REVIEW OF THE
AIR QUALITY MANAGEMENT PLAN

EMISSIONS INVENTORY

Progress Report No. GRDM-2019 PR.3, Final Report

May 2019

COMPILED BY

Lethabo Air Quality Specialists (Pty) Ltd
CK 2018/109208/07
P.O. Box 2174, Noorsekloof, 6331
info@laqs.co.za
www.laqs.co.za
Tel: (+27) 42 296 0229
Fax: (+27) 86 536 5597

Contents

ABBREVIATIONS AND DEFINITIONS

AQA	Air Quality Act, Act 39 of 2004
AQM	Air Quality Monitoring
AQMP	Air Quality Management Plan
AQO	Air Quality Officer
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DEADP	Department of Environmental Affairs and Development Planning
DEA	Department of Environmental Affairs
EIA	Environmental Impact Assessment
GRDM	Garden Route District Municipality
H_2S	Hydrogen Sulphide
IDP	Integrated Development Plan
IWMP	Integrated Waste Management Plan
mg/ton	Milligrams per Ton
MSA	Municipal Systems Act
MSW	Municipal Solid Waste
NO	Nitrogen Monoxide
NO_2	Nitrogen Dioxide
NOx	Nitrogen Oxides
NPI	National Pollution Inventory
PM10	Particulate Matter with aerodynamic diameter smaller than 10 micron
SAAQIS	South African Air Quality Information System
SANRAL	South African National Roads Agency Limited
SAWS	South African Weather Service
SO_2	Sulphur Dioxide
SO_3	Sulphur Trioxide
THC	Total Hydrocarbon Content
tpa	Tons per Annum
TPM	Total Particulate Matter
USEPA	United States of America Environmental Protection Agency
WWTW	Wastewater treatment works

AIR POLLUTION EMISSIONS INVENTORY

1 INTRODUCTION

An air quality management plan (AQMP) was compiled for the Garden Route District Municipality (GRDM) in 2007 and included in GRDM's Integrated Development Plan (IDP) shortly thereafter.

As is required by law, the AQMP must be revised on a 5 to 6-yearly basis to ensure that it remains current. As a result it was revised in 2012/13 and the revised plan was also included in GRDM's IDP.

The process of revision of the 2012/13 version of the AQMP commenced early in 2019 after Lethabo Air Quality Specialists (Pty) Ltd (LAQS) was awarded the contract to do so. The following items were included in the Service Level Agreement (SLA) entered into between GRDM and LAQS:

1 Assessment of compliance with existing AQMP

2 Status quo assessment

3 Compile an emissions inventory

4 Assess the level of air quality monitoring and modelling in the district

5 Assess the relevant municipal resources in the district

6 Review the air quality duties, functions and responsibilities within Garden Route District Municipality

7 Conduct a public participation process

8 Review and compile and AQMP for the Garden Route District Municipality

LAQS's findings of the first item are contained in its report No. GRDM-2091 Progress Report No. 1 of April 2019.

As the two items are interlinked, LAQS assessed the air quality status quo and municipal activity as a single investigation and its findings are contained in its report No. GRDM-2019 Progress Report No. 2 of April 2019.

The third item identified is the compilation of an emissions inventory for the District with special emphasis on evaluating the following:

-- Access, analyse and make recommendations on the current air quality emissions inventory of each local municipality and the Garden Route District Municipality.

-- Identify gaps in the existing inventory.

-- Make recommendations to strengthen and expand existing emission inventory.

This progress report gives the outcome of the emissions inventory compiled by LAQS. It deals primarily with emissions that occurred within the Garden Route district during 2018. It excludes all sources for which authorisations may have been granted as they were not operational during 2018.

2 TYPES OF EMISSION SOURCES

Air pollution emission sources are usually grouped into four major headings. These are:

-- Industrial sources

-- Residential sources

-- Mobile emissions, e.g. vehicle emissions

-- Other sources, not included in those above

Industrial sources can further be divided into two categories, i.e. point sources (e.g. chimney stacks) and area sources (e.g. stockpiles, disposal sites, tailings dams, etc.). Additional industrial sources, e.g. fugitive emissions, can be classified as one of these two major sources.

Residential sources are usually regarded as grid sources where the whole of a residential area is covered by a rectangular grid and the emissions per grid cell estimated from the population density and socio-economic level of the area.

Mobile sources consist of moving sources along roads, train lines, shipping lanes, etc.

Other sources contain those that do not readily fall into any one of those listed above, e.g. municipal landfill sites, wastewater treatment works (WWTW), etc.

While much effort has been spent on compiling the emissions inventory, it is accepted that it is unlikely that each and every source has been taken into account. The outcome of the assessment was the compilation of a comprehensive spreadsheet that will enable GRDM and municipal AQOs to add new sources or modify existing sources as more reliable information in received over time.

In compiling this emissions inventory LAQS relied heavily on the assistance of all concerned, i.e. GRDM as well as the seven individual municipalities. GRDM provided data of all listed industries and their measured emissions while the individual municipalities provided data of industries not listed, landfill sites, etc.

3 INDUSTRIAL SOURCES

Major sources of industrial emissions were identified during revision of GRDM's AQMP in 2012/13. Since then GRDM spent a considerable effort to obtain as much information as possible about industrial emissions with the result that a fairly complete source inventory exists. However, some of the industries, specifically those that are not regarded as controlled emitters, have no information about the actual emissions of pollutants from their processes as quantification of emissions was never required.

Industrial sources can be grouped into two categories, i.e. those requiring atmospheric emission licenses (AELs) and those that do not. Industries requiring AELs are defined in one of the following Government Notices:

- Declaration of a Small Boiler as a Controlled Emitter, contained in Government Notice 831 of 1 November 2013 (GN831).
- The List of Activities Which Result in Atmospheric Emissions, contained in Government Notice 893 of 22 November 2013 (GN893) and its amendments.

3.1 INDUSTRIES WITH AELs

Annual emissions of controlled pollutants from industries with AELs were calculated from actual measured concentrations reported annually as is required in each individual AEL.

Annual emissions of pollutants not controlled by either of the two Government Notices, and not measured during annual emissions verification exercises, e.g., CO, CO_2, etc., were calculated from emission factors published by the USEPA in their CHIEF (Clearing House for Industrial Emission Factors) software. These emission factors are commonly referred to as “AP-42”.

3.2 INDUSTRIES WITHOUT AELs

In the process of compiling a source inventory GRDM obtained information about production rates, fuel consumption, fuel type, etc. For industries that do not require AELs, annual emissions were calculated from this information and emission factors contained in AP-42.

Most of the sources listed by GRDM operate some form of fuel burning appliance with the result that emission factors were used to estimate the emissions of the main pollutants from combustion sources.

Where non-combustion sources are concerned, relevant emission factors provided by AP-42 were used in conjunction with production capacities to estimate emissions from those individual sources.

In some cases emissions from industries that do not require AELs were quantified for their own internal use, but still made the results available to GRDM. In such cases the measured concentrations were used in preference to emissions estimated from emission factors.

Throughout this document all emissions are given in tons per annum and abbreviations used have the following meaning:

-- TPM: Total particulate matter

-- SO_2: Sulphur dioxide

-- NOx: Nitrogen oxides

-- CO: Carbon monoxide

-- CO_2: Carbon dioxide

-- HF: Hydrogen fluoride

-- VOCs: Volatile organic compounds

-- THC: Total hydrocarbons

-- Odours: All odorous compounds causing complaints, i.e. hydrogen sulphide (H_2S), mercaptans, trimethylamine (TMA) and naphthalene (creosote)

3.3 ANNUAL INDUSTRIAL EMISSIONS

The sources were grouped into the seven municipalities included in GRDM, i.e. Bitou, Knysna, George, Mossel Bay, Hessequa, Kannaland and Oudtshoorn and the totals for each municipality were determined. The sources in each municipality are listed in Tables 3.3.1 to 3.3.7 below.

The methods used to calculate annual emissions are noted with each source and the following definitions apply:

(1): Only measured data was used to calculate annual emissions

(2): A combination of measured data and AP-42 emissions factors were used to calculate annual emissions. AP-42 was used to estimate CO and CO_2 emissions only where these emissions were not measured.

(3): AP-42 emissions factors were used to calculate all annual emissions, based on the fuel consumption of such sources.

A column is provided to show odorous emissions. All odorous emissions, i.e. those that lead, or have led, to complaints are included under this single heading. The components in included are:

(a): Hydrogen sulphide

(b): Mercaptans

(c): Trimethylamine

(d): Naphthalene

Measured emissions data was used as far as possible to calculate annual emissions from the various sources. Where specific compounds were not measured, data contained in AELs was used to estimate annual emissions using internationally published emission factors. Where table cells have been left blank insufficient data was available to estimate emissions.

The sources are listed alphabetically per municipality. The totals given for each industry include all sources associated with that industry, i.e. the total emissions from all stacks and all area sources.

Where values for any compound are reported as “0.0” it means that none was measured. In cases where emissions were calculated from emission factors, low values, i.e. lower than 0.05 tons per annum, the values are reported as “0.0(*)” values.

