Project done on behalf of
Zitholele Consulting (Pty) Ltd

QUALITATIVE AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED EXTENSION OF THE EXISTING GENERAL WASTE DISPOSAL SITE AT THE TUTUKA POWER STATION

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REPORT DETAILS

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GLOSSARY AND ABBREVIATIONS

AEL	Atmospheric Emission License
APPA	Air Pollution Prevention Act
AQA	Air Quality Act
BMD	Benchmark Dose
BPM	Best Practicable Means
C_6H_6	Benzene
California OEHHA	California Office of Environmental Health Hazard Assessment
CAPCO	Chief Air Pollution Control Officer
CO	Carbon Monoxide
DEA	Department of Environmental Affairs
DME	Department of Minerals and Energy
EC	European Community
ESLs	Effects Screening Levels
g	gram
h	hour
H_2S	Hydrogen Sulphide
GWDS	General Waste Disposal Site
IP&WM	Integrated Pollution and Waste Management
LFG	Landfill Gas
LOAEL	Lowest Observed Adverse Effect Level
m	meter
MEI	Maximally Exposed Individual
MRL	Maximum Risk Levels
NEMA	National Environmental Management Act
NO_2	Nitrogen Dioxide
NOAEL	No Observed Adverse Effect Level
NPi	National Pollutant Inventory
NWS	New South Wales
OU	Odour Unit
pb	Lead

PBPK	Physiologically Based Pharmokinetic
PM10	Particulate Matter with an aerodynamic diameter of less than 10 μm
RELs	Reference Exposure Levels
RfC	Inhalation Reference Concentrations
SA	South Africa
SABS	South African Bureau of Standards
SANS	South African National Standards
SAWS	South African Weather Service
SGG	Sub-surface Gas
SO_2	Sulphur Dioxide
TARA	Toxicology and Risk Assessment Division of the Texas Natural Resource Conservation Commissions
TOC	Threshold Odour Concentration
tpm	Tonnes per month
tpd	Tonnes per day
TSP	Total Suspended Particulate
UF	Uncertainty Factor
URFs	Unit Risk Factors
US ATSDR	United States Federal Agency for Toxic Substances and Disease Registry
US EPA	United States Environmental Protection Agency
US EPA IRIS	United States Integrated Risk Information System
US FDA	United States Food and Drug Agency
VFA	Volatile Fatty Acids
WHO	World Health Organisation

EXECUTIVE SUMMARY

INTRODUCTION

Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by Zitholele Consulting (Pty) Ltd (hereafter referred to as Zitholele) to undertake a qualitative air quality impact assessment for a proposed extension of the existing General Waste Disposal Site (GWDS) at the Tutuka Power Station (hereafter referred to as proposed Tutuka GWDS).

Eskom currently operates an authorised general waste disposal site within the Tutuka Power Station premises near Standerton. General waste, including garden waste and building rubble, from Tutuka Power Station, New Denmark Colliery, Thuthukani Township, selected contractors and neighbouring farmers is currently disposed of at the site. The site has reached its capacity and waste has since October 2008 been transported to Kriel 200 km from the current site. It is proposed that the current site be extended to accommodate waste disposal for an additional 50 years.

The main purpose of the study was to determine potential health and nuisance impacts as a result of proposed operations at the proposed Tutuka GWDS and establish appropriate buffer and management zones for the facility.

TERMS OF REFERENCE

The terms of reference for the qualitative assessment of the proposed operations at the expanded Tutuka GWDS is as follows:

- Description of the regional climate and site-specific atmospheric conditions impacting on the dispersion potential of the waste site;
- Overview of the legislation and regulatory context as it pertains to the regulation of atmospheric emissions and air pollutant concentrations;
- Analysis of the baseline air quality, based on any available observational data which may be of relevance to the study site;
- Review types of emissions from landfill sites (construction and operational);
- Identification of potentially sensitive receptors in the vicinity of the proposed extension susceptible to air quality impacts (health and odour impacts);

- Indication of expected impact area based on health buffer and odour management zones recommended locally and internationally taking into consideration local meteorology and operational procedures.

IMPACT ASSESSMENT MAIN FINDINGS

A qualitative air quality impact assessment has been undertaken for the proposed Tutuka GWDS aimed at assessing associated impacts with the proposed operations and to determine delineated buffer and management zones. The main findings can be summarised as follows:

- **Dispersion potential of the site:** The dispersion potential for the site was determined by assessing meteorological data from the closest SAWS station of Standerton. The dominant wind direction at Standerton for the period 2006 – 2008 was from the east (~14% frequency of occurrence) and from the west (~10% frequency of occurrence). Day-time conditions were characterised by an increase in westerly winds (~15% frequency of occurrence) with night-time conditions reflecting an increase in easterly winds and high calm conditions (33.7%).

- **Atmospheric stability:** A high frequency of very stable conditions occurs from the east with a high frequency of unstable conditions from the west. For ground level, or near ground-level releases, the highest ground level concentrations would occur during weak wind speeds and stable (night-time) atmospheric conditions.

- **Ambient air quality in the vicinity of the site:** Sources that may contribute to the ambient air quality within the vicinity of the proposed Tutuka GWDS include industrial activities (i.e. Tutuka Power Station), mining operations, vehicle emissions, domestic fuel burning, farming activities, and biomass burning.

- **Buffer and management zone delineation:** In terms of air quality the recommended separation distance for landfill sites as provided by the Australia EPA is given as 500 m from residential developments for odour, dust and gas migration problems. The proposed Tutuka GWDS meets the recommended separation distances of 500 m from residential developments (with the Thuthukani Township ~1.5km to the west-southwest). Based on health impacts from previous quantitative studies for General Waste Disposal Sites the maximum impact distance was ~200m

– 300m. Based on odour impacts from previous quantitative studies undertaken for General Waste Disposal Sites, the impact distance (assuming the odour criteria of $2OU/m^3$ for residential areas of greater than 2000 residents) ranges from ~1250 m – 1720 m.

SIGNIFICANCE RATING

The impact assessment for the proposed Tutuka GWDS addressed emissions from the operational phase of the landfill. Emissions associated with the operational phase of the landfill include the following:

- Fugitive dust emissions from vehicle entrainment; and
- Landfill gas emissions

Possible air quality impacts associated with these emissions were:

- Health risks associated with predicted inhalable particulate and landfill gas concentrations;
- Cancer risks associated with predicted landfill gas concentrations;
- Odour impacts associated with predicted landfill gas concentrations; and
- Nuisance impacts as a result of predicted dustfall levels.

