen dioxide (NO ₂)	Concentrations are fairly high surrounding the major highways and traffic zones. The largest number of exceedances of the NO ₂ National Ambient Air Quality Standard is from the Buccleuch and Newtown monitoring stations.
Particulate Matter (PM ₁₀)	Concentrations of PM ₁₀ are generally highest at the stations located within low-income areas. Concentrations frequently exceed the daily and annual ambient standards at these stations.
Particulate Matter (PM _{2.5})	There are only data available from the Buccleuch station for the period 2004 to 2015. There are, however, exceedances of the daily and annual ambient standards during these years.
Carbon Monoxide (CO)	Ambient concentrations of CO are relatively low throughout the CoJ.
Ozone (O ₃)	Ambient concentrations are relatively high within the vicinity of the Delta Park station, with a number of exceedances of the 8-hour running average ambient air quality standard.
Benzene (C ₆ H ₆)	A limited amount of data for the ambient concentrations of benzene was only available from the Buccleuch monitoring station, and as such, was excluded from this analysis. Data recovery and the quality of data that was available were poor.
Lead (Pb)	Ambient concentrations of lead have decreased significantly throughout the country and are no longer monitored in most ambient monitoring networks.

3.3 Ambient air quality monitoring gaps

The City of Johannesburg has a lot of the requirements in place to operate a fully functional ambient air quality monitoring network. There are qualified staff who are able to run the stations, the macro-siting of the monitoring stations is generally good and captures the ambient air quality in a variety of areas within the City, including; an urban background site, low-income residential areas with heavy influence of domestic combustion emissions, a traffic site, a traffic and CBD site, and a site heavily impacted by wind-blown dust. The micro-siting of the stations is generally quite good although

continuous care needs to be taken to ensure that the growth of trees does not impinge on the fetch of the stations.

In terms of the traceability of the measurements, the majority of the infrastructure is in place however it needs to be fine-tuned to meet the needs of the network.

A number of recommendations to improve the air quality monitoring activity within the City of Johannesburg are provided as follows:

- 1) It is recommended that scheduled maintenance occur more frequently so as to limit the number of monitoring stations that are not operational at any given time and improve data recovery.
- 2) It is recommended that the management system documentation be consolidated – consider basing the management system documentation on an international standard such as ISO 17025:2005 and the draft requirements that are being developed in the Norms and Standards for Air Quality Monitoring. This will allow for ease of use and understanding.
- 3) Currently no standard operating procedures exist for data management and validation – these will need to be developed as a matter of urgency to ensure that there is consistency in how the data are validated and processed.
- 4) Emphasis needs to be placed on understanding the traceability requirements of the measurements and this should feed through to procedures on calibration and criteria for the selection of service providers and supplies calibration relevant materials.
- 5) No program for the calibration of meteorological equipment currently exists. Cognisance of the meteorological calibration requirements needs to be taken in account when calibrating the instrumentation in the stations.
- 6) A consolidated approach needs to be considered when planning training for the technical staff to ensure that the requisite skills are available.
- 7) The micro-siting of some of the stations needs to be evaluated and impedances to the airflow need to be addressed.

3.4 Impact of air pollution in CoJ

An evaluation of health studies can be used to understand (in part) the status quo of health and the associated challenges experienced in the City of Johannesburg. Although health studies have been conducted in the City since 2003, a review of these studies has indicated that they did not focus on the link between air pollution and human health *per se*. Some studies did consider concentrations of air pollutants, while others reported on general health outcomes rather than air pollution-related health outcomes. The results from the recent DEA Vaal Triangle Airshed Priority Area (VTAPA) Health Study were not yet public at the time of this report, and thus were not included. However, as there are areas within the CoJ in the VTAPA, those results would assist in understanding the current health of the population as well as the linkages between health and air pollution. Thus a summary of what is known on the status of health is provided here.

The trends in the leading Year of Life Lost (YLL) for Johannesburg between 2008 and 2012 are shown in Figure 10 (DHB, 2015). The YLL is a “measure of premature mortality based on the age at death and therefore highlight the causes of death that should be targeted for prevention” (DHB, 2015, p. 219), and thus can provide a high-level understanding of the health status of citizens in CoJ. This graph can provide context to understand the potential impact of air pollution on health, as exposure to air pollution can be related, though is not the only factor leading to conditions such as respiratory infections, ischaemic heart disease and cerebrovascular disease. In addition, tuberculosis is an existing disease that can make a person more susceptible to the negative health impacts from exposure to air pollution. All of these are shown as part of the top 10 causes of YLL in CoJ. Figure 10 shows that the lower respiratory infections percentage of YLL have dropped from 11.3% to 7.9%, and stayed at a ranking of 3. Ischaemic heart disease has stayed at a ranking of 6, and cerebrovascular disease has increased from 3.1% (ranking of 7) to 4.0% (ranking of 5). Tuberculosis has also stayed constant with a ranking of 2, though the percentage has decreased.

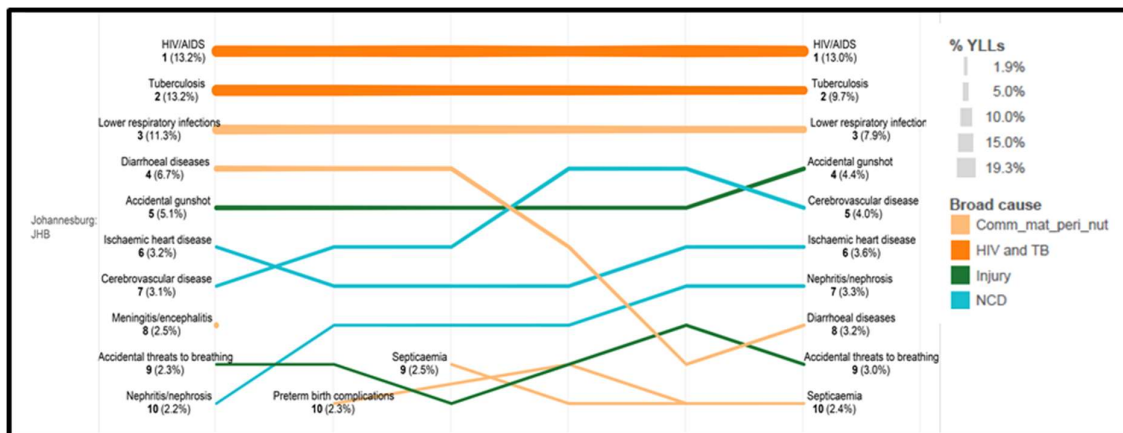


Figure 10. Trends in leading YLLs in City of Johannesburg between 2008 and 2012, rank (% of total YLLs), 2008-2013 (DHB, 2015). The meaning of the colour and thickness of the line are provided in the legend.

3.5 Air quality complaints

The CoJ has kept an air quality complaints register since 2007, and these were assessed to understand the nature and source of the complaints, as well as the action taken on the complaints. Over the 9 years, a total of 111 complaints were recorded, with a high variety in number of complaints per year (Figure 11). Most of the complaints were related to burning, dust or odour.

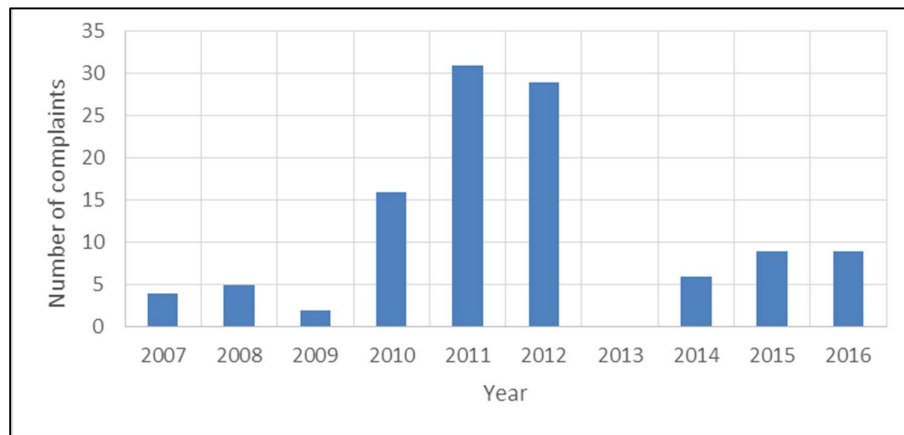


Figure 11. Number of air quality related complaints from provided complaint registers.

An air pollution complaints register form could provide a good building block for capturing and resolving air pollution-related complaints. It is however not currently functioning effectively due to the following reasons:

- Information capturing is not consistent
- There does not seem to be a process in place to track complaints and to ensure that they are being resolved.
- It is thus difficult to determine where complaints have originated from.

A spreadsheet with a possible way to digitally capture the complaints was developed and included in the Status Quo Report to assist the CoJ.

4 Status Quo: Emissions inventory

The emissions inventory forms an integral part of the AQMP by providing an overview of the emission sources within the City such that management may be directed and modelling may be appropriately informed regarding source characteristics and magnitude of emissions. The emissions inventory developed for the CoJ AQMP project includes both a municipal (CoJ) and a regional emissions inventory for 2014. Both inventories are gridded where appropriate. The CoJ specific inventory is at a 1km grid cell resolution while the regional is at a 3km grid cell resolution. Figure 12 shows the two emissions grid domains which are identical to the air quality modelling domains.

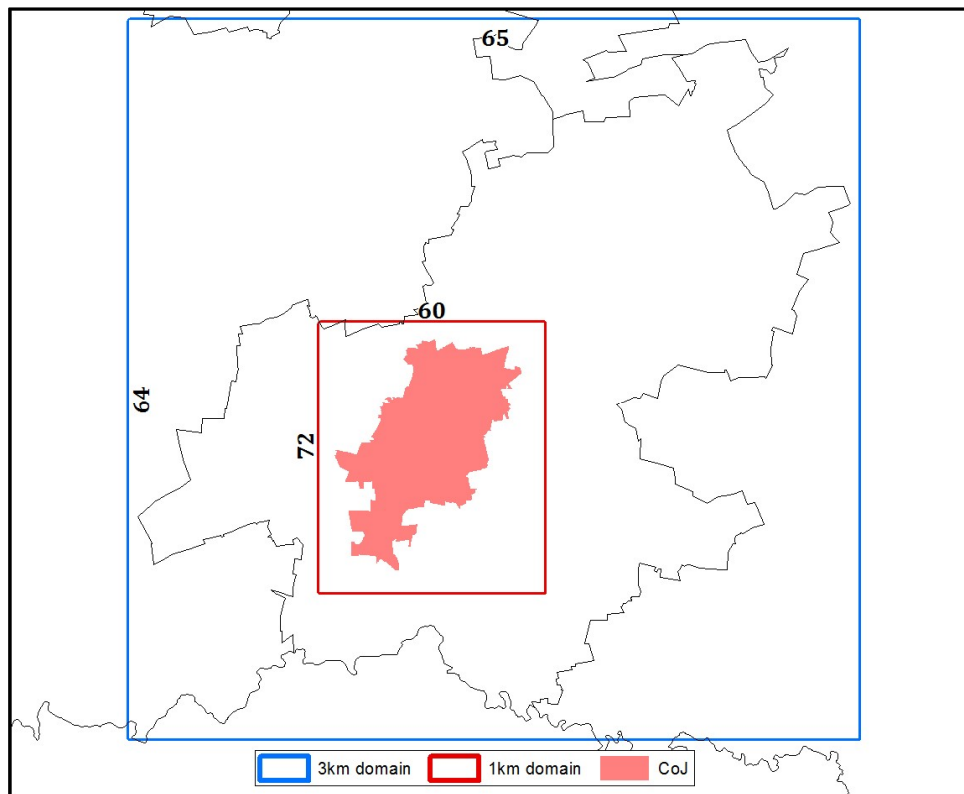


Figure 12. Emissions grid domains considered for the development of emissions inventories.

The methodologies used for estimation are consistent between domains, and thus no matter which domain is being reported on the methodology is the same.

The sectors covered in this emissions inventory include:

- Biogenic VOC
- Biomass burning
- Aircraft emissions
- Household fuel combustion
- Windblown dust from Tailings Storage Facilities (TSF)
- Industrial sources
- On-road vehicles
- Waste treatment

Figure 13 provides the estimated CoJ total annual emissions for important pollutants colour-coded by sector; and Table 7 displays the estimated total annual emissions of the criteria pollutants. The vehicle emissions in this figure were estimated using a Travel Demand Model (TDM).

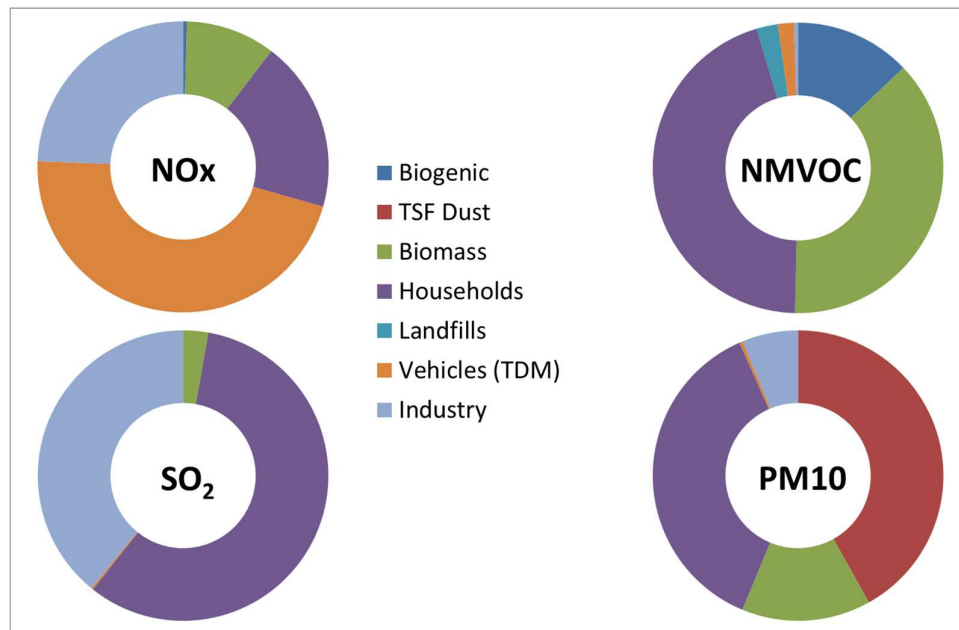


Figure 13. Summary of sector contribution to total annual criteria pollutant emissions within CoJ (using the TDM for the vehicle emissions estimates).

Table 7. Total annual emissions of criteria pollutants in CoJ for 2014 (tons per annum).