3.3.1 BITOU MUNICIPALITY

The sources of air pollution identified in the Bitou region and their estimated emissions are:

BITOU	**Emissions, tons per annum**								
Source	**TPM**	**SO_2**	**NOx**	**CO**	**CO_2**	**HF**	**VOCs**	**THC**	**Odours**
JC Pine Mills (2)	0.7	1.3	0.6	3.1	1 005				
Kurland Bricks (3)	45.9	30.2	24.1	20.1	7 540	4.3			
Vantell Bricks (3)	18.0	11.8	9.5	7.9	2 961	1.7			
TOTAL, tons per annum	**64.6**	**43.3**	**34.2**	**31.1**	**11 506**	**6.0**			

Table 1: Industrial Emission Sources in Bitou

3.3.2 KNYSNA MUNICIPALITY

The sources of air pollution identified in the Knysna region and their estimated emissions are:

KNYSNA	Emissions, tons per annum								
Source	**TPM**	**SO_2**	**NOx**	**CO**	**CO_2**	**HF**	**VOCs**	**THC**	**Odours**
Geelhoutvlei Timbers (1)	4.9	0.0	5.7	13.6	859				
Wilcross Timbers (3)	1.3	0.1	1.6	2.0	647				
TOTAL, tons per annum	**6.2**	**0.1**	**7.3**	**15.6**	**1 506**				

Table 2: Industrial Emission Sources in Knysna

3.3.3 GEORGE MUNICIPALITY

The sources of air pollution identified in George and their estimated emissions are:

GEORGE	Emissions, tons per annum								
Source	**TPM**	**SO_2**	**NOx**	**CO**	**CO_2**	**HF**	**VOCs**	**THC**	**Odours**
AEL HOLDERS									
Botha & Barnard (1)	0.5	0.0	1.0	15.5	127	0.0	0.0	0.0	
Cape Pine (2)	39.2	0.0	35.8	82.2	40 660	0.0	0.0	1 215	
George Crematorium (1)	1.4	0.3	4.0	2.1					
Houttek Iuventus (1)	0.7	0.0	0.6	27.1	81	0.0	0.0	0.0	
Much Asphalt (2)	3.2	6.9	0.3	0.1	2 964	0.0	0.0	0.0	
Optimum Waste (2)	0.6	0.0	8.0	10.6	1 677	0.0	0.0	0.0	
PG Bison – Thesen (2)	44.1	11.2	41.0	268.6	87 290	0.0	0.0	0.0	
South Cape Galvanising (1)	1.0								
OTHERS									
Express Laundry (3)	0.4	0.0(*)	0.5	0.6	211				
George Timber & Palette (3)	1.6	0.1	1.9	2.3	758				

Lancewood (2)	131.4	50.5	24.9	13.5	15 464				
Nova Feeds (3)	0.1	0.2	0.5	0.1	557				
Outeniqua Bakeries (3)	0.0(*)	0.1	0.4	0.1	402				
Pioneer Foods (3)	0.0(*)	0.1	0.4	0.1	402				
Ramcom trucks (3)	0.0(*)	0.0(*)	0.1	0.0(*)	71				
SAB Hop Farms (3)	0.7	2.4	6.7	1.7	7 214				
Touw Meubels (3)	0.5	0.0(*)	0.6	0.8	254				
Woodfirst CC (3)	55.3	3.5	67.7	82.9	26 957				
TOTAL, tons per annum	**280.7**	**75.3**	**194.4**	**508.3**	**185089**	**0.0**	**0.0**	**1215.0**	

(*): less than 0.05 ton per annum

Table 3: Industrial Emission Sources in George

3.3.4 MOSSEL BAY MUNICIPALITY

The sources of air pollution identified in Mossel Bay and their estimated emissions are:

MOSSEL BAY	**Emissions, tons per annum**								
Source	**TPM**	**SO_2**	**NOx**	**CO**	**CO_2**	**HF**	**VOCs**	**THC**	**Odours**
AEL HOLDERS									
Gourikwa Power Station (2)	1.0	5.7	1 059	48.7	564 473				
PetroSA (1)	89.2	84.9	275.0	363.6	34 632				
PG Bison Woodline (3)	4.8	0.3	5.8	7.2	2 328				3.3 (d)
Rheebok Bricks (2)	50.6	39.0	24.7	42.1	6 103	5.6			
Southern Cape Fish Meal (2)	0.3	0.7	1.0	1.3	2				30.0 (a,c)
South Cape Ostrich Tnrs (2)	0.7	8.8	2.6	0.1	619				0.5 (a)
Techno Asphalt (2)	2.3	0.0	2.9	1.0	3 985				
OTHERS									
Afripet (3)	0.0(*)	0.0(*)	0.10	0.0(*)	70				
Afrofishing (3)	0.6	10.0	1.1	0.2	1 094				
ATKV Hartenbos (3)	0.0(*)	0.0(*)	0.10	0.0(*)	115				

De Bakke Santos (3)	0.0(*)	0.1	0.3	0.1	341				
Mossel Bay Hospital (3)	0.0(*)	0.0(*)	0.0(*)	0.0(*)	84				
Mossel Bay Panel Beaters (3)	0.0(*)	0.0(*)	0.0(*)	0.0(*)	4				
Nestlé (3)	99.0	141.1	46.4	37.1	35 438				
Point Caravan Park (3)	0.0(*)	0.0(*)	0.0(*)	0.0(*)	62				
Power Pellet Fuel (3)	0.0(*)	0.0(*)	0.0(*)	0.0(*)	12				
The Point Hotel (3)	0.0(*)	0.0(*)	0.0(*)	0.0(*)	25				
Voorbaai – Tank farm (3)							374.0	1 961	
TOTAL, tons per annum	**248.6**	**290.6**	**1 419**	**501.4**	**649 386**	**5.6**	**374.0**	**1 961**	**33.8**

(*): less than 0.05 ton per annum

Table 4: Industrial Emission Sources in Mossel Bay

3.3.5 HESSEQUA MUNICIPALITY

The sources of air pollution identified in the Hessequa region and their estimated emissions are:

HESSEQUA	Emissions, tons per annum								
Source	**TPM**	**SO_2**	**NOx**	**CO**	**CO_2**	**HF**	**VOCs**	**THC**	**Odours**
AEL HOLDERS									
Combo Timbers (2)	0.3	0.0	0.1	1.8	846				
Imerys (2)	0.1	0.1	0.7	0.6	716				
Organic Aloe (3)	0.1	0.0	0.1	0.0	60				
Riversdal Saagmeule (2)	7.1	0.0	4.5	2.5	1 248				
South Cape Poles (2)	10.4	0.7	0.4	14.1	5 078				0.4 (d)
Spitskop stene (3)	26.5	17.4	7.4	11.6	4 350	2.5			
OTHERS									
Jireh Foods (3)	0.1	0.3	0.7	0.2	774				
TOTAL, tons per annum	**44.6**	**18.5**	**13.7**	**30.9**	**13 071**	**2.5**			**0.4**

Table 5: Industrial Emission Sources in Hessequa

3.3.6 KANNALAND MUNICIPALITY

The sources of air pollution identified in the Kannaland region and their estimated emissions are:

KANNALAND	**Emissions, tons per annum**								
Source	**TPM**	**SO_2**	**NOx**	**CO**	**CO_2**	**HF**	**VOCs**	**THC**	**Odours**
Parmalat (3)	29.4	45.5	14.1	11.1	10 883				
Ladismith Kaas (3)	46.0	65.5	21.5	17.2	16 454				
Ladismith Cellar (3)	7.6	10.8	3.5	2.8	2 704				
TOTAL, tons per annum	**83.0**	**121.8**	**39.1**	**31.1**	**30 040**				

Table 6: Industrial Emission Sources in Kannaland

3.3.7 OUDTSHOORN MUNICIPALITY

The sources of air pollution identified in the Oudtshoorn region and their estimated emissions are:

OUDTSHOORN	**Emissions, tons per annum**								
Source	**TPM**	**SO_2**	**NOx**	**CO**	**CO_2**	**HF**	**VOCs**	**THC**	**Odours**
AEL HOLDERS									
Johnsons Bricks (3)	58.5	38.4	16.3	25.6	9 611	5.4			
Klein Karoo International (1)	10.5	35.4	11.8	0.0	576				0.50 (a)
PSP Timbers (3)	29.9	1.9	36.6	44.8	14 556				1.0 (c)
OTHERS									
African Sky Hotels (3)	0.0(*)	0.0(*)	0.1	0.0(*)	85				
Cango Winery (3)	0.0(*)	0.0(*)	0.1	0.0(*)	85				
Dyselsdorp Liquorice (3)	0.1	1.5	0.2	0.0(*)	164				
Klein Karoo Dairy (3)	0.0(*)	0.0(*)	0.1	0.0(*)	68				
Parmalat (3)	0.1	1.5	0.2	0.0(*)	164				
World Class Connection (3)	2.4	3.4	1.1	0.9	851				
TOTAL, tons per annum	**101.5**	**82.2**	**66.6**	**71.3**	**26 160**	**5.4**	**0.0**	**0.0**	**1.5**

(*): less than 0.05 ton per annum

Table 7: Industrial Emission Sources in Oudtshoorn

3.4 TOTAL INDUSTRIAL EMISSION RATES

The total emission rates of the various pollutants listed above amount to the following:

Total particulate matter:	829 tpa
Sulphur dioxide:	632 tpa
Nitrogen oxides:	1 774 tpa
Carbon monoxide:	1 190 tpa
Carbon dioxide:	916 758 tpa
Hydrogen fluoride:	19.5 tpa
Volatile organic compounds:	374 tpa
Total hydrocarbons:	3 176 tpa
Odorous compounds:	35.7 tpa

3.5 DISCUSSION OF INDUSTRIAL EMISSIONS

Much of the emissions listed in the various tables above are based on emission factors and pertinent industrial activities. As a result the values reported must be interpreted with care as they are subject to a reasonable degree of uncertainty.

AP-42 emission factors are based on technologies that prevailed in the USA during the mid-1960s to early 1990s. While it can be argued that the scenario that prevailed in the USA at that time may be applicable to some sources currently in operation in South Africa, cognisance must be taken of technological developments since that period.

Boiler combustion efficiencies have improved, air pollution control technologies have improved, process efficiencies have improved, etc., all contributing to a potential reduction in air pollutant emissions.

Both GN831 and GN893 stipulate that all industries with AELs must have their emissions verified annually and must report the findings to the appropriate licensing authority. The information thus gathered by GRDM will reflect actually measured emissions data and not values estimated from emission factors.

The resulting annual emissions can be regarded as reliable, but it must be borne in mind that emission verification results only apply to the operating conditions that prevailed at the time of the verification exercise. As all industrial process show some degree of variability, it can be expected that annual emission verification results will vary accordingly. Accurate average emission can, therefore, only be determined after at least five years' annual verification results and the accuracy will improve as additional results are added to the data pool.

4 RESIDENTIAL SOURCES

In estimating possible emissions from domestic sources attention was only paid to the use of combustible energy sources, e.g. coal, wood, etc., and not electricity as only minor power generation occurs in the Garden Route district. Residential combustible energy consumption can be grouped under the following two sub-headings:

-- Heating, cooking and lighting

-- Recreational, e.g. fireplaces, barbecues, etc.