Table 1: Impact significance rating of the operational phase at the proposed Tutuka GWDS

Impact	Duration [a]	Spatial Scale[b]	Probability [c]	Magnitude [d]	Significance Points (SP)	Significance [e]
PM10	Long-term (4)	Localised (2)	Medium probability (3)	Low (4)	30	MODERATE
Dustfall	Long-term (4)	Localised (2)	Medium probability (3)	Low (4)	30	MODERATE
Health Risk	Long-term (4)	Localised (2)	Medium probability (3)	Low (4)	30	MODERATE
Cancer Risk	Long-term (4)	Localised (2)	Medium probability (3)	Low (4)	30	MODERATE

Impact	Duration [a]	Spatial Scale[b]	Probability [c]	Magnitude [d]	Significance Points (SP)	Significance [e]
Odour	Long-term (4)	Localised (2)	Medium probability (3)	Low (4)	30	MODERATE

NOTES:

(a) The impacts are given as long-term as the particulate and gaseous emissions from the landfill will continue during the entire operation of the proposed Tutuka GWDS.

(b) Localised particulate and gaseous impacts (from a few hectares in extent) are expected due to the operational phase.

(c) The probability is given as medium as exceedances of the particulate ambient standards as well as health criteria for non-carcinogenic pollutants and carcinogenic pollutants as well as odour impacts may occur off-site due to the operational phase.

(d) As the impacts are expected to be in the vicinity of the proposed site (<1 km), the magnitude is given as low.

(e) Impacts are rated as MODERATE.

RECOMMENDATIONS

- It is recommended that the proposed Tutuka GWDS be operated according to the Minimum Requirements for Waste Disposal by Landfill (Second Edition 1998).

- As the Minimum Requirements currently do not provide recommended buffer zone distances for landfill sites it is recommended that a buffer zone (delineation exclusively on the basis of health impact zones) be a minimum distance of 500 m from the proposed Tutuka GWDS as stipulated by the Australia EPA. Based on odour impacts from previous quantitative studies undertaken for General Waste Disposal Sites, it is recommended that the management zone (delineation based on nuisance issues, i.e. odour impacts and dust fallout) be a distance of ~1500m from the proposed Tutuka GWDS. It should be noted, however, that these recommended buffer and management zone delineations are based on previous studies undertaken. In order to more accurately understand the delineated zones required for the proposed Tutuka GWDS, a quantitative assessment should be undertaken.

- Ambient PM10 concentrations and dust fallout measurements should be undertaken in the vicinity of the proposed Tutuka GWDS prior to its operation in order to establish background ambient air quality. Once the proposed Tutuka GWDS is in operation, the ambient measurements will provide an indication of impacts due to the General Waste Disposal Site.

- The proposed Tutuka GWDS operator should control on-site fugitive dust emissions by effective management and mitigation due to the potential cumulative impacts of this pollutant in the study area.

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QUALITATIVE AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED EXTENSION OF THE EXISTING GENERAL WASTE DISPOSAL SITE AT THE TUTUKA POWER STATION

1. INTRODUCTION

Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by Zitholele Consulting (Pty) Ltd (hereafter referred to as Zitholele) to undertake an air quality impact assessment for a proposed extension of the existing General Waste Disposal Site (GWDS) at the Tutuka Power Station (hereafter referred to as proposed Tutuka GWDS) (Figure 1-1).

Figure 1-1: Location of the proposed General Waste Disposal Site

Eskom currently operates an authorised general waste disposal site within the Tutuka Power Station premises near Standerton. General waste, including garden waste and building rubble, from Tutuka Power Station, New Denmark Colliery, Thuthukani Township, selected contractors and neighbouring farmers is currently disposed of at the site. The site has reached its capacity and waste has since October 2008 been transported to Kriel 200 km from the current site. It is proposed that the current site be extended to accommodate waste disposal for an additional 50 years.

The main purpose of the study is to determine potential health and nuisance impacts as a result of operations at the proposed Tutuka GWDS and establish appropriate buffer and management zones for the facility.

1.1 Terms of Reference

The terms of reference for the qualitative assessment of the proposed operations at the expanded Tutuka GWDS is as follows:

- Description of the regional climate and site-specific atmospheric conditions impacting on the dispersion potential of the waste site;
- Overview of the legislation and regulatory context as it pertains to the regulation of atmospheric emissions and air pollutant concentrations;
- Analysis of the baseline air quality, based on any available observational data which may be of relevance to the study site;
- Review types of emissions from landfill sites (construction and operational);
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- Indication of expected impact area based on health buffer and odour management zones recommended locally and internationally taking into consideration local meteorology and operational procedures.

1.2 Study Approach and Methods

Meteorological mechanisms govern the dispersion, transformation, and eventual removal of pollutants from the atmosphere. An analysis of the ventilation potential of prevailing synoptic systems, and of the nature and frequency of occurrence of weather perturbations, provides for an effective characterization of the macro-scale dispersion potential. Diurnal variations in dispersion potentials associated with meso-scale ventilation processes are most successfully evaluated on the basis of hourly average observations and estimations.

A weather station is located at Standerton, approximately18 km to the south-west of the site measuring hourly average meteorological data, including wind speed, wind direction and temperature. Wind speed and solar radiation are used to calculate hourly stability classes.

Existing sources of emission will be identified as part of the desktop study and available ambient monitored data will be evaluated. In addition, topographical data will be extracted and included for discussion.

A comprehensive and current legislative and regulatory review will be undertaken for inclusion in the desktop study. The air quality data will be analysed and compared to both local and international guidelines and standards.

Types of emissions expected to result from a general waste site will be identified and reviewed based on available emissions data from similar disposal sites.

Buffer and odour management zones will be recommended based on local meteorology and operational procedures as well as local and international guidance on impact zones around landfill sites.

1.3 Outline of Report

Legal requirement and human health criteria applicable to the proposed Tutuka GWDS are presented in Section 2. The study area, synoptic climatology and atmospheric dispersion potential of the area and the existing air quality are discussed in Section 3. A qualitative impact assessment is documented in Section 4. The buffer zone delineation is provided in Section 5 and significance rating is given in Section 6. Recommendations and conclusions are presented in Section 7.

2. ASSESSMENT CRITERIA AND REGULATORY REVIEW

Prior to assessing the impact of the proposed Tutuka GWDS, reference needs to be made to the environmental regulations and guidelines governing the impact of such operations.