	NO _x	SO ₂	NMVOC	PM ₁₀
Emissions (tons per annum)	8 554.07	6 397.41	14 636.54	23 774.90

The estimated share of emissions between sectors indicates that different sources are important for different pollutants. Thus management of specific sources may result in improvements of air quality, but only for certain pollutants. This means that source specific management efforts need to be done in concert to effectively improve air quality. That being said there are still key sectors to be targeted.

Household fuel combustion (purple in Figure 13) is estimated to contribute heavily to non-methane volatile organic compounds (NMVOC), SO₂ and PM₁₀ emissions. In spatial terms these emissions are isolated to a few geographical areas, where high coal and/or wood consumption was allocated according to the methodology used. A more disperse source such as on-road vehicles is estimated to contribute highly to NO_x emissions; which then impacts larger regions. Dust impacts PM, though the zone of highest impact is geographically limited (i.e. to areas immediately around the source). Industrial emissions, while not fully quantified here due to lack of data, contribute heavily to SO₂ emissions in particular.

While the use of a TDM was found to improve the spatial representation of emissions as compared to other methods, it was found to underestimate the emissions from the on-road vehicle sector. Thus there was higher uncertainty in this source category.

When possible, it is advisable to compare results from different approaches, such as emission estimates from the TDM (bottom-up), and a top-down approach; this is because both methods have their own limitations and assumptions, and thus the comparison assists in constraining the final results. In addition, in most emission inventories in South Africa this top-down method is used; and for that reason it is also helpful to compare the results from this method to the TDM.

In this emissions inventory, the vehicle emissions were estimated with the TDM, which is a bottom-up approach. These overall results for CoJ are presented in Figure 13. In addition, vehicle emissions were estimated using a top-down approach for comparison; these are presented in Figure 14.

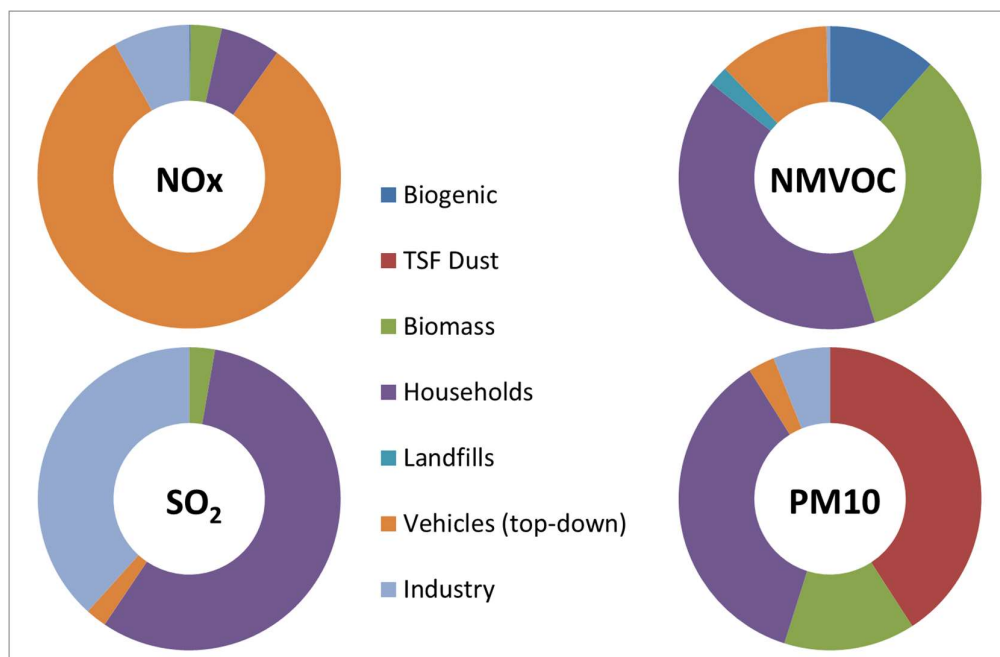


Figure 14. Summary of sector contribution to total annual criteria pollutant emissions within CoJ (using top-down approach for vehicle emissions).

The differences in the approaches do impact the sector's share to each of the pollutants. However, the main source category per pollutant is not impacted and the main management findings are the same, even in the on-road vehicle sector. In order to decrease NO_x emissions, it is critical to focus on interventions in the transport sector; interventions in this sector may also impact SO₂ and NMVOC emissions, though on-road vehicles do not dominate the emissions of those pollutants in CoJ.

4.1 Emissions inventory gaps

The emissions inventory derived here must still be seen in context of the gaps and limitations listed in each section. In addition potential improvements are provided for each sector. These primarily deal with access and/or creation of better data to drive more accurate estimates. The potential impact of these gaps from the gap assessment is highlighted in Table 8 per sector. There is much room for improvement in accessing industrial and airports data; and this requires dialogue with data holders and both creation and maintenance of good relationships. For household fuel combustion, dedicated (i.e. focused on emissions information) fuel use surveys are required for the regions in CoJ that exhibit high usage. Similarly more directed travel surveys can help derive finer spatial and temporal demand information for use in the TDM. Additionally, further work is required to include class 4 and 5 roads within the TDM.

Table 8. Summary of emissions inventory gap analysis.

Sector	Under/over estimation	Spatial significance
Biogenic VOC	Under-estimated	Regional
Biomass burning	Under-estimated	Regional
Aircraft landings and take-offs	Under-estimated	Local
Household fuel combustion	Over- or Under-estimated	Regional
Wind-blown dust	Under-estimated	Local
Industrial sources	Under-estimated	Local - regional
On-road vehicles (TDM method)	Under-estimated	Regional
Landfills	Over- or Under-estimated	Local
Waste-water	NA	Local

Note that the column “spatial significance” refers to the potential spatial extent an uncertainty in a sector would have. So for example the under-estimation in the biogenic VOC has a regional impact, i.e. the under-estimation is consistent regionally.

4.1.1 Waste Burning

Although waste burning was not estimated in this AQMP, it has been raised as an area of concern both with regards to, the burning of waste by communities as well as at landfill sites.

4.2 Trends in emissions in CoJ

Through the continual development of emissions inventories via the AQMP framework, an entity is able to track changes in emissions and implementation of any mitigation measures. The 2003 AQMP did not contain emissions estimates as such, and focused rather on planning actions for emissions inventory development and potential mitigation measures to apply to sectors that are seen to be high emitters (e.g. transport and domestic fuel combustion). It is thus not possible to draw either methodological comparisons or track changes between previous emissions inventories and this 2014 estimate since there are none that are officially sanctioned for use by CoJ.

5 Status Quo: Air quality modelling

The primary aim of air quality modelling in this AQMP was to identify air pollutant hotspots. This is achieved by simulating the transport and transformation of pollutant emissions on an hourly basis within the CoJ boundary and applying various analyses to the output. The air quality model used to achieve this is the Comprehensive Air Quality Model with Extensions (CAMx) developed by Ramboll-ENVIRON (see www.camx.com). CAMx requires as input hourly emissions, meteorological data, initial and boundary conditions and photolysis rates. For the CoJ AQMP, meteorological data was simulated using the Weather Research and Forecasting (WRF) model Version 3 (Skamarock et al., 2008).

5.1 Model-measurement comparison

A comparison with model output and measurements is necessary to ascertain model performance and usability of output, and was performed on the input WRF meteorological fields as well as the CAMx air quality output. For both verifications, however, measurements are sparse within CoJ or cannot be easily accessed. In terms of air quality, for 2014, only the VTAPA Diepkloof site was operational and thus the CAMx output verification could only happen at one point. It is difficult to ascertain the actual performance of the model for the City as a whole at only one point, though the comparison does highlight important considerations. It is clear from the results of the comparison that the deficiencies in the emissions inventory due to lack of data have an impact on the model output. The simulated ambient air concentrations do show an underestimation of NO_x at Diepkloof, which in turn impacts the ozone concentrations. In addition, from the diurnal comparisons of SO₂ it is clear there is a missing local source(s). These model outputs will continue to improve, and thus be able to be used even more to support air quality management, as the emissions inventory improves.

5.2 Hotspot analysis

A hotspot analysis of criteria pollutants from the CAMx simulations was performed (keeping in mind the limitations of the model output) and the main findings will be directly applicable to air quality management in the CoJ.

Areas near communities with heavy residential fuel burning and mine tailings storage facilities (TSF's) were identified as hotspots for PM₁₀ (Figure 15). This is similar to what is found in the

monitoring data analysis. This highlights the importance of keeping monitoring stations in areas with residential fuel burning and near TSFs. The Tembisa and Ivory Park area is identified as a hotspot, and currently there are three monitoring stations within that area (two in Ekurhuleni as part of the Highveld Priority Area network (HPA) and one in CoJ network) (Figure 16). Thus this is an opportunity for collaboration with HPA and Ekurhuleni to maximise the efficient coverage of the monitoring stations. If possible, the Ivory park station could be moved to an area such as Zandspruit or Eikenhof that also came up as a simulated hotspot for PM₁₀.

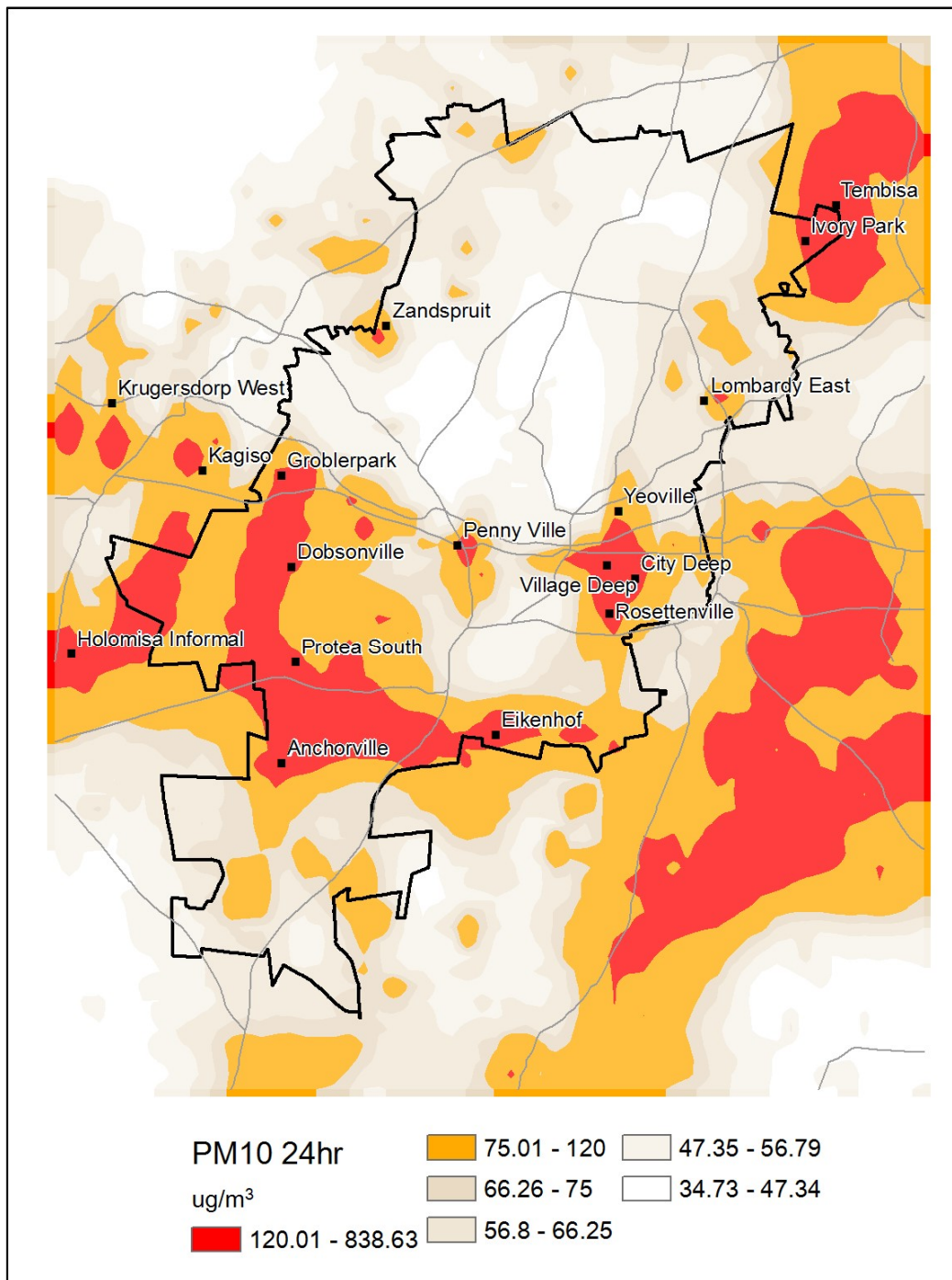


Figure 15. Simulated 99th percentile of 24-hour average PM₁₀ for 2014.