The largest source of residential emissions emanate from the first category, i.e. space heating, cooking and lighting in predominantly poor areas and informal settlements.

4.1 ENERGY SOURCES USED IN GRDM

During the 2011 census Statistics South Africa (StatsSA) gathered information about the energy used for heating, cooking and lighting in households across the country and provided the following numbers of households and types of fuel used:

COOKING					
	Electricity	**Gas**	**Paraffin**	**Wood**	**Coal**
Bitou	14 064	1 600	509	358	9
Knysna	17 159	2 222	1 784	588	17
George	44 879	3 772	2 725	1 846	34
Mossel Bay	24 061	2 119	1 304	304	25
Hessequa	13 369	1 595	29	767	11
Oudtshoorn	17 036	1 706	675	2329	34
HEATING					
Bitou	7 873	702	1 702	1 494	35
Knysna	13 005	1 023	1 794	2 267	78
George	30 452	1 938	5 576	5 057	53
Mossel Bay	15 736	1 185	2 478	753	33
Hessequa	10 544	451	95	1 703	5
Kannaland	4 037	105	19	1 393	14
Oudtshoorn	13 491	376	509	3 788	132
LIGHTING					
Bitou	15 653	38			

Knysna	19 440	56			
George	48 737	119			
Mossel Bay	26 292	91			
Hessequa	15 063	41			
Kannaland	55 71	22			
Oudtshoorn	18 679	27			

Table 8: Numbers of Household per Fuel Type Used

Unfortunately StatsSA did not gather any information about the quantities of fuel used by each household with the result that some assumptions must be made in this regard.

According to fuel suppliers anthracite is used widely for household purposes in the Garden Route district. Municipal officials, however, are of the opinion that wood is used much more frequently than anthracite. From the Table above, however, it can be seen that electricity is by far the greatest energy source used in GRDM and it can be seen that gas is used mostly for cooking purposes while wood is burned mostly for heating purposes. Paraffin, wood and coal is used almost exclusively for cooking and heating purposes.

4.2 ENERGY CONSUMPTION IN GRDM

The calorific values of the domestic fuels used in GRDM are:

-- Coal 21.2 MJ/kg

-- LPG 46.1 MJ/kg

-- Paraffin 28.7 MJ/kg

-- Wood 15.9 MJ/kg

This implies that each kilogram of coal has the same energy content as 0.46 kg LPG, 0.73 kg paraffin and 1.32 kg wood.

While it is a fairly simple task to obtain the facts given above, determining the annual mass emission rate from household burning is an extremely complex task. It is influenced by many factors, including:

-- Seasonal variation, i.e. temperature fluctuations

-- Degree of electrification

-- Population density

-- Availability of suitable fuels

The impacts of these factors are extremely difficult to quantify and emissions are, therefore, difficult to estimate. In addition, very little research has been done on the actual emissions from residential burning activities as most research projects concentrated on the impact on ambient air quality, health risk, etc. Nevertheless, at least one research project provided useful data. This project was funded by the Department of Minerals and Energy (DME) and was carried out in 1997 at Qalabotjha in the Free State. This is a village of approximately 15 000 people living in approximately 2 500 residences, i.e. 6 people per household. The area was provided with limited electrification which was sufficient for essential services.

During that project coal was replaced with low-smoke fuels and the reduction in ambient particulates was investigated. While it did not describe actual emission rates, the project determined that the people of Qalabotjha consumed approximately 20 tons of coal per day during mid-winter.

This information can only be interpreted for a similarly sized population in Garden Route with the following assumptions:

-- Approximately 25% less anthracite will be used in the GRDM due to warmer winter temperatures and higher calorific value of the fuel.

-- Maximum coal usage will occur for four winter months of the year, i.e. 15 tons will be used per day.

-- A further reduction of 25% will occur for four months during spring and autumn, resulting, i.e. 10 tons will used per day.

-- A further 25% reduction will occur during the remaining summer months, i.e. 5 tons will be used per day.

These assumptions imply that approximately 3 600 tons of coal, or 1 660 tons LPG, 2 660 tons paraffin or 4 800 tons of wood, will be burned by a population of 15 000 people in GRDM in one year. This is equal to approximately 240 kg coal per person, 110 kg LPG per person, 175 kg paraffin or 320 kg wood per person per year.

4.3 EMISSION FACTORS

According to AP-42 typical emission factors for anthracite and wood combustion for space heating are as follows (kg/ton fuel):

FUEL	Coal	LPG	Paraffin	Wood
Pollutant				
Particulates	4.5	0.04	0.29	1.83
Sulphur dioxide	17.7	0.006	1.04	0.11

Nitrogen oxides	1.3	1.36	2.93	2.24
Carbon monoxide	0.3	0.23	0.73	2.74
Carbon dioxide	2 580	927	3 150	891

Table 9: Domestic Fuel Emission Factors

4.4 POPULATION DATA

In its Progress Report No. GRDM-2019 PR.2, dealing with the status quo in GRDM, LAQS estimated that the following population numbers reside in GRDM:

Municipality	Population, approximate
Bitou	73 860
Knysna	85 430
George / Uniondale	237 650
Mossel Bay	106 760
Hessequa	60 580
Kannaland	25 430
Oudtshoorn	105 940
Total population	**695 650**

Table 10: GRDM Population per Municipal Area

These numbers were derived from GRDM’s 2015 Integrated Waste Management Plan.

GRDM’s IWMP also provides details of the estimated number of households and number of people in each household in 2013. The IWMP further divides the households into low / very low income groups, middle income group and high / very high income groups in each of the seven municipalities, yielding the following data:

Municipality	No Households	Average No. people per household	Low / very low income, %	Medium income, %	High / very high income, %
Bitou	18468	2.9	64.02	13.80	22.18

Knysna	23097	3.1	56.72	14.99	28.30
Mossel Bay	29382	3.2	52.75	15.41	31.85
George	56400	3.6	51.80	17.29	30.91
Hessequa	16438	3.3	49.19	22.48	28.33
Kannaland	6249	4	63.30	18.60	18.10
Oudtshoorn	22469	4.4	55.79	18.91	25.30

Table 11: Households and Income Groups in GRDM

It can be assumed that the medium, high and very high income groups are not likely to use any of the fuels discussed so far for cooking and heating purposes, other than for recreational purposes and the few that may have installed gas stoves.

It can further be assumed that it is unlikely that low and very low income groups will use gas for cooking and heating purposes, but rely mostly on paraffin, wood and coal as energy sources.

Assuming that the low and very low income population percentages are still valid in each of the municipalities, the number of people that are likely to use paraffin, wood and coal in each municipality can be estimated from the population statistics given above. In addition, the number of people in each area dependent on paraffin, wood and coal as energy sources can be derived from Table 8 above, thus providing the following numbers:

Municipality	Low income Population	Paraffin	Wood	Coal
Bitou	47 285	24 908	21 864	512
Knysna	48 456	21 003	26 540	913
George / Uniondale	125 360	95 172	28 920	1 267
Mossel Bay	55 302	28 857	26 171	274
Hessequa	29 799	1 570	28 146	83
Kannaland	16 097	325	15 615	157
Oudtshoorn	59 104	8 682	48 724	1 698
Total population	**381 403**	**180 518**	**195 981**	**4 905**

Table 12: GRDM Population per Municipal Area Using Fossil Fuels

4.5 EMISSIONS

Applying the per capita energy consumption derived in Section 4.2, the emission factors listed in Table 9 and the population numbers dependent on each type of fuel results in the following estimated annual emissions:

Emissions	**TPM**	**SO_2**	**NOx**	**CO**	**CO_2**
Bitou	14.6	7.5	28.6	22.4	20 282
Knysna	17.6	8.6	30.1	26.0	19 710
George / Uniondale	23.1	23.7	69.9	37.6	61 494
Mossel Bay	10.9	7.0	26.1	17.4	20 529
Hessequa	16.7	1.6	21.0	24.9	8 942
Kannaland	9.3	1.3	11.4	13.7	4 729
Oudtshoorn	30.8	10.5	39.9	44.0	19 730
TOTAL	**123.0**	**60.2**	**227.0**	**186.0**	**155 416**

Table 13: Estimated Emissions from Residential Sources

It must be stressed that these figures are based on some rough assumptions and can only be verified through an intensive investigation into population densities, fuel burning habits (frequency, types and quantities of fuels), etc. It is, therefore, recommended that such a survey is undertaken on a statistical basis as an objective of the AQMP.

4.6 RECREATIONAL BURNING

The incidence of recreational burning of coal, wood, charcoal, etc., in fireplaces and barbecues is regarded as extremely low when compared to space heating and cooking activities in low socio-economic areas. The resultant annual emission rates will, therefore, be so low that it is not regarded as a notable source of air pollutants.

Nevertheless, it must be borne in mind that all of the pollutants mentioned above are emitted during such activities.

4.7 GARDEN REFUSE BURNING

Regardless of whether it is legal or not, some garden refuse burning activities occur within the GRDM and must be regarded as a notable source of air pollutants as a result of the wide variety of pollutants that are released and the nuisance created by the smoke produced.

According to AP-42 all of the pollutants listed in Section 4.1 are emitted, in addition to methane and non-methane hydrocarbons.

The major issue associated with garden refuse burning is probably the nuisance value of the smoke and odours accompanying the burning of garden refuse.

5 MOBILE EMISSIONS

Mobile emissions are those caused by sources that are not stationary and can be grouped as follows:

-- Road traffic

-- Railways

-- Aircraft

-- Ships

Of these the greatest risk is associated with motor vehicles as emissions occur more frequently in close proximity to people.

5.1 ROAD TRAFFIC

5.1.1 Emission Factors

Vehicle emission factors have been developed by the European Union for use in member countries. However, these factors cannot be applied directly to local conditions due to variations in the following factors:

-- Differences if vehicle fleet composition, e.g. cars, trucks, diesel powered cars and trucks, motor cycles, etc.

-- Differences in vehicle fleet age

-- Differences in fuel composition

-- Differences in speed

-- Differences in topography, i.e. mountains, flat regions, altitude, etc.