2.1 National Environmental Management: Waste Act, 2008

The Waste Bill was passed by the National Assembly in October 2008 and was sent to the President for ascension. The Act was assented to 6 March 2009 with the objectives of the act being:

a. to protect health, well-being and the environment by providing reasonable measures for:
    i. minimising the consumption of natural resources;
    ii. avoiding and minimising the generation of waste;
    iii. reducing, re-using, recycling and recovering waste;
    iv. treating and safely disposing of waste as a last resort;
    v. reventing pollution and ecological degradation;
    vi. securing ecologically sustainable development while promoting justifyable economic and social development;
    vii. promoting and ensuring the effective delivery of waste services;
    viii. remediating land where contamination presents, or may present, a significant risk of harm to health or the environment; and
    ix. achieving integrated waste management reporting and planning;
b. to ensure that people are aware of the impact of waste on their health, well-being and the environment;
c. to provide for compliance with the measures set out in paragraph (a); and
d. generally, to give effect to section 24 of the Constitution in order to secure an environment that is not harmful to health and well-being.

The general duty in respect of waste management is provided in Chapter 4, Part 2 of the Act and states that:

1) a holder of waste must, within the holder's power take all reasonable measures to:
    a) avoid the generation of waste and where such generation cannot be avoided, to minimise the toxicity and amounts of waste that are generated;
    b) reduce, re-use, recycle and recover waste;
    c) where waste must be disposed of, ensure that the waste is treated and disposed of in an environmentally sound manner;

d) manage the waste in such a manner that it does not endanger health or the environment or cause a nuisance through noise, odour or visual impacts;
e) prevent any employee or any person under his or her supervision from contravening this Act; and
f) prevent the waste from being used for an unauthorised purpose.

2) Any person who sells a product that may be used by the public and that is likely to result in the generation of hazardous waste must take reasonable steps to inform the public of the impact of that waste on health and the environment.
3) The measures contemplated in this section may include measures to—
   a) investigate, assess and evaluate the impact of the waste in question on health or the environment;
   b) cease, modify or control any act or process causing the pollution, environmental degradation or harm to health;
   c) comply with any norm or standard or prescribed management practice;
   d) eliminate any source of pollution or environmental degradation; and
   e) remedy the effects of the pollution or environmental degradation.
4) The Minister or MEC may issue regulations to provide guidance on how to discharge this duty or identify specific requirements that must be given effect to, after following a consultative process in accordance with sections 72 and 73.
5) Subsection (4) need not be complied with if the regulation is amended in a non-substantive manner.

2.2 Minimum Requirements for Waste Disposal by Landfill, Second Edition, 1998

The proposed project must comply with the Minimum Requirements for Waste Disposal by Landfill (Second Edition 1998). The objectives of the Minimum Requirements for Waste Disposal by landfill are:

- To improve the standard of waste disposal in South Africa
- To improve guidelines for environmentally acceptable waste disposal for a spectrum of landfill sizes and types.
- To provide a framework of minimum waste disposal standards within which to work and upon which to build.

2.3 Air Quality Criteria

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality standards and guideline values indicate safe exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality guidelines and standards are normally given for specific averaging or exposure periods.

2.3.1 South African Ambient Air Quality Standards

The South African Bureau of Standards (SABS) was engaged to assist DEA in the facilitation of the development of ambient air quality standards. This included the establishment of a technical committee to oversee the development of standards. Standards were determined based on international best practice for PM10, dustfall, sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO), lead (Pb) and benzene. The new Standards were published in the Government Gazette (no. 32816) on 24 December 2009 (Table 2-1).

Table 2-1: National Ambient Air Quality Standards for South Africa

Substance	Molecular Formula / Notation	Averaging Period	Concentration (µg/m³)	Frequency of Exceedance	Compliance Date
Sulphur dioxide	SO_2	10 minute	500	526	Immediate
		1 hour	350	88	Immediate
		24 hour	125	4	Immediate
		1 year	50	0	Immediate
Nitrogen Dioxide	NO_2	1 hour	200	88	Immediate
		1 year	40	0	Immediate
Particulate Matter	PM10	24 hour	120	4	Immediate – 31 Dec 2014
			75	4	1 Jan 2015
		1 year	50	0	Immediate – 31 Dec 2014
			40	0	1 Jan 2015
Ozone	O_3	8 hour	120	11	Immediate
Benzene	C_6H_6	1 year	10	0	Immediate – 31 Dec 2014
			5	0	1 Jan 2015

Substance	Molecular Formula / Notation	Averaging Period	Concentration (µg/m³)	Frequency of Exceedance	Compliance Date
Lead	Pb	1 year	0.5	0	Immediate
Carbon Monoxide	CO	1 hour	30 000	88	Immediate
		8 hour	10 000	11	Immediate

2.3.2 Dustfall

Foreign dustfall standards issued by various countries are given in Table 2-2. It is important to note that the limits given by Argentina, Australia, Canada, Spain and the US are based on annual average dustfall. The standards given for Germany are given for maximum monthly dustfall and therefore comparable to the dustfall categories issued locally. Based on a comparison of the annual average dustfall standards it is evident that in many cases a threshold of ~200 mg/m^2/day to ~300 mg/m^2/day is given for residential areas.

Locally dustfall is evaluated according to the criteria published by DEA. In terms of these criteria dustfall is classified as follows:

SLIGHT	-	less than 250 mg/m^2/day
MODERATE	-	250 to 500 mg/m^2/day
HEAVY	-	500 to 1200 mg/m^2/day
VERY HEAVY	-	more than 1200 mg/m^2/day

The Department of Minerals and Energy (DME) uses the uses the 1 200 mg/m^2/day threshold level as an action level. In the event that on-site dustfall exceeds this threshold, the specific causes of high dustfall should be investigated and remedial steps taken.

"Slight" dustfall is barely visible to the naked eye. "Heavy" dustfall indicates a fine layer of dust on a surface; with "very heavy" dustfall being easily visible should a surface not be cleaned for a few days. Dustfall levels of > 2000 mg/m²/day constitute a layer of dust thick enough to allow a person to "write" words in the dust with their fingers.

Table 2-2: Dustfall standards issued by various countries.