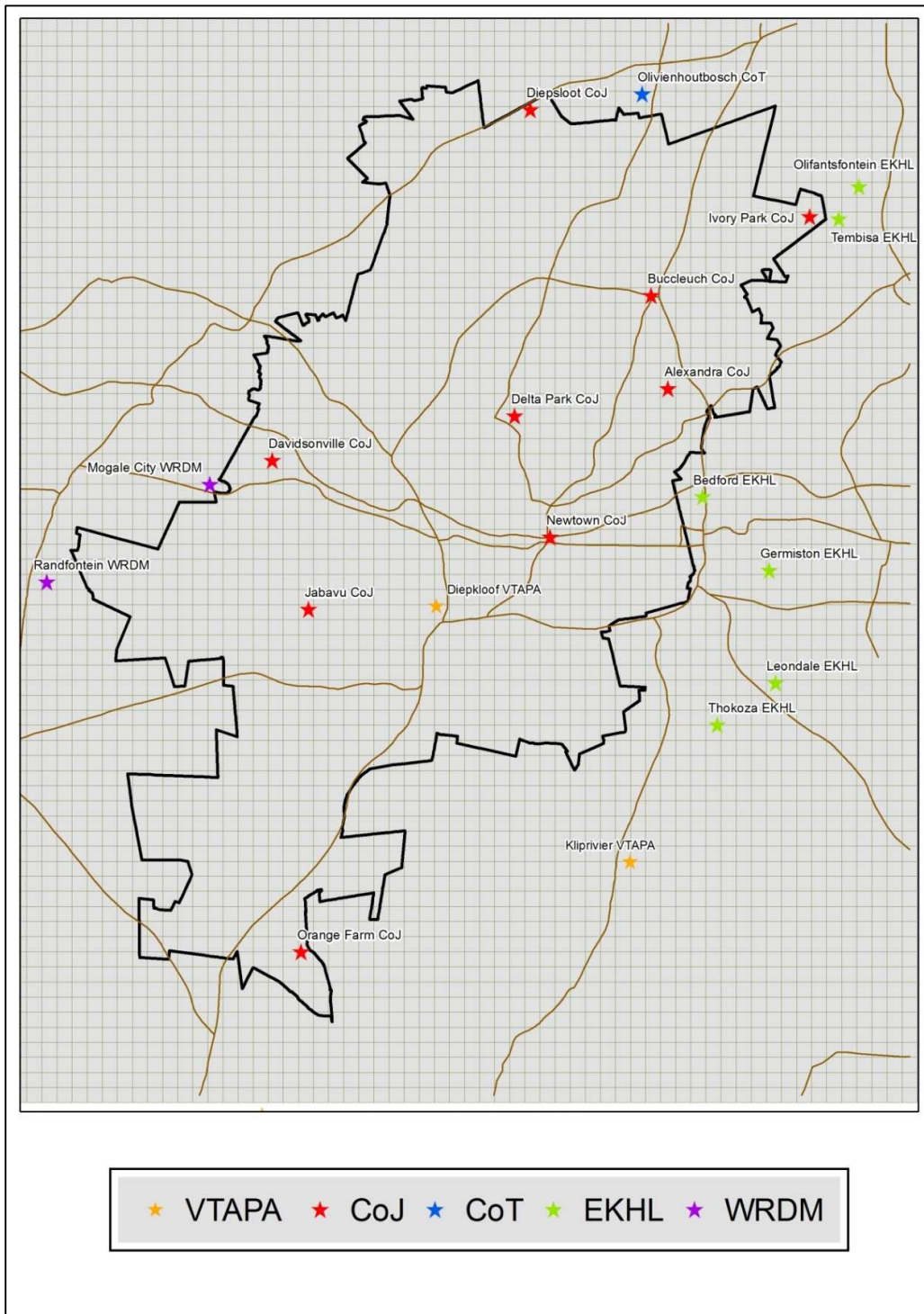


Figure 16. Monitoring stations in and near CoJ from City of Tshwane (CoT), Ekurhuleni (EKHL), West Rand (WRDM), and VTAPA networks.

The hotspot analysis showed that the simulated hotspots for ozone are in areas further away from emission sources (e.g. traffic) (Figure 17). Though there are periods, such as weekends, when traffic stations do also show exceedances. This is consistent with what was found in the ambient monitoring analysis, especially with the comparison between Delta Park, and Newtown and Buccleuch. Thus the model outputs and the monitoring analysis highlight the importance of maintaining an urban background site such as Delta Park.

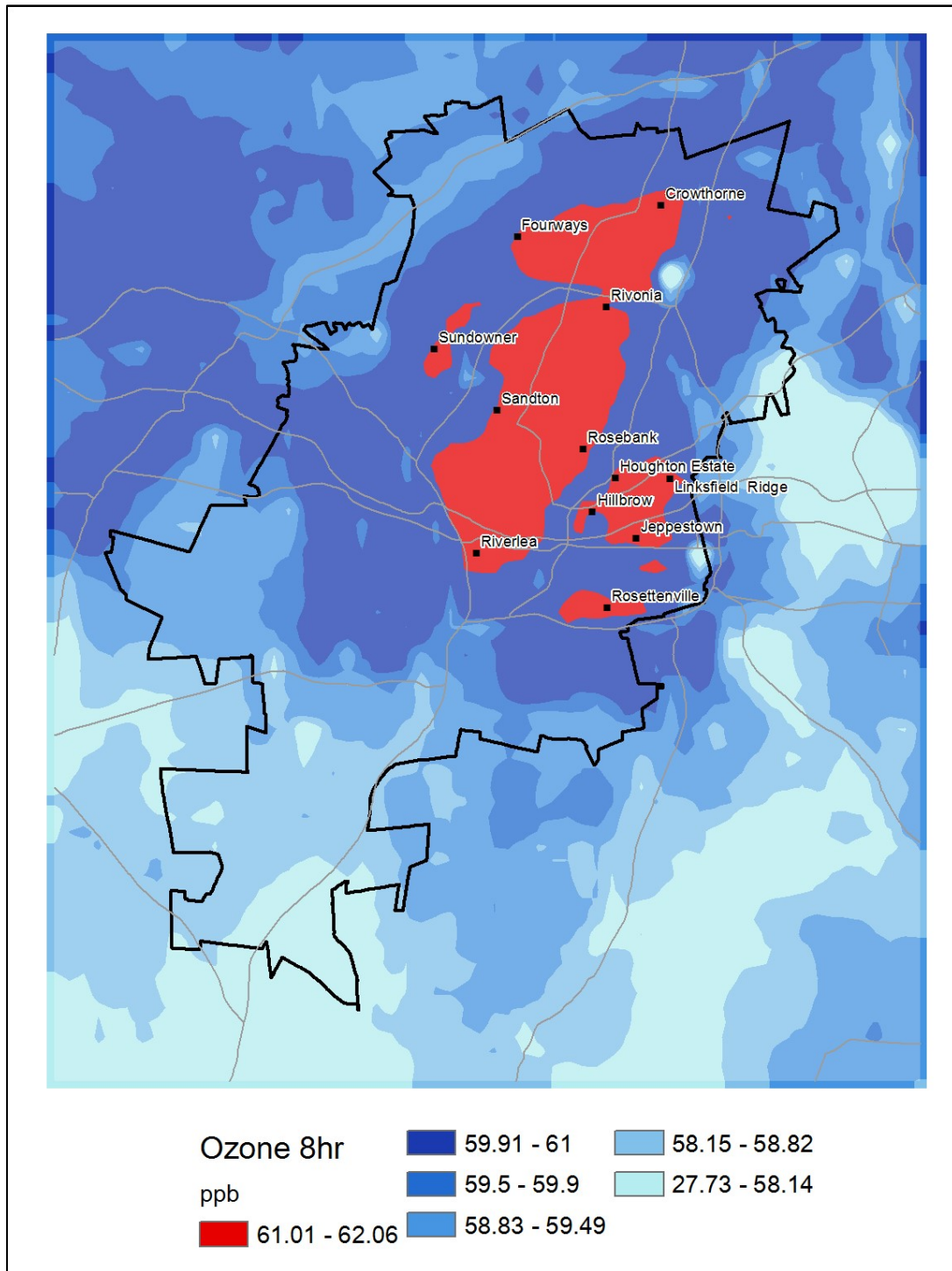


Figure 17. Simulated 99th percentile of 8-hour (running average) ozone for 2014.

Finally, across the hotspot analysis it was evident that trans-boundary pollution is an important factor for the CoJ. This was highlighted by the fact that Kelvin power station (green star in Figure 18) routinely was identified as a hotspot, which is especially clear for SO_2 (Figure 18). The analysis of the monitoring data does show that there are not many exceedances of SO_2 in the CoJ. However, SO_2 from Kelvin can form secondary particles, which could add to the PM loading in the City. A gap in the emissions inventory was missing data from sources that were outside the CoJ boundary, and thus it is likely that the impact of trans-boundary pollution is underestimated. This presents an opportunity for collaboration between CoJ and surrounding municipalities.

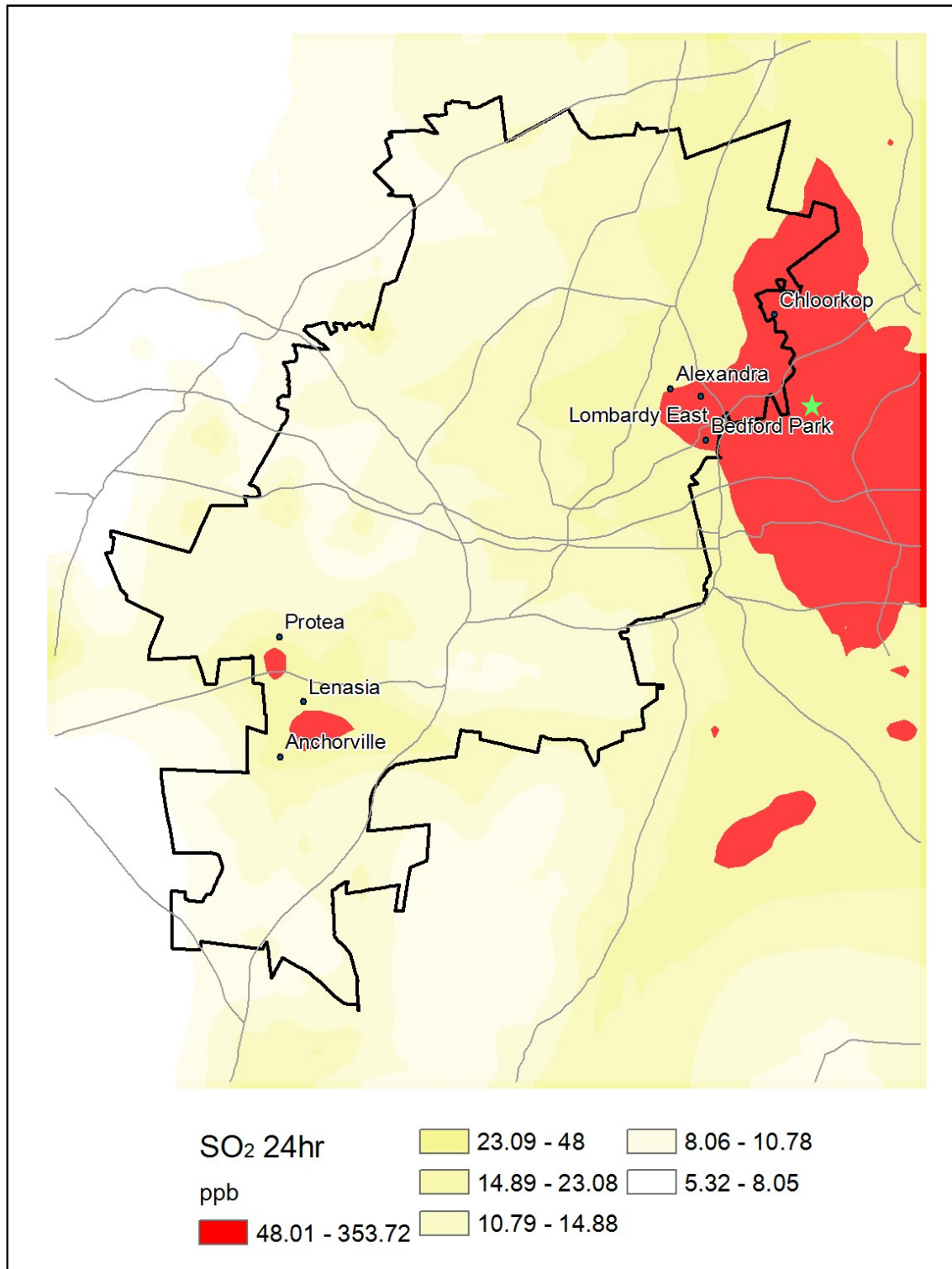


Figure 18. Simulated 99th percentile of 24-hour average SO₂ for 2014.

5.3 Emission reduction scenario modelling

Through stakeholder engagement two sectors were identified as being a feasible means to investigate scenario modelling for the CoJ, that being wind-blown dust from TSFs and the on-road vehicle sector. Both of these sectors contribute greatly to emissions in the CoJ (Figure 13). Since the impact on air quality due to mitigation of wind-blown dust emissions from TSFs is linear and spatially limited, the wind-blown dust emission scenarios themselves represent the result; while for on-road vehicles further air quality modelling with CAMx is required to translate emissions changes to impact of the scenario.

5.3.1 Wind-blown dust from TSF

Two scenarios were modelled for all the TSF considered:

- Short-term Scenario (1-2 years): 40% CE (control efficiency) on the “baseline” exposed areas, to reflect the short-term (1-2 years) rehabilitation (vegetation established but not demonstrated to be self-sustaining).
- Medium-term Scenario (2-5 years): 90% CE on the “baseline” exposed areas, to reflect revegetation (medium-term).

With these mitigation measures in place, the total PM₁₀ emissions from windblown dust in CoJ will reduce from 9381 tpa to 5629 tpa in the short-term (1-2 years) and to 938 tpa in the medium-term (2-5 years). Similarly the PM_{2.5} emissions from windblown dust will reduce from 2739 tpa to 1643 tpa in the short-term and further to 274 tpa in the medium-term.

Figure 19 highlights the sector contributions to PM₁₀ emissions assuming that TSF emissions meet medium-term goals, and all other sectors are held constant at 2014 levels. From Figure 19 it is clear the large impact that these mitigation measures can have on PM₁₀ emissions.

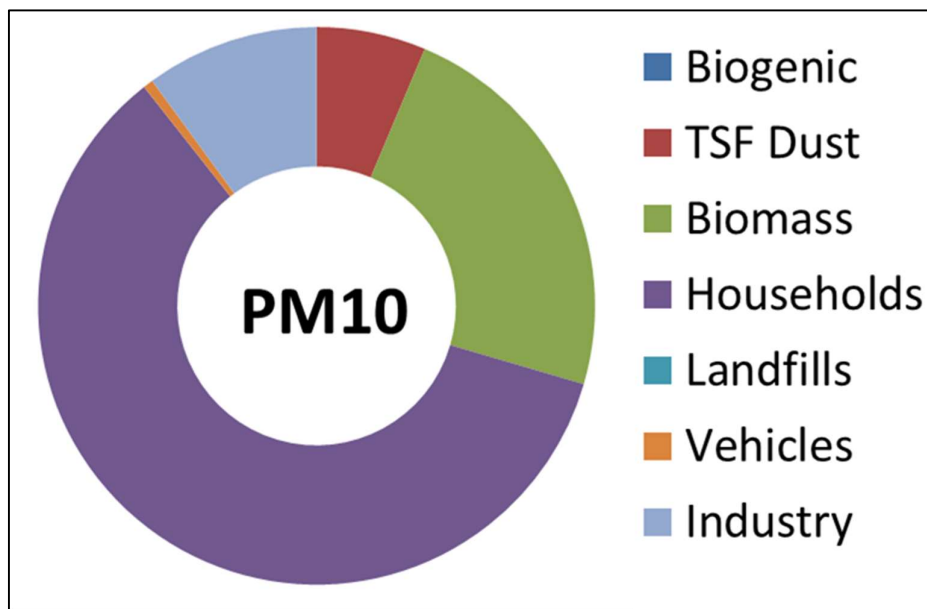


Figure 19. Sector contributions to PM₁₀ emissions assuming that TSF emissions meet medium-term goals and all other sectors are held constant at 2014 levels (as in Figure 13).