Nevertheless, by far the majority of motor vehicles sold in South Africa are based on equivalent European products with the result that it can be assumed that engine technology is comparable with European conditions.

South African fuels follow EU specifications, albeit with a time lag of several years due to upgrades required at local fuel refineries to allow production of EU-level fuels.

The EU developed a set of 6th order polynomials in order to estimate emissions of various pollutants from petrol and diesel powered vehicles. The general format of the polynomials is:

$$y = a + bx + cx^2 + dx^3 + ex^4 + fx^5 + gx^6 \text{ where}$$

y = pollutant emission rate, g/km

x = speed, km/h

a to g = coefficients unique to each pollutant

In addition, coefficients are defined for a classification of 40 different types of vehicles, covering all types of private and commercial road transport used in Europe today.

While the classification used in EU countries is extensive, it cannot be applied to the same level of efficiency in South Africa due to two major shortcomings:

-- Inadequate traffic counts on local roads

-- Unavailable vehicle fleet composition information

5.1.2 Traffic Counts

The South African National Roads Agency Ltd (SANRAL) carries out vehicle counts on major routes from time to time, including the N2 and N12 national roads. These traffic counts provide totals for light motor vehicles (LMVs) and heavy motor vehicles (HMVs) as well as average speeds for both groups. The heavy motor vehicles were further grouped in short, medium and long vehicles.

SANRAL provided details of traffic counts conducted during 2018 in each direction along various sections of the N2 national road within the borders of GRDM. The resulting directional count data were used to calculate the total traffic flows along the various road sections included in this emissions inventory. In addition, annual average daily traffic (AADT) flows along the major provincial roads in the Garden Route district were obtained from provincial government sources.

The road sections selected are:

N2 National Road:

Nature's Valley	Before Plettenberg Bay
Goose Valley Plettenberg Bay	Between Plett & Knysna
Before Knysna	After Knysna (Brenton)
Before Sedgefield	Before Wilderness
Kaaimans Pass	George after N2/N12 split
George pbefore Thembalethu	George York St
Glentana	Groot Brak
Klein Brak	Hartenbos

Mossel Bay Die Bakke
Mossgas
Albertinia
Riversdale
Heidelberg

N12 National Road:

George to Oudtshoorn
Oudtshoorn to De Rust

Provincial Roads:

R328 Oudtshoorn to Cango
R328 Oudtshoorn to Hartenbos
R62 Oudtshoorn to Ladismith
R323 Ladismith to Riversdal
R305 Stilbaai to N2
R102 Mossel Bay - Voorbaai
R102 Mossel Bay - Heiderand

The following counted annual traffic volumes were reported for 2018 along each of these road sections:

Road section	**Vehicle counts**				
	Total	LMV	SHMV	MHMV	LHMV
Nature's Valley	2 072 026	1 798 519	79 317	46 496	147 694
Before Plettenberg Bay	2 758 813	2 408 444	119 125	59 563	171 681
Goose Valley Plett' Bay	4 214 182	3 864 405	139 911	55 964	153 902
Between Plett & Knysna	3 139 033	2 756 071	160 844	57 444	164 674
Before Knysna	4 691 799	4 241 386	198 182	72 066	180 165
After Knysna (Brenton)	4 163 799	3 768 238	166 136	59 334	170 091
Before Sedgefield	3 565 391	3 105 456	170 176	78 189	211 570
Before Wilderness	4 218 963	3 775 972	168 337	84 168	190 486
Kaaimans Pass	5 643 816	5 169 735	203 855	80 594	189 632
George after N2/N12 split	5 753 287	5 246 998	258 207	70 880	177 201
George at Thembalethu	5 742 838	5 203 011	291 507	70 178	178 143
George York St	6 210 851	5 614 609	339 858	71 549	184 835
Glentana	5 300 055	4 701 149	293 464	89 836	215 606

Groot Brak	4 598 663	4 083 613	221 472	82 408	211 171
Klein Brak	5 561 051	4 927 091	329 659	88 754	215 546
Hartenbos	6 966 379	6 262 775	386 982	91 469	225 153
Mossel Bay Die Bakke	5 743 530	5 151 946	289 876	82 822	218 886
Mossgas	2 983 250	2 103 191	246 417	211 214	422 428
Albertinia	2 553 788	2 122 198	133 793	69 054	228 743
Riversdale	2 299 277	1 892 305	118 022	69 185	219 765
Heidelberg	1 872 286	1 484 723	100 766	65 886	220 911
George to Oudtshoorn	1 245 780	1 122 448	56 733	19 733	46 866
Oudtshoorn to De Rust	2 510 486	2 369899	66 076	14 059	60 452
PGWC Cango	399 344	376 581	16 389	5 918	455
Oudtshoorn to Hartenbos	509 175	451 505	28 258	8 074	21 338
Oudtshoorn to Ladismith	679 265	599 695	38 989	11 140	29 441
Ladismith to Riversdal	252 580	218 635	166 083	47 452	125 410
Stilbaai to N2	799 715	697 515	50 078	14 308	37 814
Voorbaai	9 564 095	9 023 895	388 944	140 452	10 804
Heiderand	6 584 235	6 307 200	199 465	72 029	5 541

S-, M-, LHMV: Short, medium, long heavy motor vehicles

Table 14: Annual Counted Vehicle Flows

As can be seen from this table, the heaviest traffic flow along any section of the N2 national road is past Hartenbos outside Mossel Bay where in excess of 6.9 million vehicles were counted in 2018. By far the highest traffic density is experienced along the R102 provincial road between Hartenbos and Mossel Bay through the Voorbaai area where approximately 9.5 million vehicles were counted during 2018.

The EU emission factors indicate that the emissions of slow moving vehicles are generally higher than when at speed. This is due to internal engine combustion efficiencies which result in more efficient fuel combustion at higher speeds.

It can, therefore, be argued that the emissions of all vehicles in urban driving cycles, especially in town centres, will be higher than for rural driving cycles. With no vehicle count data in town centres in the Garden Route district it is, therefore, not possible to estimate the level of emissions in each town.

This issue is of particular importance in areas of high traffic flows, e.g. Knysna (where all of the traffic along the N2 national road is forced to pass through the town centre), Voorbaai in Mossel Bay, etc. The problem is exacerbated during stop-start driving conditions which are enforced by traffic lights, high traffic volumes, etc., and could imply serious air quality impacts during peak holiday seasons.

It is recommended, therefore, that vehicle counts in major traffic flow areas are obtained with some degree of urgency.

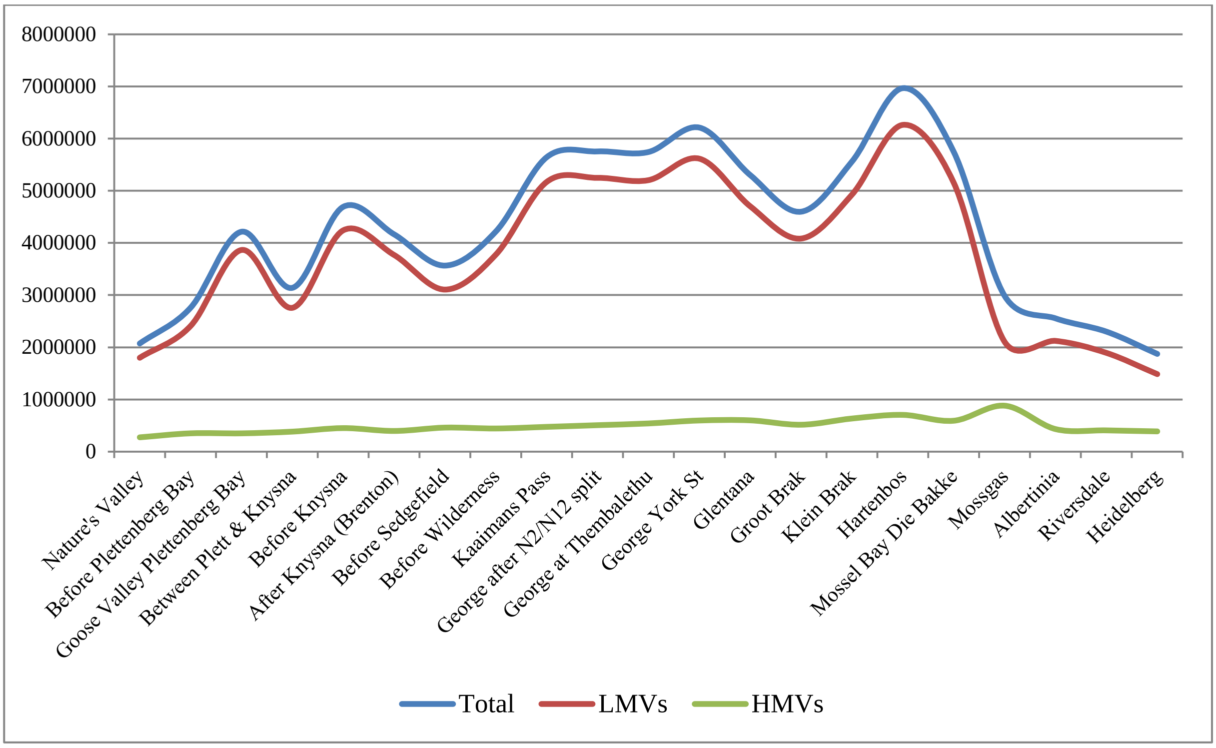

Figure 1: Traffic Flow Volumes on N2 Within GRDM region

Using the hourly vehicle traffic counts provided by SANRAL, LAQS determined an average weekly and monthly traffic flow profile for all routes and the outcome is shown graphically below.