Country	Annual Average Dust Deposition Standards (based on monthly monitoring) (mg/m²/day)	Maximum Monthly Dust Deposition Standards (based on 30 day average) (mg/m²/day)
Argentina	133	
Australia	133 (onset of loss of amenity) 333 (unacceptable in New South Wales)	
Canada Alberta: Manitoba:	179 (acceptable) 226 (maximum acceptable) 200 (maximum desirable)	
Germany		350 (maximum permissible in general areas) 650 (maximum permissible in industrial areas)
Spain	200 (acceptable)	
USA: Hawaii Kentucky New York Pennsylvania Washington Wyoming	 200 175 200 (urban, 50 percentile of monthly value) 300 (urban, 84 percentile of monthly value) 267 183 (residential areas) 366 (industrial areas) 167 (residential areas) 333 (industrial areas)	

A perceived weakness of the current dustfall guidelines is that they are purely descriptive, without giving any guidance for action or remediation (SLIGHT, MEDIUM, HEAVY, and VERY HEAVY). It has recently been proposed (as part of the SANS air quality standard setting processes) that dustfall rates be evaluated against a four-band scale, as presented in Table 2-3. Proposed target, action and alert thresholds for ambient dustfall are given in

Table 2-4. Table 2-3, therefore provides the dustfall range per band description with the upper limit of the range given in Table 2-4 permissible frequency of exceedance. Due to the proposed operations of the Tutuka GWDS, the dust fallout at residential areas in the vicinity should be <600 mg/m²/day and the dust fallout on site should be <1200 mg/m²/day.

According to the proposed dustfall limits an enterprise may submit a request to the authorities to operate within the Band 3 ACTION band for a limited period, providing that this is essential in terms of the practical operation of the enterprise (for example the final removal of a tailings deposit) and provided that the best available control technology is applied for the duration. No margin of tolerance will be granted for operations that result in dustfall rates in the Band 4 ALERT.

Table 2-3: Bands of dustfall rates proposed for adoption

BAND NUMBER	BAND DESCRIPTION LABEL	DUST-FALL RATE (D) (mg m^{-2} day^{-1}, 30-day average)	COMMENT
1	RESIDENTIAL	D < 600	Permissible for residential and light commercial
2	INDUSTRIAL	600 < D < 1 200	Permissible for heavy commercial and industrial
3	ACTION	1 200 < D < 2 400	Requires investigation and remediation if two sequential months lie in this band, or more than three occur in a year.
4	ALERT	2 400 < D	Immediate action and remediation required following the first exceedance. Incident report to be submitted to relevant authority.

Table 2-4: Target, action and alert thresholds for ambient dustfall

LEVEL	DUST-FALL RATE (D) (mg m^{-2} day^{-1}, 30-day average)	AVERAGING PERIOD	PERMITTED FREQUENCY OF EXCEEDANCES
TARGET	300	Annual	
ACTION RESIDENTIAL	600	30 days	Three within any year, no two sequential months.
ACTION INDUSTRIAL	1 200	30 days	Three within any year, not sequential months.
ALERT THRESHOLD	2 400	30 days	None. First exceedance requires remediation and compulsory report to authorities.

2.4 Health and Odour Thresholds

Air quality screening levels for non-criteria pollutants are published by various sources. These sources include:

(a) World Health Organization (WHO) guideline values for non-carcinogens and unit risk factor guidelines for carcinogens,

(b) Chronic and sub-chronic inhalation reference concentrations and cancer unit risk factors published by the US-EPA in its Integrated Risk Information System (IRIS),

(c) Acute, sub-acute and chronic effect screening levels published by the Texas Natural Resource Conservation Commission Toxicology and Risk Assessment Division (TARA),

(d) Reference exposure levels (RELs) published by the Californian Office of Environmental Health Hazard Assessment (OEHHA), and

(e) Minimal risk levels issued by the US Federal Agency for Toxic Substances and Disease Registry (ATSDR).

2.4.1 Health Thresholds for Non-Carcinogenic Exposures

Various non-carcinogenic exposure thresholds for pollutants of interest in the current study are given in Table 2-5.

WHO guideline values are based on the no observed adverse effect level (NOAEL) and the lowest observed adverse effect level (LOAEL). Although most guideline values are based on NOAELs and/or LOAELs related to human health endpoints, certain of the guidelines given for 30 minute averaging periods are related to odour thresholds. The short term ESLs issued by TARA for certain odorous compounds are similarly intended to be used for a screening for potential nuisance impacts related to malodour.

Inhalation reference concentration (RfCs) related to inhalation exposures are published in the US-EPA's IRIS database. RfCs are used to estimate non-carcinogenic effects representing a level of environmental exposure at or below which no adverse effect is expected to occur. The RfC is defined as "an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime" (IRIS, 1998). Non-carcinogenic effects are evaluated by calculating the ratio, or hazard index, between a dose (in this case the dosage) and the pollutant-specific inhalation RfC. In the current study reference is made to the chronic inhalation toxicity values published by US-EPA (IRIS, 2009).

RfCs are based on an assumption of lifetime exposure and thus provide a very conservative estimate when applied to less-than-lifetime exposure situations. The RfC is also not a direct or absolute estimator of risk, but rather a reference point to gauge potential effects. Doses at or below the RfC are not likely to be associated with any adverse health effects. However, exceedance of the RfC does not imply that an adverse health effect would necessarily occur. As the amount and frequency of exposures exceeding the RfC increase, the probability that adverse effects may be observed in the human population also increases. The US-EPA has therefore specified that although doses below the RfC are acceptable, doses above the RfC are not necessarily unsafe.

The US ATSDR uses the NOAEL/uncertainty factor (UF) approach to derive maximum risk levels (MRLs) for hazardous substances. They are set below levels that, based on current information, might cause adverse health effects in the people most sensitive to such substance-induced effects. MRLs are derived for acute (1-14 days), intermediate (>14-364 days), and chronic (365 days and longer) exposure durations, and for the oral and inhalation routes of exposure. MRLs are generally based on the most sensitive substance-induced end point considered to be of relevance to humans. ATSDR does not use serious health effects (such as irreparable damage to the liver or kidneys, or birth defects) as a basis for establishing MRLs. Exposure to a level above the MRL does not mean that adverse health effects will occur.

Table 2-5: Health risk criteria for non-carcinogenic exposures via the inhalation pathway (as downloaded June 2009 for RAIS, OEHHA and ATSDR).