5.3.2 On-road vehicles

For this emission scenario investigation a TDM was employed to simulate the impact of Rea Vaya and Gautrain on the transport system. Since the major primary pollutants from vehicles include NO_x and NMVOC (pollutants that interact and transform chemically), the emission changes had to be modelled with CAMx to investigate changes in ambient air quality.

Three scenarios and a base case were generated. The scenarios are defined in terms of intensity of effectiveness, namely low, moderate and high. The base case (called “Do Nothing”) represents a network without any of the interventions (and thus effects) in place. All scenarios and base case occur in a transport system with projected demand for 2037, representing full use of the systems and associated direct and indirect impacts.

It should be noted that while Rea Vaya was modeled as being completed in all phases of development, the Gautrain was simulated as it is currently (i.e. no expansion plans are included).

For the Do Nothing Case, the emission totals greatly increase, and are between 3-7 times larger than those estimated for the 2014 emissions inventory developed here. In the current 2014 emissions inventory, the transport sector already dominates NO_x emissions.

The Hi Diversion scenario, where the Rea Vaya network has been completed in all phases of development and there is a modal shift of 62% from private cars to Rea Vaya (currently, it is assumed to be ~10%), there is only ~4% change in emissions compared to the Do Nothing Scenario

(Figure 20). This highlights the fact that while current plans for BRT expansion and the Gautrain can have positive impacts on emissions, their impact in isolation is minimal.

Table 9. Emission totals (tpa) for the Do Nothing case and ratio thereof to the 2014 base.

Pollutant	Total (tpa)	Ratio to 2014 (Do Nothing / 2014 base)
NO _x	15 810.22	3.04
NM VOC	2 179.72	6.50
PM _{2.5}	425.50	3.81
CO	25 051.76	4.91
SO ₂	81.37	4.98
NH ₃	2 107.12	5.00

Table 10. Emission totals (tpa) for the Hi Diversion case and change (mass and percentage) from Do Nothing.

Pollutant	Total (tpa)	Mass change (tpa)	% change
NO _x	15135.62	-674.60	4.27
NM VOC	2074.75	-104.97	4.82
PM _{2.5}	406.25	-19.25	4.52
CO	24035.38	-1016.38	4.06
SO ₂	77.74	-3.64	4.47
NH ₃	2013.22	-93.89	4.46

When these interventions are modelled in CAMx, the HI Diversion scenario simulates decreases in NO concentrations along the central region and extending towards the north-west as compared to the Do Nothing (map not shown here). These decreases are in line with Rea Vaya BRT routes. The magnitude of decreases is relatively low and is expected due to the 4% decrease in emissions. The interlinkages of the transport sectors across boundaries are also highlighted in the simulated ambient concentrations of pollutants. In the TDM, behavioural and economic considerations are included, and thus demand shifts geographically in response to these interventions, which in these simulations led to an increase in NO in parts of Ekurhuleni in the Hi Diversion scenario compared to

the Do Nothing scenario. And, as increases in NO outside of CoJ can have air quality impacts within CoJ, it is important that there is collaboration throughout the Province on transport interventions.

The decreases in NO when comparing the HI Diversion to the Do Nothing will generally bring an increase in ozone; however these changes in concentration are very small (none over 1ppb (not shown)). The majority of the changes occur over the central region where NO₂ decreases are most prominent. In terms of annual average ozone changes there are only very few areas that exhibit any decrease.

Compared to the 2014 emissions inventory, these increases in emissions from increased demand are simulated to drastically increase ambient concentrations of NO_x. Figure 20 highlights the increase in the 99th percentile of 1-hourly averaged NO₂ concentrations from 2014 base to the Do Nothing scenario, and the increase in the annual mean. In the ambient monitoring analysis it was seen that traffic sites already are in exceedance of the NAAQS for NO₂, and thus such unchecked growth in the transport sector, or interventions implemented in isolation, would greatly deteriorate air quality.

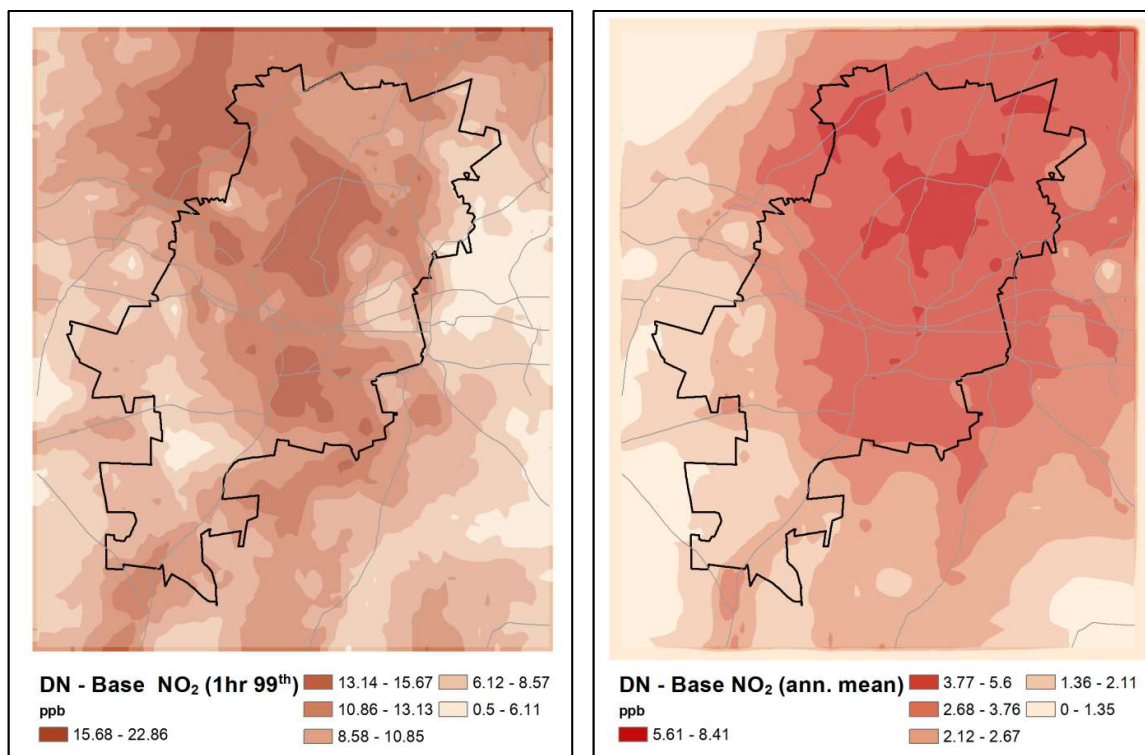


Figure 20. Simulated change in NO₂ concentrations (1hr 99th and annual mean) for Do Nothing minus 2014 base.

These impacts are often seen when applying very specific on-road vehicle interventions where the decrease in vehicle kilometres travelled brings about a decrease in NO, but an associated increase in ozone. To accomplish a reduction in NO_x AND ozone on a regional scale, the CoJ either needs to

implement much more aggressive NO_x reductions and/or must implement parallel mitigation of high NMVOC emitters. In the 2014 emissions inventory developed here, these NMVOC interventions could focus on either biomass burning or domestic fuel use. If possible, mitigation measures should be applied to both vehicles and domestic fuel use. Further to this, a more widespread and comprehensive approach to traffic alleviation will be more effective in reducing poor air quality. The BRT cannot achieve this in isolation; as is seen through this investigation.

6 Status Quo: Resource gap assessment

The financial and capacity resources that the CoJ currently has (and plans to have) in order to manage air quality in the CoJ, and those needed to achieve goals in the AQMP, were assessed. The focus of this assessment was on the capacity within EISD, however, it is noted that air quality management is a cross-sectoral issue, and there will need to be capacity across the City to manage air quality effectively. The assessment of the needed human resources for the City of Johannesburg's EISD for air quality management were informed by the DEA Business Case, the findings of the monitoring gap assessment, the modelling gap assessment, the emissions inventory gap assessment, and the development of the air quality management plan goals. The proposed overall organogram is shown in Figure 21 below. The proposed organogram has a total of 19 staff. The current structure of the office has 10 positions approved in its organogram. This proposed structure would include specialists under regulation, covering compliance monitoring (by-law enforcement, and AEL and Section 23 compliance monitoring).

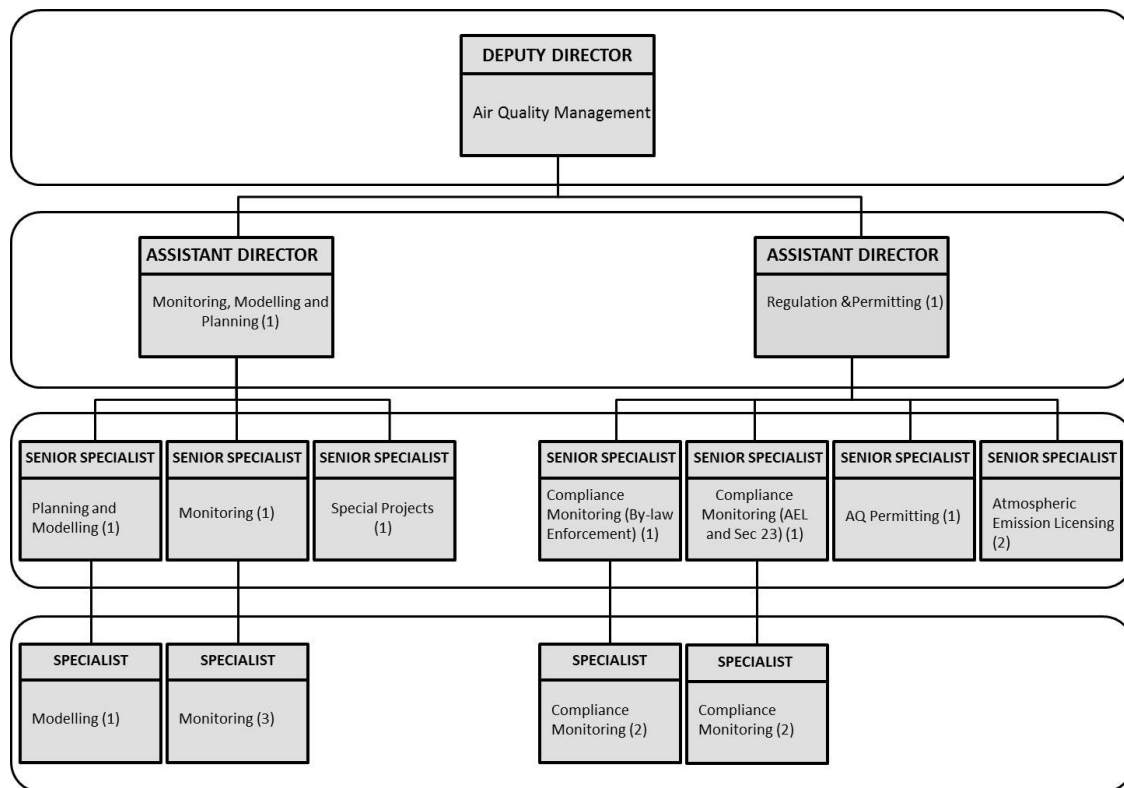


Figure 21. Proposed organogram for the air quality management division of EISD.

This team would be responsible for air quality management for the CoJ, and would work across sectors in order to improve air pollution. The total estimated operational costs were ~R12.7 million per year, though this would not include necessary budget for special programmes that may come from the AQMP (Section 9.4 contains a more detailed discussion on budgetary needs).

7 Conclusions from Status Quo Assessment

While air quality management activities have been on-going since 2003, there has been a lack of a continuous concerted effort to improve air quality. Currently, the air pollution in the City is not in compliance at many sites of the NAAQS. It is not possible to estimate trends in neither ambient air pollution nor air pollutant emissions due to a lack of historical data. The estimated share of emissions between sectors highlighted that different sources are important for different pollutants, and thus management of specific sources may result in improvement of air quality, but only for certain pollutants. This means that source specific management efforts need to be done in concert to effectively improve air quality.

Key sectors to target both from the impact on emissions and the need for better data are industrial, residential from burning of solid fuels, and on-road vehicles. Thus cross-sectoral collaboration is vital to improve air quality. In addition, CoJ is heavily impacted by trans-boundary pollution, and thus

collaboration across municipalities and across levels of government are also needed to improve air quality in the airshed.

The air quality emissions and model scenarios show that depending on the sector being investigated, the impacts can either be very localised or widespread. Mitigating emissions from TSFs will be effective in reducing PM₁₀ exceedances within the immediate vicinities. The options for mitigating TSFs are effective and well-known. It will therefore be a case of communicating with the relevant stakeholders to put a plan in place for moving forward. In terms of the vehicle traffic scenario, it was found that much more aggressive (than purely BRT) interventions are required to change ambient air quality concentrations. This is due to the complex network that is the urban transport system. Introducing interventions along narrow corridors do reduce pollution in these areas but spatially extended impacts require further and more detailed analysis. This should be achieved in conjunction with the City's transport department; where air quality must play a role in determining the costs and benefits of any large scale traffic intervention.

Much of these results must be seen in light of the respective uncertainties and gaps in data. However for the gaps and needs highlighted, there are implementable paths for improvement, which form the basis for the actions in this AQMP.

8 Approach to air quality management and improving air quality

Air quality management is an on-going and continuous process in order to improve and then maintain good air quality that is in compliance with national standards. This can be seen with the necessary periodic review and update of Air Quality Management Plans every five years. However, this continuous monitoring is not just restricted to these periodic reviews, but rather it is an on-going and iterative process.

Figure 22 highlights the overall and iterative process for managing air quality, together with some of the tools needed. This cycle highlights the overarching activities necessary to manage and improve air quality, as well as the key role for new research and information to inform this cycle. Though not explicitly stated in the flow, this process does involve many stakeholders, including government, the public, industries, and academia.