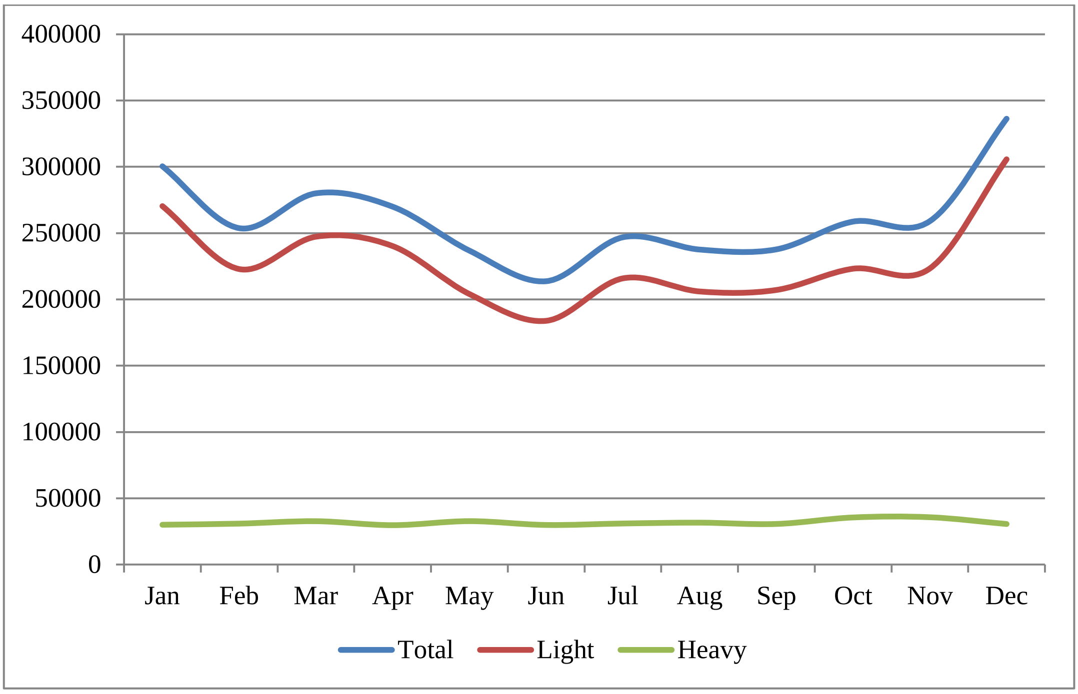

Figure 2: Monthly Variations in Traffic Flow on N2 in Knysna

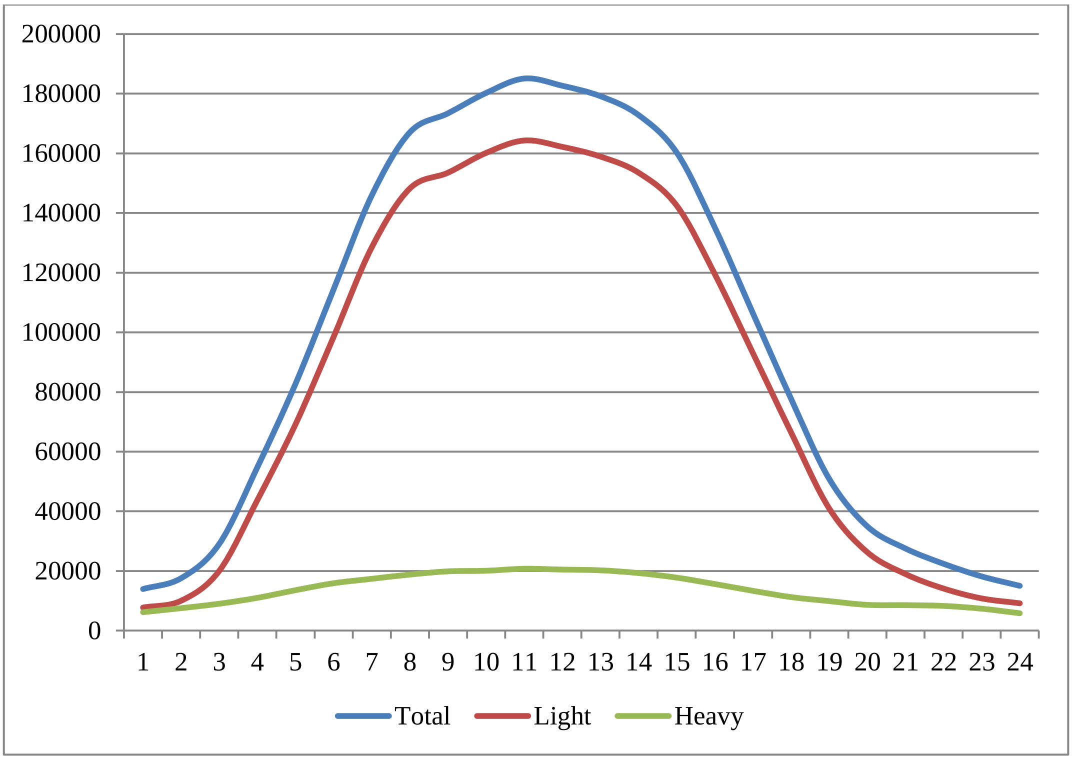

Figure 3: Daily Variations in Traffic Flow on N2; Weekdays

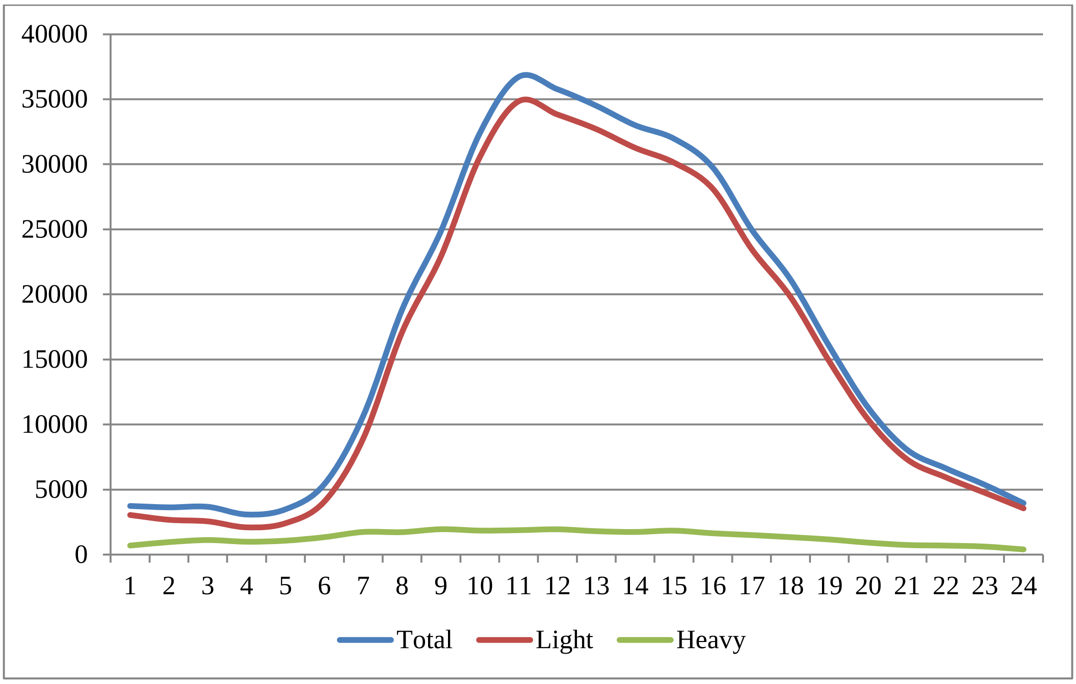

Figure 4: Daily Variations in Traffic Flow on N2; Saturdays

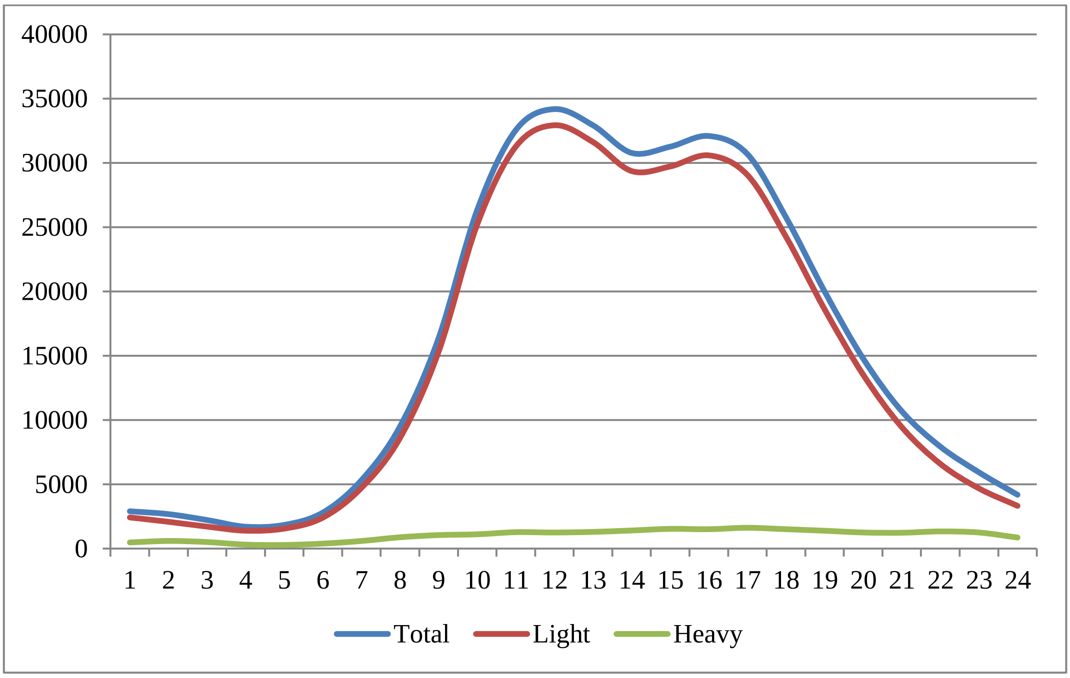

Figure 5: Daily Variations in Traffic Flow on N2; Sundays

The following can be derived from the various figures:

Figure 1:

The number of vehicles entering / leaving the Garden Route district at Nature's Valley and that entering / leaving at Heidelberg during 2018 is about the same at approximately 2 million vehicles. This number increases to approximately 4 million vehicles in the vicinity of Plettenberg Bay, Knysna and Wilderness. Thereafter it increases to approximately 6 to 7 million vehicles around George and Mossel Bay after which the traffic volume along the N2 drops substantially to approximately 2 to 2.5 million vehicles.