Constituent	WHO Guidelines (2000) (µg/m³)		US-EPA IRIS Inhalation Reference Concentrations (June 2009) (µg/m³)		Californian OEHHA (June 2009) (µg/m³)		US ATSDR Maximum Risk Levels (MRLs) (June 2009) (µg/m³)			TARA ESLs (1997) (µg/m³)	
	Acute & Sub-acute Guidelines (ave period given)	Chronic Guidelines (year +)	Sub-chronic Inhalation RfCs	Chronic Inhalation RfCs	Acute RELs (ave period given)	Chronic RELs	Acute (1-14 days)	Intermediate (>14-365 days)	Chronic (365+ days)	Short-term ESL (1hr)	Long-term ESL (year+)
1,1,1 – Trichloroethane			5000	5000			10912	3819		10800	1080
1,1,2-Trichloroethane										550	55
1,1,2,2-										70	7
1,1-Dichloroethane			5000	500						4000	400
1,1-Dichloroethene								79		40	4
1,2-Dichloroethane									2428	160	4
1,2 – Dichloroethylene										7930	793
1,2 – Dichloropropane			13	4			231	32		1150 (a)	115
1,2,3 -										1250	125
1,2,4 -				7						1250	125
1,3,5 -			60	6						1250	125
1,3-Butadiene				2		20				110	11
1,4-Butanediamine											
1,5-Ddiaminopentane											
1-Pentane										90 (a)	9

Constituent	WHO Guidelines (2000) (µg/m³)		US-EPA IRIS Inhalation Reference Concentrations (June 2009) (µg/m³)		Californian OEHHA (June 2009) (µg/m³)		US ATSDR Maximum Risk Levels (MRLs) (June 2009) (µg/m³)			TARA ESLs (1997) (µg/m³)	
	Acute & Sub-acute Guidelines (ave period given)	Chronic Guidelines (year +)	Sub-chronic Inhalation RfCs	Chronic Inhalation RfCs	Acute RELs (ave period given)	Chronic RELs	Acute (1-14 days)	Intermediate (>14-365 days)	Chronic (365+ days)	Short-term ESL (1hr)	Long-term ESL (year+)
2-Propanol											
2-Butoxyethanol										240	24
2-Methylpentane										289 (a)	28.9
3-Methylpentane										3500	350
Acetaldehyde	2000 (TC) 24-hrs	50 (TC)		9	470	140				90 (a)	9
Acetone							61762	30881	30881	5900	590
Acrylonitrile				2		5	217			43	4.3
Aldehydes											
Aluminium				5						50	5
Ammonia				100	3200 (1 hr)	200	1184		70	170	17
Arsenic					0.2	0.015				0.1	0.01
Benzene				30	1300 (6 hrs)	60	29	19	10	75 12 (24-hrs)	1
Benzo(a)pyrene										0.03	0.003
Boron				20						100	10

Constituent	WHO Guidelines (2000) (µg/m³)		US-EPA IRIS Inhalation Reference Concentrations (June 2009) (µg/m³)		Californian OEHHA (June 2009) (µg/m³)		US ATSDR Maximum Risk Levels (MRLs) (June 2009) (µg/m³)			TARA ESLs (1997) (µg/m³)	
	Acute & Sub-acute Guidelines (ave period given)	Chronic Guidelines (year +)	Sub-chronic Inhalation RfCs	Chronic Inhalation RfCs	Acute RELs (ave period given)	Chronic RELs	Acute (1-14 days)	Intermediate (>14-365 days)	Chronic (365+ days)	Short-term ESL (1hr)	Long-term ESL (year+)
Bromodichloromethane											
Butane										19000	1900
Butyl mercaptan										1.8 (a)	0.18
Butylcellosolve										240	24
Butyric acid										18 (a)	1.8
Cadmium		0.005 (GV)				0.02				0.1	0.01
Caproic acid										48 (a)	4.8
Carbon disulphide	100 (GV) 24-hrs		700	700	6200 (6 hrs)	800			934	30	3
Carbon Tetrachloride		6.1 (TC)	20		1900 (7 hrs)	40		189	189	126	13
Carbonyl sulphide										8	0.8
Chlorinated dibenzo-p-dioxins & chlorinated dibenzo-furans(h)						0.00004					
Chlorine					210 (1 hr)	0.2				15	1.5
Chlorobenzene						1000				460	46
Chloroethane										500	50

Constituent	WHO Guidelines (2000) (µg/m³)		US-EPA IRIS Inhalation Reference Concentrations (June 2009) (µg/m³)		Californian OEHHA (June 2009) (µg/m³)		US ATSDR Maximum Risk Levels (MRLs) (June 2009) (µg/m³)			TARA ESLs (1997) (µg/m³)	
	Acute & Sub-acute Guidelines (ave period given)	Chronic Guidelines (year +)	Sub-chronic Inhalation RfCs	Chronic Inhalation RfCs	Acute RELs (ave period given)	Chronic RELs	Acute (1-14 days)	Intermediate (>14-365 days)	Chronic (365+ days)	Short-term ESL (1hr)	Long-term ESL (year+)
Chlorodifluoromethane				50000						18000	1800
Chloroform					150 (7 hrs)	300	488	244	98	98	9.8
chromium (II) and (III) compounds								0.1		1	0.1
Chromium (VI) compounds				0.1		0.2		0.3		0.1	0.01
Cobalt				0.006					0.1	0.2	0.02
Copper					100 (1 hr)					10	1
Cresol (all isomers)						600				5 (a)	0.5
Cumene			90	400						500 (a)	50
Cyclohexane				6000						1435 (a)	143.5
Cyclohexanone										481 (a)	48.1
Decane										10000	1000
Dichlorobenzene		1000 (GV)	2000 (a) 2500 (b)	200 (a) 800 (b)		800 (d)	12025 (d)	1202 (d)	60 (d)	2500 (e) 1500(f) 600 (g)	250 (e) 150 (f) 60 (g)

Constituent	WHO Guidelines (2000) (µg/m^3)		US-EPA IRIS Inhalation Reference Concentrations (June 2009) (µg/m^3)		Californian OEHHA (June 2009) (µg/m^3)		US ATSDR Maximum Risk Levels (MRLs) (June 2009) (µg/m^3)			TARA ESLs (1997) (µg/m^3)	
	Acute & Sub-acute Guidelines (ave period given)	Chronic Guidelines (year +)	Sub-chronic Inhalation RfCs	Chronic Inhalation RfCs	Acute RELs (ave period given)	Chronic RELs	Acute (1-14 days)	Intermediate (>14-365 days)	Chronic (365+ days)	Short-term ESL (1hr)	Long-term ESL (year+)
Dichlorodifluoromethane			2000	200						49500	4950
Dichlorofluoromethane										420	42
Dimethyl disulphide											
Dimethyl sulphide										3 (a)	0.3
Dodecane											
Ethane (simple asphyxiant)											
Ethanol											
Ethyl Acetate										14400	1440
Ethyl Benzene		22000 (GV)	1000	1000		2000	43422	3040	1303	2000 (a)	200
Ethyl chloride (chloroethene)			4000	10000		30000	39579			500	50
Ethyl mercaptan										0.8 (a)	0.08
Ethylbutyrate										39 (a)	3.9
Ethylene dibromide						0.8				3.8	0.38
Fluorotrichloromethane										28000	2800