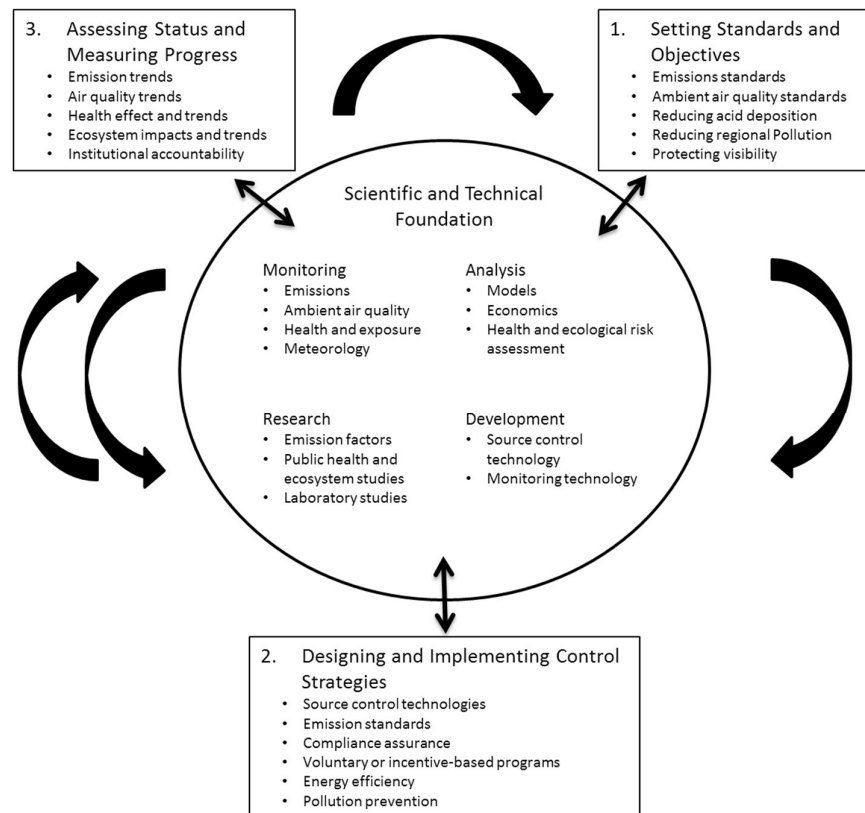


Figure 22: Air Quality Management Cycle (adapted from The National Academies, 2004).

In order to improve air quality, it is important to understand the problem, and then establish goals in improving air quality based on the available evidence base. A strategy would then be developed to plan the necessary emission reductions that need to occur in order to meet the goals, as well as the control strategies on how to achieve these goals (e.g. in which sectors). Then these strategies are implemented, and there is on-going evaluation in order to understand if goals are met, as well as to identify additional or new problems.

This process has been expanded upon for air quality management in South Africa. Figure 23 displays the environmental governance cycle adapted from the National Framework for Air Quality Management in the Republic of South Africa (DEA, 2012). This cycle provides a more detailed view of the air quality management cycle than Figure 22, especially for the necessary steps for implementation of strategies to improve air quality. This figure has been adapted from DEA (2012) to include the critical role of enabling factors and air quality management (AQM) tools, such as air quality monitoring, in this entire cycle. In addition, “authorisations” has been updated to “regulations and intervention implementation” to include more levers.

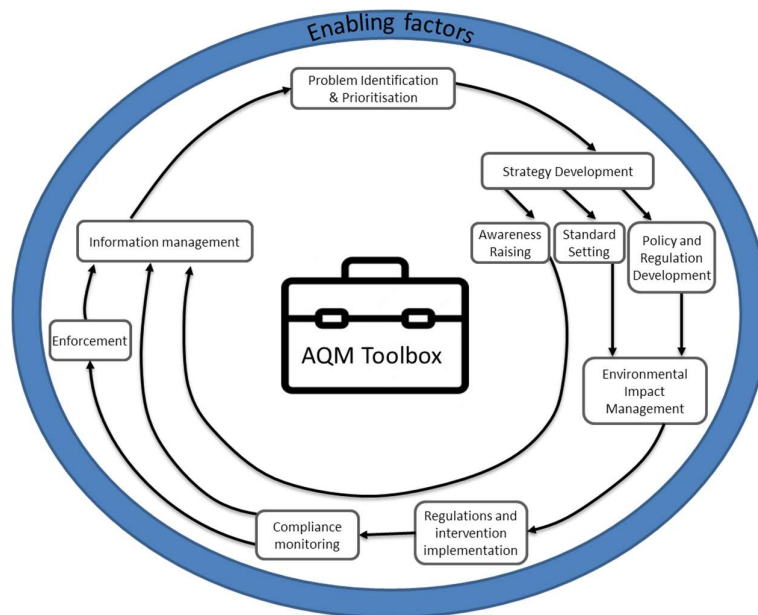


Figure 23: Environmental Governance Cycle (adapted from DEA, 2012). (AQM = Air quality management)

Enabling factors are those that support the governance cycle. The tools are those that are used in and across the governance cycle. These aspects are not used in only one stage, but are used throughout the cycle. Examples of enabling factors and tools include,

- Enabling Factors

- Operational activities
 - Finance
 - Capacity and capabilities
 - Information flows
 - Communication
- Collaboration
 - Across sectors
 - Across levels of government
 - Across stakeholders
 - Trans-boundary
- Scientific Research, Innovation and Evidence-base

- Tools that CoJ maintains to use in the cycle

- Air quality monitoring
- Spatial and temporal evaluation tools (Dispersion and air quality modelling)
- Emissions inventory
- Impact, risk and/or vulnerability assessments

8.1 Improvement and application of environmental governance cycle in the City of Johannesburg

The Status Quo Assessment, which included stakeholder engagement, identified current gaps in air quality management in the City. These gaps are hindering improving air quality in the City and effective air quality management.

The problem complexes that were identified in this assessment included both enabling factors from the governance cycle, as well as key sectors that have been identified as priorities. It is envisioned that the City would be able to apply the governance cycle more effectively through improved enabling factors on the identified priority areas. Thus, in this AQMP, the governance cycle would be the means in which the City would implement its goals.

8.2 Prioritised problem complexes

In order to improve air quality in the City of Johannesburg, it was identified that air quality management needed to improve, and emission reductions are needed in prioritised sectors.

8.2.1 Improving air quality management

The specific enabling factors identified and prioritised as problems to improve in this AQMP were,

- Effective and regular cross-sectoral collaboration
- Improving the air quality management system
 - o Improving and having access to the necessary tools
- Strengthen and maintain capacity
- Communication, internally and with CoJ citizens
- Innovation, research and evidence based decision-making

Through improving these enabling factors, the environmental governance cycle will be more effective.

8.2.2 Emission reductions

The specific sectors identified and prioritised as problems which need effort to reduce emissions are,

- Domestic fuel burning
- Industry
- Vehicles
- Dust from tailings storage facilities (TSF).

Developing and implementing such emission reductions would apply the environmental governance cycle. For all of these, a key starting point in order to develop the strategy and set goals

is to have a comprehensive and up-to-date emissions inventory. This AQMP did develop an emissions inventory for 2014 for the City, and in this development key gaps were highlighted for all of these sectors. As the governance cycle goes on, this information will be added to refine the emission reduction plans and interventions.

8.3 Transboundary pollution and collaboration

The province of Gauteng consists of three metropolitan municipalities, the City of Johannesburg, the City of Ekurhuleni and the City of Tshwane, as well as two district municipalities, Sedibeng and West Rand. In addition, the southern part of the province (and part of CoJ) is in the Vaal Triangle Airshed Priority Area (VTAPA), the eastern part of the province is in the Highveld Priority Area, and the Waterberg-Bojanala Priority area borders the province to the north and northeast (Figure 24). While the administrative borders indicate that the municipalities are responsible for managing air quality, these areas are all impacted by pollution from other areas (i.e. transboundary pollution) and they have similar management issues. Thus, it is critical that the AQMPs and the air quality management activities across Gauteng are well aligned.

In addition, due to the close proximity of the metropolitan/district municipalities to each other, trans-boundary pollution is a common problem. Thus, the alignment between municipal and Provincial AQMPs, and between municipalities, is critical to effectively manage and improve air quality in the Province.

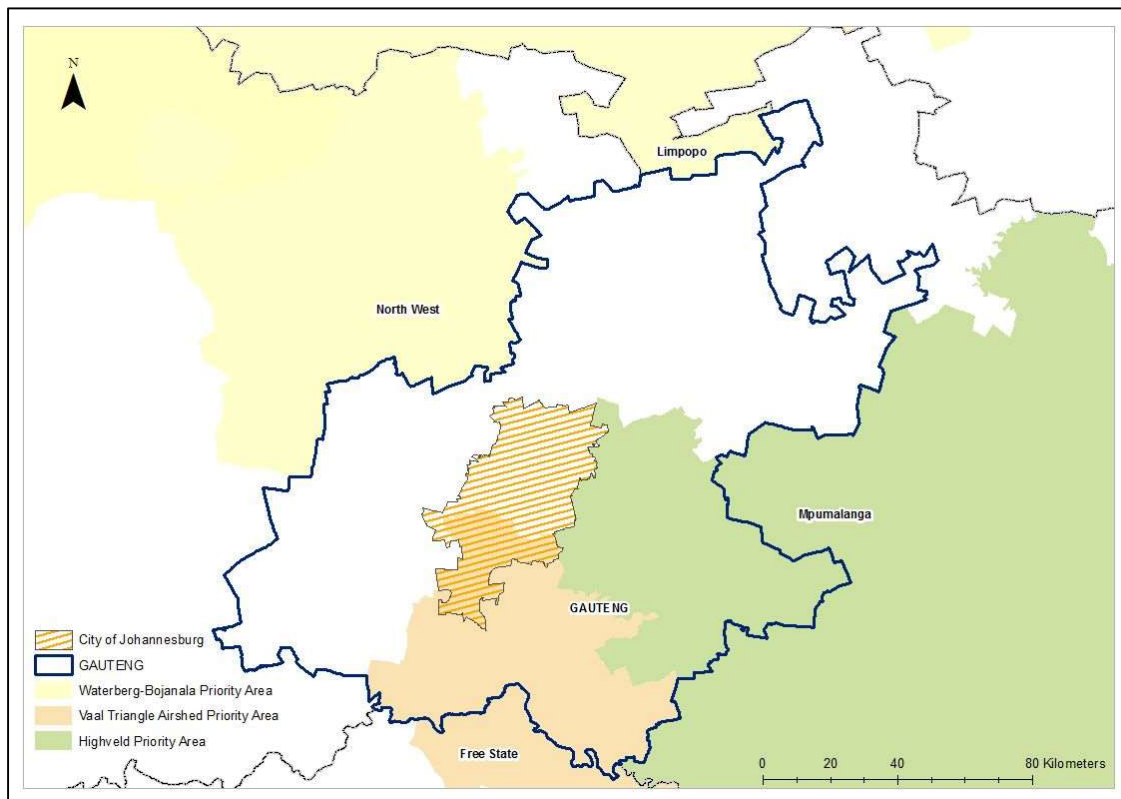


Figure 24: CoJ and Gauteng in relation to the three Air Quality Priority Areas.

8.3.1 Alignment with Gauteng Provincial AQMP

Gauteng Province developed its AQMP in 2009, with its main aim being

“to develop an AQMP for the province, with clear clean air objectives and associated strategies to ensure improvement in the provincial ambient air quality and the maintenance thereof. This must be based on a comprehensive database providing an accurate account of the current status of air quality and air quality management in the province” (GDACE, 2009: 9).

The AQMP identified seven problem complexes related to emissions and non-emissions aspects of the province. The emissions problem complexes include: Climate Change and Energy, Domestic Fuel Burning, Industrial Emissions, Mine Tailings Dams, Noise Pollution and Vehicle Tailpipe Emissions. The non-emission problem complex was listed as Cooperative Governance and Information Management (GDACE, 2009). These align well with the CoJ’s problem complexes, including the fact that there are both enabling factor problem complexes and emission reduction problem complexes.

9 Air Quality Management Actions

Considering the environmental governance cycle and the highlighted problem complexes in Section 8, a vision, mission and goals for air quality in the City of Johannesburg were developed. These are developed with a five year time horizon.

9.1 AQMP vision, mission and AQMP Goals

9.1.1 Vision

The vision of the 2019 CoJ AQMP is “To achieve acceptable air quality levels in the City of Johannesburg.”

Where, “acceptable air quality” is defined as that which

- Complies with National Ambient Air Quality Standards (NAAQS)
- Supports liveable, sustainable and resilient communities
- Is odourless, tasteless and looks clear

Currently, as highlighted in Section 3, there are stations with air quality that does not comply with the National Ambient Air Quality Standards. Therefore in order to meet the vision, there are a number of measures that must be put into place. Air quality management is continuous, and the process applied follows the environmental governance cycle (Section 8). This plan is the first step to set-up the necessary systems and strategies to achieve this vision. The improvements identified include both improving the enabling factors that allow for effective air quality management as well as emission reductions in prioritised sectors. Together, these improvements will work towards acceptable air quality in the City.

9.1.2 Mission

In order to improve air quality, multiple stakeholders and sectors will have to work together; and the trajectory to improve air quality must be evidence-based. While the process to improve air quality follows the environmental governance cycle, enabling factors such as collaboration and scientific research, innovation and evidence-base are key areas of development for this process to be effective in CoJ. Thus in the mission of this AQMP, the importance of the enabling factors is highlighted.

“The City of Johannesburg will work collaboratively with stakeholders to improve air quality in the City, in order, to minimise the impacts of air pollution on human health and the environment. The City will use evidence-based decision making and planning to achieve compliance with national ambient air quality standards.”

9.1.3 AQMP Goals

An important part of an AQMP is to set air quality goals, objectives and activities for the next five years to move the City of Johannesburg towards its mission of having acceptable air quality throughout the city.

These goals were developed directly from the problem complexes identified in the Status Quo Assessment and highlighted in Section 8, that are hindering progress to improve air quality. These include specific enabling factors and sectors for emission reductions, namely,

- Enabling factors,
 - o Effective and regular cross-sectoral collaboration;
 - o Improving the air quality management system;
 - Improving and having access to the necessary tools;
 - o Strengthen and maintain capacity;
 - o Communication, internally and with CoJ citizens;
 - o Innovation, research and evidence based decision-making;
- Emission reductions,
 - o Domestic fuel burning;
 - o Industry;
 - o Vehicles;
 - o Dust from TSF.

These highlighted sectors for emission reductions were aligned with the need for effective and regular cross-sectoral collaboration in the goals below; this is because the implementation of the projects needed to reduce emissions in these sectors will be across sectors in the City.

The goals for the AQMP are:

- 1. Collaborate with stakeholders in developing and implementing emission reduction strategies designed towards achieving ambient air quality standards and international and domestic greenhouse gas commitments and targets.**

This goal highlights the importance of working with collaborators to improve air quality. As emission sources are from a variety of sectors, any emission reduction plan would need to be multi-sectoral with numerous stakeholders. Thus collaboration is vital to improving air quality. The four sectors that were identified as key sectors for emission reductions will be the focus of these emission reduction strategies, however the impact of on-going and planned policies and projects of the city will be assessed across all applicable sectors. These emission reductions will focus on both air quality and climate change concerns. The two issues are strongly linked through their emissions sources, many of which can release pollutants that have air quality and climate change implications. Thus policies and interventions that impact greenhouse gas (GHG) emissions may many times also impact air pollutant emissions; however it is also true that not all policies provide win-win options for

both. Due to these linkages, it is important to quantify the impacts of both (i.e. GHG and air quality) in these emission reduction strategies together.