In LAQS's opinion, the number of vehicles entering / leaving GRDM can be regarded as "through traffic", i.e. traffic flowing through the Garden Route region *en route* to other destinations. A large portion of the increased traffic flow around Plettenberg Bay, Knysna and Wilderness is regarded as tourism related while the increased traffic flow around George and Mossel Bay is regarded as local business and commuter traffic, i.e. people living in one area and working in another.

Figure 2:

From this figure it can be seen that traffic flows show a substantial increase of approximately 35% during December and January, i.e. prime holiday season.

Figure 3:

Daily weekday traffic reaches a peak at about mid-day and increases / decreases before and after this time is spread equally during morning and afternoons. Traffic flows overnight are low.

Figure 4:

Saturday traffic volumes reach a peak at approximately 10h00 – 11h00 and then decreases steadily until about 16h00 after which flows decrease sharply. This is seen as typical Saturday shopping and day leisure traffic flows.

Figure 5:

Sunday traffic volumes reach a maximum at about mid-day and remain high until about 17h00 after which it decreases substantially. This is seen as typical Sunday lunch and visiting traffic flows.

5.1.3 Vehicle Fleet Composition

Apart from the coarse classification data provided by SANRAL, no detailed vehicle fleet composition data is available.. As a result LAQS made some assumptions about the composition so that emissions could be estimated, using the EU polynomials to fit local conditions. These are:

-- 35% of all LMVs are powered by diesel

- 20% of all LMVs are SUVs
- 50% of all SUVs are powered by petrol and 50% by diesel
- There are no differences in emissions between all petrol powered LMVs, regardless of engine size.
- There are no differences in emissions between all diesel powered LMVs, regardless of engine size.
- All heavy motor vehicles are diesel powered and they only exist in one of three categories, i.e. short, medium and long HMVs.
- There are no differences in emissions between all diesel powered HMVs, regardless of vehicle size.
- While emission factors are available for Euro 6 compliance, the current South African vehicle fleet is a mixture of Euro 1 to Euro 4 compliant components. It was assumed, therefore, that an average of the four Euro levels will best describe emission factors for local conditions.

5.1.4 Road Vehicle Emissions

Using all of the information discussed above, the total annual emissions of carbon monoxide (CO), total hydrocarbon compounds (THC), nitrogen dioxide (NOx), total particulate matter (TPM) and carbon dioxide (CO_2) were estimated and the outcome is given below.

	LIGHT MOTOR VEHICLES					HEAVY MOTOR VEHICLES				
POLLUTANT	**CO**	**THC**	**NOx**	**PM**	**CO_2**	**CO**	**THC**	**NOx**	**PM**	**CO_2**
Nature's Valley	23.6	0.9	8.0	0.54	2 563	4.0	0.9	21.5	0.49	2 277
Before Plettenberg Bay	72.8	3.3	29.8	1.84	14 751	11.6	2.5	60.7	1.38	6 432
Goose Valley Plettenberg Bay	10.2	0.4	1.9	0.08	1 485	1.0	0.2	5.0	0.11	532
Between Plett & Knysna	101.4	4.6	41.5	2.56	20 550	14.9	3.2	76.2	1.71	8 058
Before Knysna	19.2	1.2	8.9	0.53	5 126	3.7	0.8	16.7	0.42	1 837
After Knysna (Brenton)	54.5	2.5	22.3	1.38	11 038	6.0	1.3	30.9	0.70	3 270
Before Sedgefield	155.7	5.1	52.2	3.43	22 498	16.2	3.5	83.9	1.96	9 235
Before Wilderness	50.3	2.3	25.9	1.69	10 923	6.4	1.4	33.0	0.77	3 644
Kaaimans Pass	14.0	0.9	6.5	0.39	3 749	2.3	0.5	10.6	0.26	1 165
George after N2/N12 split	32.9	1.1	11.0	0.72	4 752	2.1	0.4	10.4	0.24	1 158
George at Thembalethu	32.6	1.1	10.9	0.72	4 712	2.2	0.4	10.8	0.25	1 212
George York St	187.7	6.2	62.9	4.13	27 118	12.8	2.5	62.2	1.41	6 999
Glentana	98.2	3.2	32.9	2.16	14 191	8.3	1.7	41.4	0.95	4 617
Groot Brak	68.3	2.2	22.9	1.50	9 862	5.9	1.2	29.9	0.69	3 312
Klein Brak	51.5	1.7	17.3	1.13	7 437	4.3	0.9	21.4	0.49	2 398
Hartenbos	104.7	3.4	35.1	2.30	15 124	7.6	1.5	37.2	0.85	4 177
Mossel Bay Die Bakke	64.6	2.1	21.7	1.42	9 331	4.9	1.0	24.7	0.57	2 750

Mossgas	13.2	0.4	4.4	0.29	1 905	3.9	0.9	20.9	0.49	2 282
Albertinia	190.7	6.3	63.9	4.19	27 546	28.1	6.3	149.0	3.52	16 281
Riversdale	158.1	5.2	53.0	3.48	22 849	24.8	5.6	132.2	3.12	14 417
Heidelberg	93.1	3.1	31.2	2.05	13 446	18.0	4.1	96.6	2.29	10 511
George to Oudtshoorn	58.6	1.9	19.7	1.29	8 471	4.3	0.9	21.8	0.50	2 422
Oudtshoorn to De Rust	115.2	5.3	47.2	2.91	23 351	7.2	1.5	36.3	0.82	3 835
Oudtshoorn to Cango	12.4	0.6	5.1	0.31	2 507	0.6	0.1	2.7	0.06	286
Oudtshoorn to Hartenbos	70.8	2.3	23.7	1.56	10 222	6.0	1.2	30.1	0.69	3 351
Oudtshoorn to Ladismith	117.8	3.9	39.5	2.59	17 016	10.4	2.2	52.0	1.20	5 796
Ladismith to Riversdal	33.3	1.1	11.2	0.73	4 818	34.4	7.1	172.0	3.96	19 172
Stilbaai to N2	27.5	1.3	11.3	0.69	5 572	4.1	0.8	20.5	0.46	2 169
Voorbaai	48.9	3.1	22.8	1.35	13 087	4.2	0.8	15.0	0.38	1 708
Heiderand	39.9	2.5	18.6	1.10	10 672	2.5	0.5	9.0	0.23	1 022
Totals per vehicle class	**2 121**	**79.2**	**765.6**	**49.2**	**347 245**	**263**	**56.2**	**1 335**	**31.0**	**146 324**
Totals per pollutant	**2 384**	**135.4**	**2 100**	**80.2**	**493 569**					

Table 15: Estimated Motor Vehicle Emissions, tons per annum

In addition to these emissions, it is estimated that a total of 16.8 tons per annum of methane gas is emitted from motor vehicles.

5.2 AIRCRAFT EMISSIONS

Modern commercial aircraft generally make use of turbine engines either to directly propel the aircraft or to drive one or more propellers which, in turn, propel the aircraft. Turbine engines use the same fuel, regardless of the manufacturer or size of the engine.

Aircraft emissions affect the ambient air when they occur below approximately 200 metres above ground level. Within this height limitation emissions occur during engine idling, aircraft taxi operations, take-off and landing manoeuvres.

The International Civil Aviation Organisation (ICAO) compiled a comprehensive list of emissions for many different aircraft engine types fitted to most commercial aircraft. The latest aircraft emissions databank was published in 2015 and covers all of the engine types used in commercial aircraft in South Africa. The information is, therefore, regarded as reliable and representative.

The ICAO databank provides emission factors for the emissions of total hydrocarbons, carbon monoxide and nitrogen oxides during the four operations given below as a single landing and take-off cycle value (LTO):

-- Approach, i.e. descent on short final landing procedure

-- Taxi and idle, i.e. engine running with minimum of power

-- Take off, i.e. engine at full power

-- Climb out, i.e. first 200 metres of ascent

Emission factors for most commercial aircraft that visit George airport are included, notably the following:

--	Boeing 737-200 (732):	208 flights per annum
--	Boeing 737-400 (734):	416 flights per annum
--	Boeing 737-800 (738):	1 352 flights per annum
--	Embraer E135 (ERJ):	1 352 flights per annum
--	Avroliner AR8 (AR8):	468 flights per annum

This implies a total of 73 flights per week or 3 796 flights per year to George airport and each one of these flights goes through the phases which have an impact on air quality near the airport. These phases are:

-- Approach to the airport and landing

-- Taxi to and from the terminal building and engine idle conditions

--	Take-off on the runway

--	Climb-out after take-off

Emission factors for total hydrocarbons (THC), carbon monoxide (CO) and nitrogen oxides (NOx) for each type of aircraft list above were extracted from the ICAO's 2015 databank.

Using the number of flights per type of aircraft and ICAO's emission factors, the following emissions were calculated:

Pollutant	Aircraft Type				
	732	**734**	**738**	**ERJ**	**AR8**
NOx	1.22	1.61	9.06	2.18	1.12
CO	0.26	1.04	1.96	1.51	0.94
THC	0.04	0.07	0.21	0.12	0.11

Table 17: Aircraft Emission, tons per annum

The total annual emissions from commercial aircraft at George Airport can be expected to be:

Nitrogen oxides: 10.6 tpa

Carbon monoxide: 8.9 tpa

Total hydrocarbons: 0.9 tpa

Compared to other sources in the area, the aircraft emissions are very low, but will increase or decrease in direct proportion to changes in air traffic volumes at George Airport. It must be borne in mind that the emission figure calculated above relate only to commercial passenger aircraft as no details private aircraft traffic and commercial freight aircraft traffic is known.

5.2.1 Discussion of Aircraft Emissions

The estimated emissions from commercial aircraft making use of George's airport are substantially lower than those reported in the 2012/13 emissions inventory. This is due to the following reasons:

--	The 2012/13 emissions were based on emission factors revised by the International Civil Aviation Organisation (ICAO) during 2011. These emission factors were revised by ICAO during 2015, resulting in lower emission factors for most of the aircraft listed above. Except for the Boeing 737-200 aircraft (732 in the Tables), all of the aircraft listed are or a more modern design with more efficient engines.