Constituent	WHO Guidelines (2000) (µg/m^3)		US-EPA IRIS Inhalation Reference Concentrations (June 2009) (µg/m^3)		Californian OEHHA (June 2009) (µg/m^3)		US ATSDR Maximum Risk Levels (MRLs) (June 2009) (µg/m^3)			TARA ESLs (1997) (µg/m^3)	
	Acute & Sub-acute Guidelines (ave period given)	Chronic Guidelines (year +)	Sub-chronic Inhalation RfCs	Chronic Inhalation RfCs	Acute RELs (ave period given)	Chronic RELs	Acute (1-14 days)	Intermediate (>14-365 days)	Chronic (365+ days)	Short-term ESL (1hr)	Long-term ESL (year+)
Formaldehyde	100 (GV) 30 min				55 (1 hr)	9	49	37	10	15	1.5
Heptane										3500	350
Hexane			700	200		7000			2115	1760	176
Hydrogen chloride				20	2100 (1hr)	9					
Hydrogen cyanide				3	340 (1 hr)	9				50	5
Hydrogen Fluoride					240 (1hr)	14					
Hydrogen Sulphide	7 (GV) 30-			2	42 (1 hr)	10	98	28			
Iso-octane										3500	350
Ketones											
Limonene											
Manganese		0.15 (GV)		0.05	0.17 (8hr)	0.09			0.3	2	0.2
Mercaptans (total)											
Mercury		1 (GV)	0.3	0.3	0.6	0.03			0.2	0.25	0.025
Methyl chloride (chloromethane)							1032	413	103	1030	103
Methyl ethyl disulphide											

Constituent	WHO Guidelines (2000) (µg/m³)		US-EPA IRIS Inhalation Reference Concentrations (June 2009) (µg/m³)		Californian OEHHA (June 2009) (µg/m³)		US ATSDR Maximum Risk Levels (MRLs) (June 2009) (µg/m³)			TARA ESLs (1997) (µg/m³)	
	Acute & Sub-acute Guidelines (ave period given)	Chronic Guidelines (year +)	Sub-chronic Inhalation RfCs	Chronic Inhalation RfCs	Acute RELs (ave period given)	Chronic RELs	Acute (1-14 days)	Intermediate (>14-365 days)	Chronic (365+ days)	Short-term ESL (1hr)	Long-term ESL (year+)
Methyl ethyl ketone			1000	5000	13000 (1 hr)					3900 (a)	390
Methyl isobutyl ketone			800	3000						2050	205
Methylene Chloride					14000 (1 hr)	400	2084	1042	1042	260	26
Methyl methacrylate		200 (TC)		700						340(a)	34
Methyl mercaptan				2						2 (a)	0.2
Molybdenum										100	10
n-Butyl Acetate										1850 (a)	185
n-heptane										3500	350
n-hexane			700	200		7000				1760	176
n-propyl mercaptan										6475 (a)	648
n-cymene										2745	275
Napthalene				3		9			4	440 (a)	44
Nickel					6 (1hr)	0.05		0.2	0.09	0.15	0.015
Nonane										10500	1050
Pentane										3500	350
Phenol					5800 (1 hr)	200				154 (a)	15.4
Propane										18000	1800
Propionic Acid										103	10.3

Constituent	WHO Guidelines (2000) (µg/m³)		US-EPA IRIS Inhalation Reference Concentrations (June 2009) (µg/m³)		Californian OEHHA (June 2009) (µg/m³)		US ATSDR Maximum Risk Levels (MRLs) (June 2009) (µg/m³)			TARA ESLs (1997) (µg/m³)	
	Acute & Sub-acute Guidelines (ave period given)	Chronic Guidelines (year +)	Sub-chronic Inhalation RfCs	Chronic Inhalation RfCs	Acute RELs (ave period given)	Chronic RELs	Acute (1-14 days)	Intermediate (>14-365 days)	Chronic (365+ days)	Short-term ESL (1hr)	Long-term ESL (year+)
Propyl Benzene											
Styrene			3000	1000	21000 (1hr)	900				110	11
Tetrachloroethylene (perchloroethylene)	8000 (GV) 30-min 250 (GV) 24-hrs				20000 (1 hr)	35	1357		271	340	34
Toluene	1000 (GV) 30-min (a) 260 (GV) 1-week		5000	923	37000 (1 hr)	300	3768		301	1880	188
Trichloroethylene				40		600	10748	537		1350	135
Trimethylbenzene										1250	125
Undecane											
Valeric acid										3 (a)	0.3
Vinyl acetate			200	200		200				150	15
Vinyl chloride				100	180000 (1		1278	77		130	13

Constituent	WHO Guidelines (2000) (µg/m³)		US-EPA IRIS Inhalation Reference Concentrations (June 2009) (µg/m³)		Californian OEHHA (June 2009) (µg/m³)		US ATSDR Maximum Risk Levels (MRLs) (June 2009) (µg/m³)			TARA ESLs (1997) (µg/m³)	
	Acute & Sub-acute Guidelines (ave period given)	Chronic Guidelines (year +)	Sub-chronic Inhalation RfCs	Chronic Inhalation RfCs	Acute RELs (ave period given)	Chronic RELs	Acute (1-14 days)	Intermediate (>14-365 days)	Chronic (365+ days)	Short-term ESL (1hr)	Long-term ESL (year+)
Xylene	4800 (GV) 24-hrs	870 (GV)		100	22000 (1 hr)	700	8684	2605	217	3700 (a)	370
Zinc										50	5

Notes:

(a) Given for odour.

(b) Given for 1,2 dichlorobenzene

(c) Given for 1,3 dichlorobenzene

(d) Given for 1,4 dichlorobenzene

(e) Given for m-dichlorobenzene

(f) Given for o-dichlorobenzene

(g) Given for p-dichlorobenzene

(h) Includes 2,3,7,8-tetrachlorodibenzo-p-dioxin

MRLs are intended to serve as a screening tool to help public health professionals decide where to look more closely. They may also be viewed as a mechanism to identify those hazardous waste sites that are not expected to cause adverse health effects. Most MRLs contain some degree of uncertainty because of the lack of precise toxicological information on the people who might be most sensitive (e.g., infants, elderly, and nutritionally or immunologically compromised) to effects of hazardous substances. ATSDR uses a conservative (i.e., protective) approach to address these uncertainties consistent with the public health principle of prevention. Although human data are preferred, MRLs often must be based on animal studies because relevant human studies are lacking. In the absence of evidence to the contrary, ATSDR assumes that humans are more sensitive than animals to the effects of hazardous substances that certain persons may be particularly sensitive. Thus the resulting MRL may be as much as a hundredfold below levels shown to be non-toxic in laboratory animals. When adequate information is available, physiologically based pharmacokinetic (PBPK) modelling and benchmark dose (BMD) modelling have also been used as an adjunct to the NOAEL/UF approach in deriving MRLs.