2. Regulate emission sources within the City to achieve compliance with air quality requirements.

In order to improve air pollution and in order to comply with national regulations, the City must regulate scheduled point source emitters, and this goal highlights the importance of this regulation. Through this goal the City will develop and maintain an up-to-date and comprehensive list of regulated sources, quantify the emissions per source, as well as work to assess if localised standards are necessary.

3. Develop and maintain a comprehensive air quality management system.

An air quality management system is the operational system that develops, improves and maintains the necessary air quality tools (e.g. ambient monitoring, development and improvement of emission estimates, etc.). These tools are used throughout the environmental governance cycle and provide the information necessary to understand the state of air quality, to support and measure the impact of decisions, and to prioritise problems. Thus through this goal the air quality management system will encompass the necessary tools, and will continually work to maintain, and as applicable, improve these tools.

4. Provide the appropriate capacity to deliver Air Quality Management services in a cost effective and efficient manner.

In order to implement this AQMP, appropriate capacity with the needed capabilities is required. This includes both attracting the needed capacity and capabilities, as well as capacity development of existing staff. The needed capabilities are a scarce skill, and Air Pollution Analyst is listed in the Department for Higher Education and Trainings 2015 list of occupations in high demand (DHET, 2016). Thus, CoJ does need to ensure it is in a position to attract and retain specialists in the field of air quality.

5. Empower and inform CoJ citizens about air quality through education, awareness and communication programmes.

CoJ citizens play a role across the environmental governance cycle, and thus are a critical enabling factor in order to improve air quality. The communication is two-way, with the CoJ providing information to citizens on the state of air quality (e.g. through air quality information portal, real time air quality reporting, air quality indicator, emission reduction strategies and actions) and with citizens providing input to the CoJ (e.g. complaints, problem identification). This goal would work to continually develop and improve this two-way communication with the public, and would work to clearly identify and educate the public on their important role in improving air quality.

6. Support innovation and research that informs air quality improvement and decision making.

Improving air quality is not simple; while air quality management activities have been on-going in CoJ since 2003, there are still areas out of compliance with NAAQS. Testing and implementing innovative ideas has the potential to greatly improve air quality management. In addition, research can assist to improve knowledge base and improve the air quality management tools. This goal would utilise the MOAs with universities and research organisations to engage with researchers and innovators in air quality. Through this engagement, the CoJ could then be a test bed to pilot these new ideas that could work towards improving air quality.

Through these goals, the trajectory to improve air quality and to meet the mission and vision is clear. As the AQMP is implemented, this trajectory and progress towards this mission and visions will continue to be quantified.

9.2 AQMP Implementation

The implementation of the AQMP requires that objectives and related activities are set out for each goal in order to achieve the intended outcome of that goal, and in turn the vision and mission of this AQMP. This implementation is discussed by each goal below.

Indicators are given per goal as well as per activity. The goal indicators are those that should be used to monitor and report progress on each goal.

9.2.1 Goal 1: Cross-sectoral collaboration for improving air quality

Goal 1: Collaborate with stakeholders in developing and implementing emission reduction strategies designed towards achieving ambient air quality standards and international and domestic greenhouse gas commitments and targets.

A cross-sectoral approach is necessary to achieve the vision and mission set out in this AQMP. It will be the responsibility of all sectors to capture and share needed data to estimate these impacts, and EISD will account for the impacts. In addition, EISD will be the champion for implementing activities and interventions that have a positive impact on air quality.

The objectives and activities necessary to achieve this goal are listed in Table 11. These include developing the necessary operational support of data flows through data agreements across sectors, as well as developing, implementing and tracking emission reduction strategies from on-going projects (Table 12) and new interventions.

These objectives and activities will work towards a holistic quantitative air quality and GHG emission reduction plan for the City. This includes quantification of emission reductions from past and on-going prioritised projects, as well as an assessment of needed reductions into the future to achieve commitments and targets.

Table 11. Goal 1 objectives, activities, timing and indicators.

<i>Goal 1: Collaborate with stakeholders in developing and implementing emission reduction strategies designed towards achieving ambient air quality standards and international and domestic GHG commitments and targets.</i>			
<i>Indicator: A holistic quantitative air quality and GHG emission reduction plan for the City is developed. This includes quantification of emission reductions from past and on-going prioritised projects, as well as an assessment of needed reductions into the future to achieve commitments and targets.</i>			
Objectives	Activities	Timing for implementation	Indicators
A. Activity and emissions data collected by other sectors in the City is available to EISD to estimate air quality impacts.	Data agreements between EISD and other sectors will be developed and signed. This will indicate the specific data needed, how often and in which format. This will provide the operational support for the development, implementation and tracking of emission reductions strategies across sectors.	Short-term: Data agreements in place. On-going: Data flows between sectors in CoJ.	Data agreements in place and EISD has access to and is using CoJ data from across sectors to inform emission reduction strategies.
B. The implementation and impact of on-going and prioritised projects (from Table 12) are tracked.	Estimate and track air quality and GHG impacts from projects identified from Table 12. For on-going projects, both ex-post (forward looking) and ex-ante (historical impacts) analysis can be performed.	Medium-term: emission estimates are finalised.	Emission and ambient air quality impact of prioritised projects in IDP (from Table 12) are estimated.
	The EISD will feed back the air quality estimates made with the sectors data to the sector.	Medium-term	Reports are shared and presented across departments in the City.
C. The City identifies, develops and implements emission reduction strategies in problem sectors - Domestic burning - Industry - Vehicles	Domestic burning emission inventory is updated through fuel use surveys and local emission factors to improve quantification of emissions. This better understanding of fuel use patterns will allow for targeted emission reductions strategies to be developed and implemented accounting for fuel use patterns in the CoJ. Interventions have been proposed on a national level, to	Short-term: Survey Medium to long term: Emission reduction plans implemented.	Report on fuel usage (short-term), emission reduction plan implementation and impact (long-term).

Goal 1: Collaborate with stakeholders in developing and implementing emission reduction strategies designed towards achieving ambient air quality standards and international and domestic GHG commitments and targets.

Indicator: A holistic quantitative air quality and GHG emission reduction plan for the City is developed. This includes quantification of emission reductions from past and on-going prioritised projects, as well as an assessment of needed reductions into the future to achieve commitments and targets.

Objectives	Activities	Timing for implementation	Indicators
Dust from TSF	reduce the impact of air pollution on dense low-income settlements and to ensure that ambient air quality is in compliance with the National Ambient Air Quality Standards in these areas. CoJ to incorporate interventions identified in South Africa's draft strategy to address air pollution in dense low-income settlements into their emission reduction strategies.		
	Industrial emission reduction strategies are developed and implemented based upon up-to-date and comprehensive listing and emissions information from industries in CoJ.	On-going: Comprehensive list and quantification of industries. Medium-term: Industrial emission reduction strategies implemented.	Report on emission reduction plan implementation and impact.
	Transport emission inventory is updated through traffic count data to better quantify the emissions and the spatio-temporal variation. This information is used to inform the development and implementation of emission reduction strategies.	On-going: Improving emission estimates. Medium to long term: Emission reduction plans implemented.	Report on emission reduction plan implementation and impact.
	Dust emission reduction scenarios quantified in this AQMP are used to develop and implement the emission reduction strategies for: Active TSFs, where all are partly vegetated, some have wind breaks and/or wet surface areas and/or crusted side slopes resulting in portions of these	Short-term: develop emission reduction plan. Apply the GPBZ Guidelines around all TSFs. All TSFs (Active, Dormant and Reclaimed) to	Report on emission reduction plan implementation and impact. Demonstrate visual improved vegetation cover

Goal 1: Collaborate with stakeholders in developing and implementing emission reduction strategies designed towards achieving ambient air quality standards and international and domestic GHG commitments and targets.

Indicator: A holistic quantitative air quality and GHG emission reduction plan for the City is developed. This includes quantification of emission reductions from past and on-going prioritised projects, as well as an assessment of needed reductions into the future to achieve commitments and targets.

Objectives	Activities	Timing for implementation	Indicators
	facilities to be prone to wind erosion (examples: Brakpan TSF, Randfontein TSF, Luipaardsvlei TSF). ○ Mines and owners to establish vegetation cover on inactive exposed areas prone to wind erosion throughout the operational phase of the TSF. ○ Mines and owners to provide closure plans in line with the Spatial Development Framework (SDF2040) objectives for rehabilitation and reclaiming land for other uses. ○ CoJ to apply the Gauteng Pollution Buffer Zones (GPBZ) Guideline for best-case buffer of 1000m. • Dormant TSFs, where mostly vegetated with crusted/vegetated side slopes resulting in minimal exposed areas prone to wind erosion (example: Crown TSFs) but activity on TSF roads result in dust emissions. ○ CoJ to apply the GPBZ Guideline for worst-case buffer of 500m. ○ Residential/industrial development programmes that infringe on this buffer to	demonstrate 40% CE on the “baseline” exposed areas. Medium-term: implement emission reduction plan. All TSFs (Active, Dormant and Reclaimed) to demonstrate 90% CE on the “baseline” exposed areas. Reclaiming/ rehabilitation of dormant TSFs. Co-operation with various stakeholders for inclusion of the portions of the mining belt into the regional open space system as defined by the SDF.	on previous (baseline) surfaces. No visible windblown dust under strong wind conditions. Reduced buffers around TSFs due to improved mitigation. Identified dormant TSFs being reclaimed/ rehabilitated. Portion of the mining belt included into the regional open space system as defined by the SDF.

Goal 1: Collaborate with stakeholders in developing and implementing emission reduction strategies designed towards achieving ambient air quality standards and international and domestic GHG commitments and targets.

Indicator: A holistic quantitative air quality and GHG emission reduction plan for the City is developed. This includes quantification of emission reductions from past and on-going prioritised projects, as well as an assessment of needed reductions into the future to achieve commitments and targets.

Objectives	Activities	Timing for implementation	Indicators
	provide a specialist study (accounting for the influence of wind on the dust dispersion) to demonstrate a more suitable (reduced) buffer. ○ Continuous re-vegetation of exposed areas. ○ Chemical suppressants on TSF roads. ○ Identify dormant TSFs that could be reclaimed/ rehabilitated and included into the SDF2040 objectives. ● Reclaimed TSFs, where either in the process of being reclaimed (this is typically done with water cannons) or where it has been removed with only the exposed footprint left. ○ All reclaimed TSFs with exposed footprint left to apply vegetation cover on entire exposed area. ○ Re-vegetation to be established after a year and continued thereafter. ○ Reclaimed land to be integrated into the SDF2040 for development.		

Table 12 below highlights the cross-sectoral programs identified in the IDP 2016/21 and 2019/20 that may have an impact on air quality (CoJ, 2016). These projects will be tracked for emission impacts under this goal as prioritised projects (Objective B).

Table 12. Projects per sector identified in the IDP that will be tracked under Goal 1.

Sector	Project name	Brief project description	Responsible Department	Potential air quality/ air pollutant emission impact
Industrial	Industrial-spatial economy programme	Release of zoned land - establishing new and expanding old industry nodes Unlocking the Mining Belt	Development and Planning EISD	Will increase air pollution, especially if it is heavy industry
Transport (Status: highest demand for energy (67%))	Corridors of freedom	By 2030: Maintenance and building of new roads, cycle lanes, Rea Vaya (replaced 500 taxis), pedestrian walkways, upgrading of train stations	Transport, Development and Planning, Economic Development, EISD	During construction air pollution may increase Thereafter a decrease is expected. However, a large concerted plan is needed to substantially improve air quality (see section 5.3.2)
	Reduce GHG emissions from transport	Currently converting fleet into dual fuel buses - aim to reduce GHG emissions by 10%. By 2050: 25% reduction in private car use	Transport, Development and Planning, Economic Development, EISD	Reduce air pollution

Sector	Project name	Brief project description	Responsible Department	Potential air quality/ air pollutant emission impact
		during peak hours		
	Eco-mobility	Combine walking, cycling and wheeling with efficient public transport and vehicles powered by renewable energy	Transport, Development and Planning, Economic Development, EISD	Reduce air pollution
Waste (Status: 1.8 mil t/y to landfill; running out of space)	Expand waste service Divert waste from landfill disposal Eradicate illegal dumping	Develop waste management infrastructure supportive of minimisation and recycling. Develop technologies for the treatment and disposal of certain waste streams. Fostering partnerships with formal and informal waste industry Waste separation (minimisation and recycling) and waste processing, including biogas Divert from landfill disposal by 30% by 2021 and 93% by 2040	Waste, EISD	6% waste minimization : (Integrated Waste Management plan) Decrease air pollution

Sector	Project name	Brief project description	Responsible Department	Potential air quality/ air pollutant emission impact
	Biogas-to-Electricity project at waste water works	Currently in progress. At one plant covers about 15% of the works' electricity needs	Waste EISD	Decrease air pollution
	Diphetogo	Improved quality of access to reliable, quality basic services across our City.	EISD	Diversion of 94 355 tons of total waste away from landfills Waste collection service to 858 313 formal households on a weekly basis
	A Re Sebetseng	City-wide volunteer campaign, aimed at cleaning up the city.	Waste EISD	Decrease air pollution as less waste is burned
Residential Fuel (Status: Crisis facing energy security and electricity distribution from City Power)	Expand electricity service	By 2030: Produce sufficient energy to support industry at competitive prices, ensuring access for poor households	Energy EISD	Increase air pollution (severity depending on technology types) CC –higher temperature thus more energy necessary for cooling - increase air pollution
	Diversify the sources of energy (distributed generation, PV, batteries) including renewable energy	Fuel switching, does not reduce the energy demand but does reduce electricity demand	Energy EISD	If mostly renewable energy, then theoretically should decrease air pollution
	Solar Water Geyser Programme	Provide solar geysers and energy efficiency	Energy EISD	Decrease air pollution as less electricity from coal-fired power stations will