-- In the 2012/13 emissions inventory LAQS made use of mass emission factors for the complete landing and take-off (LTO) cycle as published by IACO in 2011. The 2015 revision of ICAO's emissions provide useful information of the duration of each manoeuvre included in the LTO cycle. These manoeuvres and durations are:

- Approach: 4 mins; approaching the airport to land
- Take-off: 0.7 mins; accelerating down the runway
- Climb-out: 2.2 mins; after wheels are up
- Idle (taxi): 26 mins: taxi to and from the terminal building before take-off and after landing

Except for the duration of take-off, these approach and climb-out durations result in higher emissions than those are useful for dispersion modelling purposes where emission below 200 m above ground-level impact on air quality.

Discussions with various commercial airline pilots making use of George's airport resulted in LAQS shortening the ICAO manoeuvre durations to the following:

- Approach: 1 mins; altitude lower than 200 m
- Take-off: 0.7 mins
- Climb-out: 0.5 mins; rate of ascent varies between 500 and 800 m/minute
- Idle (taxi): 7 mins; average taxi duration for George airport

5.3 SHIPS

As is the case with road traffic, relevant details of sea traffic making use of a harbour is required in order to estimate emissions from sea traffic. The following details are required:

-- Sea vessel count
-- Duration of harbour activity
-- Sea vessel classification
-- Emission factors

5.3.1 Sea Traffic Count

Detailed harbour traffic information for 2018 was provided by the Port of Mossel Bay. Of the details included the following relevant information of each ship was extracted:

-- Name
-- Date and time of arrival
-- Date and time of departure

-- Date and duration of tug manoeuvres
-- Gross tonnage
-- Length overall

5.3.2 Duration of harbour traffic activity

The information allowed calculation of the following:

-- Average duration of manoeuvring a ship into the harbour to the quay or anchorage
-- Average duration of manoeuvring the ship away from the quay and out of the harbour
-- Time spent at the quay

The ship traffic was subsequently sorted by type and tonnage.

Three emission scenarios exist where harbour traffic is involved, i.e. entering and leaving the harbour under own steam, manoeuvring to and away from the quay and time spent at the quay. Different ship main and auxiliary engine usage apply during these scenarios and, therefore, different emission rates occur.

Of these operating cycles, no details of the duration of a ship's entering and departure operations under own steam was given and an average duration of 1 hour for both steps was assumed.

5.3.3 Emission Factors

The European Union (EU) compiled a set of emission factors for various ship sizes and engine usage during these operating scenarios. Opsis in Sweden summarised these operating conditions and emission factors and the following grouping of ships resulted inter alia:

-- Passenger ships:

   < 1 000 tons, 1 000 – 10 000 tons, 10 000 – 25 000 tons and 25 000 – 50 000 tons

-- Oil tanker:

   < 1 000 tons, 1 000 – 3 000 tons, 3 000 – 5 000 tons, 5 000 – 10 000 tons, 10 000 – 25 000 tons, 25 000 – 50 000 tons, 50 000 – 75 000 tons and > 75 000 tons

-- Bulk cargo ship:

   < 1 000 tons, 1 000 – 3 000 tons, 3 000 – 5 000 tons, 5 000 – 10 000 tons, 10 000 – 25 000 tons, 25 000 – 50 000 tons, 50 000 – 75 000 tons and > 75 000 tons

-- Container ship:

< 1 000 tons, 1 000 – 3 000 tons, 3 000 – 5 000 tons, 5 000 – 10 000 tons, 10 000 – 25 000 tons, 25 000 – 50 000 tons, 50 000 – 75 000 tons and > 75 000 tons

-- "Other" ships:

< 1 000 tons, 1 000 – 3 000 tons, 3 000 – 5 000 tons, 5 000 – 10 000 tons, 10 000 – 25 000 tons and 25 000 – 50 000 tons

-- Tugs:

< 500 tons, 500 – 1000 tons and 5 000 – 10 000 tons

For each of these groups typical main and auxiliary engine power ratings in kilowatt are given as well as the percentage of power used on each engine during each of the three operating scenarios mentioned above. This information, together with the duration of each phase of harbour traffic, allowed the calculation to total power used by each ship and the tugs that participated in each ship's movements in kilowatt-hours.

Emission factors for NOx, SO_2, CO_2, total hydrocarbons (THC) and total particulate matter (TPM) are provided for each harbour operating cycle as a function of the total power used. The units are, therefore, grams per kilowatt-hour.

Ship traffic data provided by Mossel Bay harbour was classified into the following groups:

Vessel type	**Number**	**Percentage of total**
Passenger	5	2.0
Tanker, 10 000 – 25 000 tons	39	15.4
Tanker, 25 000 – 50 000 tons	30	11.8
Tug / Supply, < 500 tons	1	0.4
Tug / Supply, 1 000 – 3 000 tons	37	14.6
Tug / Supply, 3 000 – 5 000 tons	74	29.1
Trawler, < 1 000 tons	50	19.7
Trawler, 1 000 – 3 000 tons	18	7.1
Total	**254**	

Table 18: 2018 Shipping Traffic in Mossel Bay Harbour

For dispersion modelling purposes additional information about each type of ship is required, e.g. height of the upper deck above waterline, height of chimney above the upper deck, distance of chimney to aft of the ship, etc., and these details were obtained from the internet.

5.3.4 Emissions

As a result of the information received from the Mossel Bay Harbour and the emission factor data provided by Opsis it was possible to estimate the mass emissions of the various pollutants for each ship during its visit to the harbour. The following total emissions were estimated:

-- TPM: 24.5 tpa

-- SO_2: 145.1 tpa

-- NOx: 176.1 tpa

-- CO: 12.7 tpa

-- CO_2: 8 597 tpa

-- THC: 49.1 tpa

5.3.5 Discussion of Harbour Emissions

The estimated emissions of harbour traffic are substantially lower than those reported in the 2012/13 emissions inventory. This is due to the following two factors:

-- A calculation error was made during the 2012/13 emissions inventory as the percentage of main and auxiliary engine power during each manoeuvre was not taken into account.

-- In the dispersion modelling exercise in 2012/13, it was assumed that all ship traffic make use of Mossel Bay harbour.

That is not the case as passenger ship and tankers anchor off-shore. The passenger ships transport their passenger to quayside by motor launches while tanker anchor at the off-shore fuel transfer point. The use of off-shore anchorage substantially shortens the duration of manoeuvring to and from the anchor point, as well as approach and departure from the anchor point. Furthermore, the time spent an anchor was significantly lower than the time spent at quayside by the vessels making use of the harbour itself.

However, these ships are much larger than those making use of the harbour itself and together account for approximately 83% of all sea vessel emissions.

-- All other vessels, i.e. tug/supply vessels and trawlers, made use direct of the harbour itself.

5.3 TOTAL MOBILE EMISSIONS

Total mobile emissions in tons per annum within GRDM are:

Source	TPM	SO_2	NOx	CO	CO_2	THC
Roads	80.2		2 100	2 384	493 569	135.4
Air			10.6	8.9		0.9
Sea	24.5	145.1	176.1	12.7	8 597	49.1
Total	**104.7**	**145.1**	**2 287**	**2 406**	**502 166**	**185.4**

Table 19: Total Annual Mobile Source Emissions, tons

6 OTHER SOURCES

Emission sources that cannot be grouped into any of the types listed above mainly relate to the burning of a variety of waste material in open fires and uncontrolled activities. Included in these sources are:

-- Municipal solid waste disposal

-- Wastewater treatment plants

-- Burning activities

-- Animals

These sources are dealt with individually below.

6.1 MUNICIPAL SOLID WASTE DISPOSAL

It is well known that municipal solid waste (MSW) disposal sites, or "tip sites" as it is generally referred to, are sources of significant emissions, the most prominent being methane (CH_4) and carbon dioxide, both of which are known greenhouse gases. However, emissions of CO and odorous gases in the form of H_2S are also emitted.

The USEPA suggests an extensive method for estimating the emissions from MSW sites based on the age of the site, its expected life span and the annual mass of solid waste disposed of at the site. To assist in estimating emissions from landfill operations, the USEPA developed LandGEM, the Landfill Gas Emissions Model, the latest version being 3.02.

LAQS used this model to estimate the emissions of CH_4, CO_2, CO and H2S from the active landfill sites in the GRDM region.

A number of MSW disposal sites are, or have until recently been, in operation in the Garden Route district. Details of the sites and their status were provided obtained from the Integrated Waste Management Plan (IWMP) for the Garden Route District Municipality that was compiled in 2015. From this plan the following information was obtained:

George: One site is in operation, or has been until recently. Once closed, all MSW will be disposed of in the large MSW disposal site under development in Mossel Bay. One site is in operation in Uniondale, an area administered by George Municipality

Mossel Bay: A large, regional landfill site is in operation and is located at the Mossdustria industrial area.

Hessequa: One landfill site is in operation in Riversdale

Kannaland: Two landfill sites are in operation

Oudtshoorn: One landfill site is in operation

In addition, the IWMP provided details of the annual tonnage of MSW disposed of in each site.

The number of active landfill sites is substantially lower then reported in the 2012/13 emissions inventory. This is solely due to the regional landfill sites located in Mossdustria which now accepts MSW collected in Bitou, Knysna, George, Mossel Bay and the smaller landfill sites in Hessequa.

The information provided in the IWMP served as input data for the calculations. Where insufficient information was provided, e.g. the age of a site, its expected life span, etc. some assumptions were made in order to obtain emissions information.

However, cessation of the use of a site does not mean that emissions cease accordingly as decomposition of disposed waste products continue unabated, albeit at a reduced rate.