Proposed MRLs undergo a rigorous review process. They are reviewed by the Health Effects/MRL Workgroup within the Division of Toxicology; and expert panel of external peer reviewers; the agency wide MRL Workgroup, with participation from other federal agencies, including EPA; and are submitted for public comment through the toxicological profile public comment period. Each MRL is subject to change as new information becomes available concomitant with updating the toxicological profile of the substance. MRLs in the most recent toxicological profiles supersede previously published levels.

TARA ESLs are based on data concerning health effects, odour nuisance potential, vegetation effects, or corrosion effects. ESLs are not ambient air quality standards! If predicted or measured airborne levels of a constituent do not exceed the screening level, it is not expected that any adverse health or welfare effects would results. If ambient levels of constituents in air exceed the screening levels it does not, however, necessarily indicate a problem, but should be viewed as a trigger for a more in-depth review.

In the assessment of the potential for health risks use will generally be made of the lowest threshold published for a particular pollutant and averaging period. TARA ESLs will however only be used in the event that WHO guideline values, IRIS reference exposure concentrations, ATSDR MRLs or Californian RELs are not available.

2.4.2 Health Thresholds for Carcinogenic Exposures

2.4.2.1 Unit Risk Factors

Unit risk factors (URFs) are applied in the calculation of carcinogenic risks. These factors are defined as the estimated probability of a person (60-70 kg) contracting cancer as a result of constant exposure to an ambient concentration of 1 µg/m³ over a 70-year lifetime. In the generic health risk assessment undertaken as part of the current study, maximum possible exposures (24-hours a day over a 70-year lifetime) are assumed for all areas beyond the boundary of the proposed development site. Unit risk factors were obtained from the WHO (2000) and from the US-EPA IRIS database (accessed June 2009). URFs for compounds of interest in the current study are given in Table 2-6.

2.4.2.2 Acceptable Cancer Risk

The identification of an acceptable cancer risk level has been debated for many years and it possibly will still continue as societal norms and values change. Some people would easily accept higher risks than others, even if it were not within their own control; others prefer to take very low risks. An acceptable risk is a question of societal acceptance and will therefore vary from society to society.

In spite of the difficulty to provide a definitive "acceptable risk level", the estimation of a risk associated with an activity provides the means for a comparison of the activity to other everyday hazards, and therefore allowing risk-management policy decisions. Technical risk assessments seldom set the regulatory agenda because of the different ways in which the non-technical public perceives risks. Consequently, science does not directly provide an answer to the question.

Risk assessment as an organized activity of the US Food and Drug Administration (FDA) and the EPA began in the 1970s. During the middle 1970s, the EPA and FDA issued guidance for estimating risks associated with small exposures to potentially carcinogenic chemicals. Their guidance made estimated risks of one extra cancer over the lifetime of 100 000 people (EPA) or 1 million people (FDA) action levels for regulatory attention. Estimated risks below those levels are considered negligible because they add individually so little to the background rate of about 250 000 cancer deaths out of every 1 million people who die every year in the United States, i.e. 25%. Accepting 1 in 100 000 or 1 in a million risk translates to 0.004% or 0.0004% increase in the existing cancer risk level, respectively.

Table 2-6: Unit risk factors from the California EPA (as adopted on August 2003), US-EPA Integrated Risk Information System (IRIS) (June 2009) and WHO risk factors (2000).

Compound	Californian EPA Unit Risk Factor (µg/m³)	WHO Inhalation Unit Risk (µg/m³)	US-EPA IRIS Unit Risk Factor (µg/m³)	IARC Cancer Class	US-EPA Cancer Class (a)
1,1,2,2-Tetrachloroethane		0.6×10^{-6} to 3.0×10^{-6}	5.8×10^{-5}	3	C
1,1,2-Trichloroehane			1.6×10^{-5}	3	C
1,1-Dichloroethane	1.6×10^{-6}				C
1,2-Dichloroethane	2.1×10^{-5}	(0.5×10^{-6} to 2.8×10^{-6}		2B	C
1,3-Butadiene	1.7×10^{-4}		3×10^{-5}	2A	B2
Acetaldehyde	2.7×10^{-6}	(1.5×10^{-7} to 9×10^{-7}	2.2×10^{-5}	2B	B2
Acrylonitrile	2.9×10^{-4}	2.0×10^{-5}	6.8×10^{-5}	2A	B1
Arsenic, Inorganic(a)	3.3×10^{-3}	1.5×10^{-3}	4.3×10^{-3}	1	A
Benzene	2.9×10^{-5}	4.4×10^{-6} to 7.5×10^{-6}	7.8×10^{-6}	1	A
Benzo(a)pyrene		8.7×10^{-2}	8.8×10^{-4}(b)		B2
Bromodichloromethane	3.7×10^{-5}				B2
Cadmium	4.2×10^{-3}		1.8×10^{-3}	B1	2A
Carbon tetrachloride	4.2×10^{-5}		1.5×10^{-5}	2B	B2
Chloroform	5.3×10^{-6}	4.2×10^{-7}	2.3×10^{-5}	2B	B2

Compound	Californian EPA Unit Risk Factor (µg/m³)	WHO Inhalation Unit Risk (µg/m³)	US-EPA IRIS Unit Risk Factor (µg/m³)	IARC Cancer Class	US-EPA Cancer Class (a)
Chromium VI (particulates)	1.5×10^{-1}	1.1×10^{-2} to 13×10^{-2}	8.4×10^{-2}	1	A
Dioxins			33		A
Formaldehyde	6.0×10^{-6}		1.3×10^{-5}	2A	B1
Lead	1.2×10^{-5}			B2	2B
Methylene chloride	1.0×10^{-6}		4.7×10^{-7}	2B	B2
Nickel	2.6×10^{-4}	3.8×10^{-4}	2.4×10^{-4}	A	1
Tetrachloroethylene	5.9×10^{-6}		5.9×10^{-6}	2B	
Trichloroethylene	2.0×10^{-6}	4.3×10^{-7}	1.14×10^{-4}	2A	
Vinyl chloride	7.8×10^{-5}	1×10^{-6}	4.4×10^{-5}	1	A

<u>Notes:</u>

(a) EPA cancer classifications: A--human carcinogen; B--probable human carcinogen. There are two sub-classifications: B1--agents for which there is limited human data from epidemiological studies. B2--agents for which there is sufficient evidence from animal studies and inadequate or no evidence from human epidemiological studies. C-possible human carcinogen. D-not classifiable as to human carcinogenicity. E-evidence of non-carcinogenicity for humans.