Sector	Project name	Brief project description	Responsible Department	Potential air quality/ air pollutant emission impact
		lights to low-income households and plant fruit trees		be used
	Joburg Water's hydro-conduit power generation	Solar water heaters to poor households is targeted and alternative energy solutions	Energy EISD	Decrease in air pollution from less domestic burning
	Pikitup's Waste to Energy project	Solar water heaters to poor households is targeted and alternative energy solutions	Energy EISD	Decrease in air pollution from less domestic burning
	City Power's rooftop photovoltaic and utility-scale battery storage plants	Provision of electrical services to informal communities without access.	Energy EISD	Decrease in air pollution from less domestic burning
Dust (Status: wind-blown dust from mine dumps an issue in some areas as identified in Status Quo Report)	Transformation, Modernisation and Reindustrialisation (densify cities and upgrade informal settlements)	Construction of infrastructure and housing	Economic Development, Development and Planning, EISD	Increase in air pollution during project
	Ensure household food and nutrition security (41% in acutely deprived areas)	By 2030: Food trade surplus, with one-third produced by small-scale farmers or households	Economic Development, Development and Planning, EISD	Increase air pollution (dust and pesticides)
	No projects identified in the literature searched to address dust from mine dumps – however			

Sector	Project name	Brief project description	Responsible Department	Potential air quality/ air pollutant emission impact
	could have large impacts as quantified in section 5.3.1			
	Gauteng Pollution Buffer Zones (GPBZ) Guideline 2017	Provide guidelines to ensure residents are protected from emissions from pollution generators (such as mine slimes dams and ash dumps)	Gauteng Province, CoJ AQM	Reduced air pollution (dust) impacts due to buffers around TSFs
	Spatial Development Framework (SDF) 2040	Improve spatial infrastructure such as to unlock the mining belt	CoJ	Reduced air pollution (dust) impacts due reclaimed (for development) and rehabilitated TSFs
Biogenic (Status: CoJ has the world largest urban forest)	No projects identified in the literature searched	None	NA	Increase air pollution – contributes to formation of ozone
Climate Change (Status: CoJ ranked largest GHG City in SA & 13th in the world of GHG emitters)	Reduce GHG emissions from waste management	By 2030: Reduce carbon emissions per unit of power by ~1/3 By 2050: a 43% reduction in GHG emissions To comply to COP21: 40% to 65% reduction by 2040 against the	EISD	Decrease air pollution

Sector	Project name	Brief project description	Responsible Department	Potential air quality/ air pollutant emission impact
		2007 baseline*		
	Awareness and education and training campaigns	To understand impact and enhance resilience (rely less on fossil fuel)	Group Urban and Citizen Relations	Decrease air pollution

* CoP21 Host City Paris has set a reduction target of 25% by 2020 and 75% by 2050 against a 2004 baseline year.

9.2.2 Goal 2: Regulate emission sources

Goal 2: Regulate emission sources within the City to achieve compliance with air quality requirements.

This goal will focus on keeping up-to-date on the regulated sources in the City and their emissions. In addition, through the by-laws, additional regulated sources can be added as needed. The indicator for this goal is for the regulated sources in the City to be well quantified and routinely monitored for compliance.

Table 13. Goal 2 objectives, activities, timing and indicators.

<i>Goal 2: Regulate emission sources within the City to achieve compliance with air quality requirements.</i>			
<i>Indicator: Regulated sources in the City are well quantified and routinely monitored for compliance.</i>			
Objectives	Activities	Timing for implementation	Activity Indicator
A. Regulated activities within CoJ will be documented and quantified.	Develop and maintain a detailed source inventory and emission quantification for regulated activities.	Short-term: develop source inventory and emission estimates. On-going: Maintenance of inventory.	Up-to-date source database of regulated activities in CoJ.
	Establish and maintain compliance monitoring of all air quality regulated activities.	Short-term: establish compliance monitoring. On-going: Maintenance of monitoring.	Up-to-date reporting on compliance status of regulated sources in CoJ.
	Improve enforcement of air quality legislation.	Short-term	Up-to-date reporting on enforcement of regulations.
B. Review and update air quality bylaws.	Review and update, if necessary, of bylaws to align with metropolitan, provincial and national designations.	Short to medium-term	Updated bylaws.
	Investigate an alternate approach to odour management.	Medium-term	Updated bylaws if applicable.

9.2.3 Goal 3: Air quality management system.

Goal 3: Develop and maintain a comprehensive air quality management system.

The purpose of this goal is to develop and maintain the air quality management system that develops, improves and maintains the necessary air quality tools. In order to achieve this the focus is on maintaining and improving ambient monitoring within the City, the maintenance of the emissions inventory, and developing and then using air quality modelling capacity to support decision making.

The indicator for this goal is that CoJ has an operational system to support, maintain and, as applicable, improve the air quality management tools.

Table 14. Goal 3 objectives, activities, timing and indicators.

<i>Goal 3: Develop and maintain a comprehensive air quality management system.</i>			
<i>Indicator: CoJ has an operational system to support, maintain and, as applicable, improve the air quality management tools.</i>			
Objectives	Activities	Timing for implementation	Activity Indicators
A. The CoJ maintains ambient monitoring to provide high quality ambient air quality data.	The ambient air quality data from monitoring is continuous and consistent, with routine calibrations and maintenance.	90% valid data recovery implemented immediately and continuously, with annual calibration and routine maintenance.	Monthly reports detail data availability and quality assurance and quality control measures.
	All stations measure all criteria pollutants.	Medium-term	All stations in CoJ are measuring full suite of criteria pollutants.
	Investigate use of low-cost sensors for mobile and/or short-term monitoring.	Medium-term	Report on feasibility and use of low-cost air quality sensors.
B. The emission sources impacting on air quality in the City are quantified.	Emissions inventory for sources impacting on CoJ is maintained.	On-going: Improvement and maintenance of emissions inventory.	Comprehensive emissions inventory for sources impacting on CoJ.
C. Air quality modelling capabilities improved to support decision making.	The CoJ sets a clear goal(s) on air quality modelling that will allow effective use of air quality modelling to inform decision making.	Immediate	Detailed air quality modelling plan for CoJ developed with clear goals.
	Modelling infrastructure is used to model impacts of selected sectors, projects and scenarios (starting with list from prioritised projects in Table 12).	Infrastructure (i.e. personnel, input data, model, analysis tools) are developed in short term (by year 2).	Air quality modelling activities on-going in CoJ.
	Use updated modelling output together with monitoring data to estimate human health risks, such as through population weighted exposure.	Medium to long-term	Report estimating health risks, and as possible, assessing the trends in health risks.
	Visualisation products are developed to communicate model outputs to stakeholders.	Medium-term	Modelling assessments from CoJ provide user friendly visualisations of modelling outputs.

9.2.4 Goal 4: Capacity Building

Goal 4: Provide the appropriate capacity to deliver Air Quality Management services in a cost effective and efficient manner.

The CoJ has developed the necessary structure and organogram in order to implement this AQMP to improve air quality (Section 6, Figure 21). This structure requires specific capabilities and increased capacities. This goal details the steps CoJ will undergo to ensure that the department has the necessary skills to perform air quality management functions, as well as the role for collaboration in developing skills and providing technical skills. The indicators for this goal are the department must have an up-to-date skills assessment, recruitment and capacity development plan, and an on-going process to ensure there is appropriate capacity. The recruitment and capacity development plan will only be necessary if the skill assessment highlights missing skills.

Table 15. Goal 4 objectives, activities, timeline and indicators.

<i>Goal 4: Provide the appropriate capacity to deliver Air Quality Management services in a cost effective and efficient manner.</i> <i>Indicator: The department will have an up-to-date skills assessment, recruitment and capacity development plan, and an on-going process to ensure there is appropriate capacity.</i>			
Objectives	Activities	Timing for implementation	Activity Indicators
A. Ensure the department has adequate human resources and skills to perform air quality management functions.	Recruit additional personnel/train existing staff to fulfil department organogram.	Immediate and on-going	Recruitment plan is fulfilled, and is reviewed annually.
	Identify individual training and capacity development requirements in line with needed skills for position.	Immediate and on-going	Every employee has an individual learning plan that is reviewed annually.
	Conduct necessary training and capacity developing according to individual learning plans.	Immediate and on-going	Database of trainings attended for EISD updated.
B. Utilise partnerships to develop skills and to perform specific functions.	Investigate feasibility of using MOUs with academic institutions to assist with highly technical or research related tasks.	Short-term to investigate the potential for partnerships. Medium-term to have multiple partnerships implemented.	Short-term: report detailing potential for collaborations with specific tasks and goals. Medium-term: Annual report on outcomes of partnership, and directions for going forward.

9.2.5 Goal 5: Empowerment of CoJ citizens about air quality

Goal 5: Empower and inform CoJ citizens about air quality through education, awareness and communication programmes.

CoJ citizens are a critical enabling factor in improving air quality. The communication between the CoJ and the citizens is two-way, and this goal will work to continually develop and improve this two-way communication with the public, and will work to clearly identify and educate the public on their important role in improving air quality. These improvements include developing the necessary communications infrastructure if needed, the development of communication channels, the development of content that is clear and well-presented, and the response of CoJ to air quality complaints. This communication will include innovation not only in the channels of communication, but in the presentation of the content in a way that is understandable to the public, and actionable as needed. Under this goal, the potential for air quality indices and indicators, as well as real-time ambient air quality data will be investigated. The indicator for this goal is the usage, timeliness and diversity of communication pathways between CoJ and community will be detailed and quantified.

Table 16. Goal 5 objectives, activities, timeline and indicators.

<i>Goal 5: Empower and inform CoJ citizens about air quality through education, awareness and communication programmes.</i>			
<i>Indicator: The usage, timeliness and diversity of communication pathways between CoJ and community will be detailed and quantified.</i>			
Objectives	Activities	Timing for implementation	Activity Indicators
A. Improved infrastructure for communication.	Establish a plan for the roll-out of the air quality awareness and communication plan, with provisions for the necessary infrastructure, connectivity and resource requirements.	Short to medium-term	Awareness and communication plan developed.
B. Active citizen participation and engagement.	The City provides up-to-date information to public through Air Quality Portal. The development of portal should take into account the role of new media for disseminating information.	Short-term: develop air quality portal, the content on the portal, and platform(s) for dissemination. On-going: Updating portal. CoJ reports its ambient air quality monitoring data to the South African Air Quality Information System (SAAQIS). A new SAAQIS app has recently become available and the public are now able to view the this data using this app.	Active air quality portal with up-to-date air quality information.
	EISD develops, advertises and maintains the process for citizens to register air quality complaints.	Immediate: EISD decides, and develops if needed, on complaints system.	The procedure for citizens to lodge a complaint is clearly advertised through website and new media.

	EISD responds in a timely manner to acknowledge and address complaints. Within 7 working days to acknowledge complaints, and in that correspondence to give timeline for CoJ to address complaints.	Immediate and on-going	Complaint registered, dated and updated.
--	---	------------------------	--

9.2.6 Goal 6: Innovation and research

Goal 6: Support innovation and research that informs air quality improvement and decision making.

In order to achieve the vision of this AQMP, air quality decision making must be supported through research, innovation and a strong evidence base, which are enabling factors in the environmental governance cycle. To achieve this goal, the City must be positioned to engage with researchers and to implement innovative ideas. In addition, the City can lead by example and try out innovative ways to mitigate air pollutant and GHG emissions. The indicator for this goal is for the CoJ to document and evaluate impact of innovation and research on air quality management.

Table 17. Goal 6 objectives, activities, timeline and indicators.

<i>Goal 6: Support innovation and research that informs air quality improvement and decision making.</i>			
<i>Indicator: CoJ documents and evaluates impact of innovation and research on air quality management.</i>			
Objectives	Activities	Timing for implementation	Activity Indicators
A. The City is a test bed for innovative ideas and research on understanding and improving air quality.	Develop systems, capacity and capability to pilot new ideas.	Short-term and on-going	Annual reports on projects piloted in CoJ.
	Use MOAs to engage with universities and research institution on research.	On-going as applicable.	Collaborations and outputs from collaborations with universities and research institutions are tracked and reported.
	The City engages actively with air quality management activities in South Africa in order to share lessons learned, and apply others' lessons learned.	On-going	Attendance at DEA air quality management events, and participation in activities of professional societies (e.g. National Association for Clean Air (NACA).
B. The City will lead by example, by "greening" its processes.	Air pollution and GHG emissions of local authority will be calculated, together with the impacts of local authority mitigation programmes will be estimated.	Short-term	Emission estimates of baseline scenario and policy scenario(s) for local authority.
	The potential for inclusion of air quality and climate change considerations into procurement and sub-contracting considerations for local authority will be investigated.	Short-term: investigate process and needs to change procurement policies. Medium-term: Develop air quality and climate friendly procurement rules.	Development of air quality and climate friendly procurement rules.

9.3 Timeline

Timing for implementation per activity was given per goal above. In Table 18 below the high level timing per goal is displayed. The environmental governance cycle is an on-going and iterative process, and thus many activities are labelled with grey and blue stripes to indicate “on-going” activities. It is clear from this timeline that in the short-term, the improvement of data, information and systems will be a large focus of the work. This is critical, as the improvements cannot be implemented without these steps. In the medium-term, these improvements are then applied. In year 5 of implementation, the AQMP review will commence; thus it is necessary that the indicator per goal is met starting in year 4 as to be ready for year 5. In some cases, this indicator may be achieved earlier, and in that case the indicator must be maintained until year 5.

Table 18. High-level timeline for implementation per goal (grey and blue striped cells indicate on-going activities).

	Summary of activities	Years				
		Short-term		Medium-term		Long-term AQMP Review
		1	2	3	4	5
Goal 1: Collaborations and co-benefits	Data and agreements					
	Emission reductions of prioritised project					
	Emission reduction plans					
	<i>Combine estimated emission reductions into quantitative trajectory for City, with specific policies</i>					
<i>Indicator met in time for AQMP review</i>						
Goal 2: Regulated emitters	Database and data					
	Review Bylaws					
	Update Bylaws if needed					
	<i>Well quantified and monitored regulated sources</i>					
<i>Indicator met in time for AQMP review</i>						
Goal 3: Air quality management system	Monitoring system improvement					
	Monitoring system expansion					
	Emissions inventory maintained					
	Modelling capacity developed					
	Modelling capabilities support decision making (e.g. through emission reduction plans)					
	<i>Operational management system with high quality historical and current information</i>					
<i>Indicator met in time for AQMP review</i>						
Goal 4: Capacity	Build human resources					
	Use partnerships to build human resources					
	<i>Up-to-date plan for skills assessment, and if gaps, development plan</i>					
<i>Indicator met in time for AQMP review</i>						
Goal 5: Communication with citizens	Develop communication plan and infrastructure needs					
	Air quality portal and content developed					
	Air quality portal and content live and updated					
	Effective complaint system					
	<i>Communication pathways are detailed and quantified</i>					
<i>Indicator met in time for AQMP review</i>						
Goal 6: Innovation and research	Develop pilot projects for CoJ with partners					
	Deploy projects with CoJ as test bed					
	Lead by example, Greening the City					
	<i>Document and evaluate impact of innovation and research</i>					
<i>Indicator met in time for AQMP review</i>						

9.4 Budgetary needs

The costing in the DEA Business Case Tool provided the background assumptions for the high-level budget needs for the operational budget (Table 19). Using these assumptions, the general operational costs per year is detailed in Table 20. This ~R12 million is the base operational cost necessary for an air quality management team of 19 people. This is a high-level estimate of the budget, and should be considered only indicative of total potential cost.