Based on the information obtained from the IWMP and the USEPA's methodology, the following emissions in tons per annum were estimated from MSW disposal sites in each municipality:

Municipality	**CO**	**CO_2**	**H_2S**	**CH_4**
Bitou	--	--	--	--
Knysna	--	--	--	--
George	1.0	5 728	0.3	2 088
Mossel Bay	1.0	5 770	0.3	2 103

Hessequa	0.2	1 306	0.1	476.1
Kannaland	0.1	581	0.03	211.8
Oudtshoorn	0.4	2 123	0.1	773.7
TOTAL, tpa	**2.7**	**15 508**	**0.8**	**5 653**

Table 20: Emissions From MSW Disposal Sites, tons per annum

6.2 WASTEWATER TREATMENT WORKS

It is assumed that each of the municipalities in the Garden Route district operates wastewater treatment works (WWTW). Such operations emit various organic compounds in addition to odorous emissions in the form of mercaptans and hydrogen sulphide, the mass of which is directly dependent on the quantity of waste material processed in each installation.

At the time of compiling this report no information about the quantity of waste materials processed in the WWTWs of Bitou, Knysna, Kannaland or Oudtshoorn could be obtained. As a result the information about total odorous emissions from WWTWs in the region is incomplete.

George, Mossel Bay and Hessequa provided sufficient details about the WWTWs in their respective areas and these are listed below together with the estimated annual emissions of total hydrocarbons (THC) and hydrogen sulphide (H_2S in each municipal area (tons per annum).

Municipality	**WWTWs**	**THC**	**H_2S**
George	Haarlem, Herold's Bay, Uniondale, Kleinkrantz, Outeniqua, Gwaing	8.2	7.7
Mossel Bay	Pinnacle Point, Ruitersbos, Grootbrak, Friemersheim, Regional, Brandwag, Herbertsdale	4.6	4.4
Hessequa	Stilbaai, Heidelberg, Riversdale, Albertinia, Melkhoutsfontein, Jongensfontein, Witsand, Slangrivier, Goirtitsmond, Garcia	2.5	2.3
Total annual emissions		**15.3**	**14.4**

Table 21: Annual THC and H2S Emissions, tons

6.3 BURNING OF VEGETATION

-- Burning of vegetation removed from a large area destined for development

-- Burning of waste products

6.3.1 Burning of Vegetation

It is apparently common practice for developers to clear vegetation from an area for development and then subsequently burning the vegetation on site. Currently approval for these operations is only sought from the local fire departments.

According to AP-42 the emissions emanating from the burning of vegetation is a function of the type of species being burned and the mass of material that is destroyed in this manner. Typical emission factors (kg/ton vegetation) are as follows:

-- Burning of unspecified wood types:

Particulates:	19 kg/ton
Carbon monoxide:	56 kg/ton
Methane:	6 kg/ton
Non-methane hydrocarbons:	14 kg/ton

-- Burning of unspecified weeds:

Particulates:	8 kg/ton
Carbon monoxide:	42 kg/ton
Methane:	1.5 kg/ton
Non-methane hydrocarbons:	4.5 kg/ton

According to AP-42 CO_2 emitted from these sources are generally not counted as greenhouse gas emissions because it is considered part of the short-term CO_2 cycle of the biosphere. However, it can be expected that approximately 1 550 kg/ton of CO_2 are emitted during the open burning of vegetation.

In addition to these “traditional” pollutants, many other organic compounds may be released to atmosphere, depending on the combustion efficiency achieved in the burning process. The table below gives some emission factors in kg/ton of vegetation burned.

Compounds	Emission factor
Ethane	0.7
Ethylene	2
Acetylene	1.124
Propane	0.358
Propene	1.244
i-Butane	0.028
n-Butane	0.056
Butene	1.192
Pentene	0.616
Benzene	1.938
Toluene	0.730
Furan	0.342
Methyl Ethyl Ketone	0.290
2-Methyl Furan	0.656
2,5-Dimethyl Furan	0.162
Furfural	0.486
o-Xylene	0.202

Table 22: Product of Combustion of Vegetation

6.3.2 Burning of Waste Products

The types and quantities of pollutants emitted during the uncontrolled burning of waste products are a direct function of the types and masses of wastes burned.

Emissions can consist of heavy metals (aluminium, antimony, arsenic, barium, calcium, chromium, copper, iron, lead, magnesium, nickel, selenium, silicon, sodium, titanium, vanadium and zinc), and a wide variety of organic compounds, some of which are regarded as carcinogenic, e.g. benzene, toluene, xylene, etc.

Without knowledge of the actual waste being burned, it is not possible to estimate the actual emissions from the operation.

6.4 FARM ANIMALS

During the investigations into greenhouse gas (GHG) emissions and climate change it became clear that all animals contribute to GHG emissions, notably methane gas (CH_4).

The United Kingdom's Department of Environment, Food and Rural Affairs (DEFRA) compiled the following set of methane emission factors associated with a range of farm animals:

Animal type	**Total CH_4 kg/head/year**
Dairy Breeding Herd	128.0
Beef Herd	50.74
Cattle: Others	54
Pigs	4.5
Breeding Sheep	8.19
Other Sheep	8.19
Lambs < 1year	3.276
Goats	5.12
Horses	19.4
Deer (stags & hinds)	10.66
Deer (calves)	5.33
Poultry	0.078

Table 23: DEFRA Farm Animal Emission Factors

During a survey of the number of farm animals in the Western Cape by the Provincial authorities, the following totals emerged for the Garden Route district:

Animal counts	**Bitou**	**Knysna**	**George**	**Mossel**	**Hessequa**	**Kannaland**	**Oudtshoorn**
Cattle	2 850		26 580	23 300	39 080	7 010	8 570
Pigs	245		8 410	680	900	840	715

Sheep	590		35 935	47 400	196 660	14 000	23 635
Goats	720		19 990	2 745	910	9 635	21 440
Horses	11		450	607	500	220	130
Poultry			33 920	9 095	31 750	25 310	84 920

Table 24: Farm Animal Counts

The methane emissions calculated from the emission factors and animal count data resulted in a total of 10 897 tons per annum.

7 SUMMARY OF EMISSIONS

The total emissions, rounded to the nearest whole number, estimated across the GRDM region are as follows:

Total particulate matter:	1 057 tpa
Sulphur dioxide (SO_2):	837 tpa
Nitrogen oxides (NOx):	4 288 tpa
Carbon monoxide (CO):	4 784 tpa
Carbon dioxide (CO_2):	1 589 847 tpa
Total hydrocarbons (THC):	3 378 tpa
Methane (CH_4):	22 219 tpa
Odorous compounds:	51.0 tpa

Based on the estimated annual CO_2 and CH_4 emissions, the carbon dioxide equivalent (CO_2e) emissions for greenhouse gases are estimated to be 2 100 884 tons during 2018. This value is calculated from the direct CO_2 emissions and 23 times the CH_4 emissions.

8 CONCLUSION

As can be deduced from the various sections above, a large number of emissions sources exist in the Garden Route municipal district. While attempts have been made to compile as complete a list of sources and emissions as possible, it must be borne in mind that an accurate and representative list of emissions cannot be compiled at this stage as there simply is not enough data available.

It is highly recommended, therefore, that a concerted effort is undertaken to obtain reliable emissions data for the region.

9 FOREST FIRES

The Garden route area was rocked by two massive fire incidents in 2017 and 2018.

Commonly known as the "Knysna fire", it destroyed a huge area and numerous residential properties in 2017. The "Outeniqua fire" essentially destroyed huge areas of vegetation, but its impact on residential areas was less pronounced. In both cases adverse weather conditions, e.g. high wind speeds, hampered all fire-fighting activities.

The vegetation that was destroyed during these two incidents was estimated to be:

Vegetation	Area, hectares	
	2017	2018
Indigenous	1 778	2 260
Plantation	7 327	16 255
Fynbos	20 822	59 969
Agriculture	788	99

Table 25: Vegetation Areas Destroyed by Wild Fires, hectares

Estimating the air pollutant emissions during such incidents is a complex task and subject to substantial uncertainty. The following factors influence the emissions estimation process:

-- The species of vegetation burnt

-- The moisture content of the plant species

-- The age of the plant species

-- The mass of consumable fuel per unit area, e.g. ton/hectare

The completeness of combustion that is achieved in a wild fire is dependent on the heat flux, or temperature gradient as the fire spreads. This, in turn, is influenced by the size and quantity of wild land fuels, meteorological conditions, and topographic features. As a result it is quite likely that complete combustion occurs in one area of a wild fire while incomplete combustion occurs in another. All of these factors, and several more, contribute to the uncertainty in estimating emissions from wild fires.

Nevertheless, LAQS attempted to give some indication of emissions that could potentially have occurred during the 2017 and 2018 wild fire incidents.

AP-42 provides some emission factors for wild fires, but these are based on vegetation types that occur commonly in those areas of the USA where wild fires are prominent.

In addition to these factors, empirical vegetation densities of five plant species are given.

Rather than using AP-42's vegetation densities, LAQS consulted the timber industry in the affected areas specialists to obtain relevant values for the GRDM region. Where information was lacking, AP-42 values were used as base for estimating values that are applicable to the GRDM region. It must again be pointed out that this process is subject to substantial uncertainties.

The following vegetation densities and emission factors were used:

Vegetation	**Vegetation density, tons / hectare**			
Indigenous	40			
Plantation	80			
Fynbos	14			
Agriculture	10			
Pollutant	**Emission factor, kg/ton**			
	Indigenous	**Plantation**	**Shrubs**	**Agriculture**
TPM	18	20	23	23
NOx	2	2	2	2
CO	112	126	103	103
THC	6.4	4.2	6.9	6.9
CH4	6.1	5.7	6.2	6.2

Table 26: Vegetation densities and emission factors

From the data listed above, LAQS calculated the following emissions during the two wild fire incidents:

	Emissions, tons		Total
Pollutant	**Knysna fire**	**Outeniqua fire**	
TPM	19 889	46 968	**66 857**
NOx	1 913	4 463	**6 376**
CO	112 659	260 552	**373 211**
THC	4 983	11 840	**16 823**
CH_4	5 631	13 175	**18 806**

Table 27: Estimated Wild Fire Emissions, tons

Comparing these estimated values with the total 2018 GRDM emissions inventory reported in Section 7 above shows that the single Outeniqua wildfire incident emitted the following:

TPM: Approximately 44 times more than all of the identified sources

NOx: Approximately the same quantity as all of the identified sources

CO: Approximately 54 times more than all of the identified sources

THC: Approximately 3.5 times more than all of the identified sources

CH4: Approximately 60% of all of the identified sources