Table 19. Budget assumptions as per the DEA Business Case Tool. HR costs reflected below are 20% higher than business case.

HR Resources Salary Calculation (Senior)	Values	Source of Information
Air Quality Average Annual Salary - Province	600 000.00	2014 values are increased by 20%
Air Quality Average Annual Salary - Local	420 000.00	Authority Payroll Information, 2014
Air Quality Average Annual Salary - Metro	540 000.00	Authority Payroll Information, 2014
Air Quality Average Annual Salary - District	480 000.00	Authority Payroll Information, 2014
Recruitment Cost (Advertisement, etc)	22 001.20	Authority Payroll Information, 2014
Administrator	120 001.20	
Infrastructure Costs		
Cost of Monitoring Station	1 200 000.00	Supplier Quotation, 2014
Maintenance Budget Per Station	180 000.00	15% Original Costs
Portable Equipment Cost	95 000.00	Supplier Quotation, 2014
Maintenance Budget Per Equipment	14 250.00	15% Original Costs
Training per Official	8 000.00	Supplier Quotation, 2014
Administration	75 000.00	Supplier Quotation, 2014
Major Station Maintenance Cost	250 000.00	Supplier Quotation, 2014

Table 20. Estimated operational costs per annum from DEA Business Case.

Operational Costs	Rand per annum	Additional details
HR Capital		
Air Quality Officials	10 380 000	19 staff plus an administrator
Administration + Training	83 000	
HR Total	10 463 000	
Infrastructure Operations and Maintenance		
Air Quality Monitoring Station Maintenance	1 620 000	Maintenance for 9 stations including travel costs, calibrations, consumables, calibration gases, with an allocation for significant repair to some instruments (assuming they are fully

Operational Costs	Rand per annum	Additional details
		equipped to measure all criteria pollutants)**
Portable Equipment Maintenance	4 250	Calibration and maintenance of mass flow calibrator and meteorological transfer standards
Sub-total	1 634 250	
Contingency	604 862.56	
ESTIMATED OPERATIONAL COSTS (per year)	12 702 112.56	

**The "Air Quality Monitoring Station Maintenance" budget is a generous allocation as all CoJ stations do not have a full suite of instruments of R 1.2 million capital. In fact, not all stations are operational.

9.5 Technical tools budget considerations

In addition to these operational costs, there will be a need every year for additional costs for specific project for those years. These are defined as "Technical tool review" in the Business Case and should be budgeted for as needed per year.

In the short-term, the needs include implementing the gap assessment recommendations (monitoring, modelling and EI), a fuel use survey, developing an air quality information portal, and the bylaw review. For dispersion modelling, an additional cost for CALPUFF VIEW (R15 000 per year) software license is needed; and computing resources may be as well.

9.6 Recapitalisation of monitoring instruments and expansion of stations

The instrumentation and infrastructure associated with ambient air quality monitoring has a limited operational lifespan, which is typically assumed to range between 5-10 years of operation for the meteorological and air quality monitoring instrumentation and 15-20 years for the shelters and other supporting infrastructure. The type of maintenance implemented and operational conditions may extend the lifespan of the instrumentation. The instrumentation in the CoJ network is approaching or surpassed the expected operational lifespan. In many cases, the instruments were purchased in 2004 when the network was initially set up. Thus it is also needed to budget for recapitalisation of instruments. This recapitalisation should be proactive in order to mitigate the risk of losing data from broken instruments. In addition, the state of the monitoring shelters should also be continually assessed in case there are maintenance or improvement needs (particularly in terms of micro-siting issues).

In order to estimate the cost to replacement instruments, two categories were considered. The categories and the associated costs are,

- 1) instruments older than 10 years old, which should receive highest priority for replacement – cost to replace estimated to be R2 080 000-R2 370 000
- 2) Instruments older than 5 years old, but less than 10 years old, which should receive secondary priority, – cost estimated to be R760 000- R880 000.

The instruments in category 1 are priority and should be replaced in the first two years of implementation of the AQMP. Once replaced, old but functioning instrumentation could potentially be kept in reserve for temporary replacement.

In addition to detailing the recapitalisation needs, the plan detailed the estimated budget needs for the expansion of the network to include all criteria pollutants per site is listed below in Table 21. These costs are, on average, approximately R2 862 500 per year over four years in order to expand all of the stations.

Table 21. Estimated budget to expand monitoring stations capabilities to cover all criteria pollutants.

Estimated budget to expanded stations to monitor all criteria pollutants	
<u>Buccleuch</u> O ₃ (R200 000- R230 000) BTEX (R300 000- R350 000) Cost for instrumenting station R500 000-R580 000	<u>Ivory Park</u> NO _x (R200 000 –R230 000) O ₃ (R200 000 –R230 000) CO(R200 000 –R230 000) BTEX (R300 000 – R350 000) PM _{2.5} (R300 000- R350 000) Cost for instrumenting station R1 000 000- R1 190 000
<u>Diepsloot</u> NO _x (R200 000- R230 000) O ₃ (R200 000 - R230 000) CO (R200 000 - R230 000) BTEX (R300 000 – R350 000) PM _{2.5} (R300 000 – R350 000) Cost for instrumenting station R1 200 000- R1 390 000	<u>Alexandra</u> NO _x (R200 000 - R230 000) O ₃ (R200 000 - R230 000) CO(R200 000 - R230 000) PM _{2.5} (R300 000 – R350 000) BTEX (R300 000 – R350 000) Cost for instrumenting station R1 200 000- R1 390 000
<u>Delta Park</u> NO _x (R200 000 - R230 000) SO ₂ (R200 000- R230 000) CO (R200 000- R230 000) O ₃ (R200 000- R230 000) PM ₁₀ (R300 000 – R350 000) PM _{2.5} (R300 000 – R350 000) BTEX (R300 000 – R350 000) Cost for instrumenting station R1 700 000- R1 970 000	<u>New Town</u> SO ₂ (R200 000 - R230 000) O ₃ (R200 000 - R230 000) PM _{2.5} (R300 000 – R350 000) Cost for instrumenting station R700 000 – R810 000
<u>Davidsonville</u> NO _x (R200 000 - R230 000) SO ₂ (R200 000 - R230 000)	<u>Jabavu</u> NO _x (R200 000 - R230 000) CO (R200 000 - R230 000)

Estimated budget to expanded stations to monitor all criteria pollutants	
O ₃ (R200 000 - R230 000) CO (R200 000 - R230 000) PM _{2.5} (R300 000- R350 000) BTEX (R300 000 – R350 000) Cost for instrumenting station R1 400 000 –R1 620 000	O ₃ (R200 000 - R230 000) PM _{2.5} (R300 000 – R350 000) BTEX (R300 000 – R350 000) Cost for instrumenting station R1 200 000- R1 390 000
Orange Farm NO _x (R200 000 - R230 000) CO (R200 000 - R230 000) PM _{2.5} (R300 000 - R230 000) BTEX (R300 000 – R350 000) Cost for instrumenting station R1 000 000 –R1 110 000	

9.7 Reporting on implementation of AQMP

Section 17 of the NEMAQA outlines the requirements for reporting on the AQMP. This includes, at a high-level,

1. Initiatives undertaken to during the reporting period;
2. Level of compliance with ambient air quality standards;
3. Measures taken to secure compliance with those standards;
4. Its compliance with any priority area air quality management plans applicable to it (currently, VTAPA with respect to CoJ);
5. Its air quality monitoring activities.

In the preceding sections, indicators are given per goal and per activity, and these cover all aspects listed here, except for point 4. Those points are related to VTAPA will be up-dated as part of the on-going VTAPA AQMP review.

The compliance with ambient air quality standards and air quality monitoring activities can also be fulfilled by reporting on indicators such as,

- the average concentration of all pollutants at all stations (across all averaging periods as per NAAQS);
- the number of exceedances of the NAAQS, and compared to the allowed FOE;
- the percent data recovery.

These should be reported internally to EISD monthly in order to track the performance of the operation of the ambient air quality stations. For example, an instrument error can lead to erroneous concentrations; regular checks and reporting of the data helps to ensure such malfunctions are caught in a timely manner.

Internal stakeholders in CoJ will be engaged through formal internal structures, including departmental reports on the data needs, usage and emission estimates, together with reports detailing progress on the implementation of AQMP and the state of air in CoJ. The state of air can be reported internally on a quarterly basis with reports on exceedances, average concentrations, and data completeness at all monitoring stations.

9.7.1 External Stakeholder Forum

Reporting to stakeholders will include reporting on the progress of the AQMP implementation and reaching the vision of the AQMP. Both public and internal stakeholders will be engaged through this reporting. The reporting to community stakeholders will also align with Goal 5 of this AQMP (section 9.2.5), and will also use a variety of communication channels. The Air Quality Portal, as explained in Goal 5, can be used to disseminate reporting by the CoJ. In addition, an Air Quality Forum will be developed to engage with external stakeholders. In this forum, the state of the air in CoJ, the progress on implementation and public concerns would be discussed. Trial formats for this forum should be piloted to investigate the more effective medium. In-person meetings can be held, however they may be time-intensive and costly. New media options do provide an opportunity to hold such a forum virtually, with a lower time constraint on both CoJ and the community members.

10 Summary

While air quality management activities in CoJ have been on-going since 2003, there has been a lack of a continuous concerted effort to improve air quality. Currently, the air pollution in the City is not in compliance at many sites of the NAAQS, and there are many gaps in the emission inventory.

The trajectory outlined in the AQMP is one that will work to decrease emissions from key sectors, quantify emission impacts from on-going projects, and to improve the enabling factors for air quality management. Even though the timeline for the AQMP implementation ranges from short to medium-term, all activities aim to meet the current vision. An AQMP is seen as a progressive advancement towards improved air quality for the region in question, and thus the plan itself sets the stage for activities to occur within the next 5 years. Thus this AQMP is the start of the CoJ's activities to meet their vision, "to achieve acceptable air quality levels in the City of Johannesburg".

11 References

- CoJ, 2003: *Air Quality Management Plan for the City of Johannesburg*. Final Report, report no. MTX/03/JHB/-01D.
- CoJ, 2007: State of Air Report. City of Johannesburg.
- CoJ, 2008: State of Environment Report. Bio-Physical Theme: *Climatology and climate change*. City of Johannesburg. Available at: <http://www.joburg.org.za/content/view/3959/114/>
- CoJ, 2009 (a). State of the Environment Report 2008, City of Johannesburg Environmental Management, 11th floor A Block, 158 Lovedale Street, Braamfontein, Johannesburg.
- CoJ, 2009 (b): Integrated Development Plan 2009. City of Johannesburg.
- CoJ, 2011: Growth and Development Strategy “Joburg 2040”. City of Johannesburg.
- CoJ, 2014: Carbon Disclosure Project. City of Johannesburg. Available at: [http://c40-production-images.s3.amazonaws.com/other_uploads/images/181_CDP_Cities_2014_Johannesburg_final_\(reduced\).original.pdf?1424836516](http://c40-production-images.s3.amazonaws.com/other_uploads/images/181_CDP_Cities_2014_Johannesburg_final_(reduced).original.pdf?1424836516)
- CoJ, 2015: City of Johannesburg’s Air Quality Monitoring Plan, City of Johannesburg.
- CoJ, 2016: City of Johannesburg’s Integrated Development Plan: 2016/21, City of Johannesburg.
- De Wet, T., Patel, L., Korth, M. & Forrester, C., 2008: *Johannesburg poverty and livelihood study*, Johannesburg: UJ.
- DEA, 2016: South Africa’s Third National Communication under the United Nations Framework Convention on Climate Change. Draft Report (Unpublished). Department of Environmental Affairs, Pretoria.
- DEAT, 2007: The National Framework for Air Quality Management in the Republic of South Africa. Government Gazette: 30284, 3-101. Department of Environmental Affairs and Tourism, Pretoria.
- DEAT, 2008: Manual for Air Quality Management Planning as contemplated in Sections 15-17 of the National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004). Department of Environmental Affairs and Tourism, Pretoria.
- DEAT, 2009: Vaal Triangle Airshed Priority Area Air Quality Management Plan. Report to the Department of Environmental Affairs and Tourism, March 2009. Department of Environmental Affairs and Tourism, Pretoria.
- DHB, 2015: District Health Barometer 2014-15. Health Systems Trust, Pretoria.
- DHET, 2016: List of Occupations in High Demand: 2015, Department of Higher Education and Training, Pretoria.

- Euromonitor International, 2016: *Johannesburg City Review - Overview of highlights*. [Online] Available at: <http://www.euromonitor.com/johannesburg-city-review/report> (Accessed 07/09/2016).
- GDACE, 2009: Gauteng Province Air Quality Management Plan (Final report). Gauteng Department of Agriculture, Conservation and Environment, Johannesburg.
- The National Academies, 2004: Air Quality Management in the United States, National Academic Press, Washington DC.
- NPC (National Planning Commission), 2011: National Development Plan 2030, Our future – make it work. National Planning Commission, Pretoria.
- RSA (Republic of South Africa), 2000: Municipal Systems Act (Act 32 of 2000). *Government Gazette*: 21776.
- RSA (Republic of South Africa), 2005: National Environmental Management: Air Quality Act No. 39 of 2004, Standards and Regulations. *Government Gazette*: 27318.
- RSA (Republic of South Africa), 2009: National Environmental Management: Air Quality Act No. 39 of 2004, National Ambient Air Quality Standards. *Government Gazette*: 32816.
- Skamarock, W. C., J. B. Klemp, J. Dudhia, D. O. Gill, D. M. Barker, M. G Duda, X.-Y. Huang, W. Wang, and J. G. Powers, 2008: A Description of the Advanced Research WRF Version 3. NCAR Tech. Note NCAR/TN-475+STR, 113 pp. doi:10.5065/D68S4MVH
- World Population Review, 2016: Johannesburg population data (urban). [Online]: Available at: <http://worldpopulationreview.com/world-cities/johannesburg-population/> (Accessed 07/09/2016).