(b) Provisional Unit Risk.

The European Parliament and the European Council, when considering the proposal for a Directive on Drinking Water, agreed that an excess lifetime risk of 1 in a million should be taken as the starting point for developing limit values. In South Africa, DEA has only been noted to give an indication of cancer risk acceptability in the case of dioxin and furan exposures. According to the DEA, emissions of dioxins and furans from a hazardous waste incinerator may not result in an excess lifetime cancer risk of greater than 1: 100 000 on the basis of annual average exposure (DEA, 1994). In general, excess cancer risks of less than 1:100 000 appear therefore to be viewed as acceptable to the DEA.

The SANS for Benzene (SANS 1929:2004) adopted a limit value of 5µg/m³ that is based on the value developed for the European Community (EC) Standard. This value is to be met by 2010. Depending on which unit risk factor is used, the equivalent incremental cancer risk for this standard varies from a minimum of 1.5:100 000 (California Air Resources Board (CARB)) to 3.5:100 000 (WHO) and 3.9:100 000 (US EPA), respectively. (The geometric mean of the range of WHO estimates of the excess lifetime risk of leukaemia at an air concentration of 1µg/m³ is $6x10^{-6}$. The concentrations of airborne benzene associated with an excess lifetime risk of 1:10 000, 1:100 000 and 1:1 000 000 are 17, 1.7 and 0.17µg/m³ respectively.

Whilst it is perhaps inappropriate to make a judgment about how much risk should be acceptable, through reviewing acceptable risk levels selected by other well-known organizations, it would appear that the US EPA's application is the most suitable, i.e.

"If the risk to the maximally exposed individual (MEI) is no more than $1x10^{-6}$, then no further action is required. If not, the MEI risk must be reduced to no more than $1x10^{-4}$, regardless of feasibility and cost, while protecting as many individuals as possible in the general population against risks exceeding $1x10^{-6}$"

Some authorities tend to avoid the specification of a single acceptable risk level. Instead a "risk-ranking system" is preferred. For example, the New York Department of Health produced a qualitative ranking of cancer risk estimates, from very low to very high (Table 2-7). Therefore if the qualitative descriptor was "low", then the excess lifetime cancer risk from that exposure is in the range of greater than one per million to less than one per ten thousand.

Table 2-7: Excess Lifetime Cancer Risk (as applied by New York Department of Health)

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

2.4.3 Odour Impact Evaluation

2.4.3.1 Odour Thresholds

Odour thresholds are defined in several ways including absolute perception thresholds, recognition thresholds and objectionability thresholds. At the perception threshold one is barely certain that an odour is detected but it is too faint to identify further. Recognition thresholds are normally given for 50% and 100% recognition by an odour panel. The short-term TARA ESLs and the acute WHO guideline values given for odorants most frequently represent odour limits rather than health risk thresholds as was indicated in Table 2-5.

In the assessment of potential odour impacts use was made of the 50% recognition threshold odour concentrations (TOC's) published by Verscheuren (1996) (Table 2-8). The 50% recognition threshold is the concentration at which 50% of an odour panel defined the odour as being representative of the odorant being studied.

Table 2-8: 50% Recognition odour threshold concentrations (Verscheuren, 1996)

Compound	TOC ($\mu g/m^3$)
Ammonia	2000
Carbon disulphide	200
Diethyl disulphide	0.3
Dimethyl disulphide	21.9
Dimethyl sulphide	5
Ethanethiol	5.164

Compound	TOC (µg/m³)
Hydrogen sulphide	10
Limonene	20
Methanethiol	2
Propanethiol	3
Toluene	5000
Xylene	730

2.4.3.2 Evaluation of Odour Impact Acceptability

Due to the absence of detailed local guidance, reference was made to the international literature in identifying a suitable method to use in assessing the potential acceptability of odour impacts associated with the proposed landfill. Reference was primarily made to approaches adopted in the US and in Australia due to the availability of literature on the approaches adopted in these countries.

There are two main steps in odour assessment, viz.: (i) calculation of odour units based on predicted or measured ground level air pollution concentrations, and (ii) evaluation of odour unit acceptability based on defined odour performance criteria. The ways in which these steps are carried out are discussed in subsequent subsections and a method recommended for adoption in the current study.

2.4.3.3 Odour Unit Calculation

The detectability of an odour is a sensory property that refers to the theoretical minimum concentration that produces an olfactory response or sensation. This point is called the odour thresholds and defines one odour unit per cubic metre (OU/m³), i.e. the odour unit is the concentration of a substance divided by the odour threshold for that substance or the number of dilutions required for the sample to reach the threshold. This threshold is typically the numerical value equivalent to when 50% of a testing panel correctly detect an odour. Therefore, an odour criterion of less than 1 OU/m³ would theoretically result in no odour impact being experienced.

Different states in the US and Australia apply varying methodologies in the calculation of odour units and also differ in their selection of suitable detection limits. Examples of such differences include the following:

- **Averaging periods** – the New South Wales (NSW) EPA (2006b) and the Draft Queensland EPA (1999) guideline use a 1-hour average air pollution concentration, whereas the Victoria EPA recommend the use of 3-minute average.
- **Percentiles** – the NSW EPA (2006b) specify the use of the 99.9th percentile when selecting 3-minute averaging air pollutant concentrations to be used in OU calculation given a "level 3" assessment. A level 3 assessment requires that comprehensive atmospheric dispersion modelling be done, as opposed to screening dispersion modelling acceptable in a level 2 odour impact assessment The Queensland and Victoria EPAs both recommend that the 99.5th percentile be used.

2.4.3.4 Odour Performance Criteria

In practice, the character of a particular odour can only be judged by the receiver's reaction to it, and preferably only compared to another odour under similar social and regional conditions. The NWS EPA, having referred to the literature in its determining the level at which an odour is perceived to be of nuisance, gives this level as ranging from 2 OU/m^3 to 10 OU/m^3 depending on a combination of the following factors:

- **Odour quality** – i.e. whether the odour results from a pure compound or from a mixture of compounds. Pure compounds tend to have a higher threshold, lower offensiveness, than a mixture of compounds
- **Population sensitivity** – any given population contains individuals with a range of sensitivities to odour. The larger the population, generally the greater the number of sensitive individuals contained.
- **Background level** – refers to the likelihood of cumulative odour impacts due to the co-location of sources emitting odours
- **Public expectation** – whether a given community is tolerant of a particular type of odour and does not find it offensive. Background agricultural odours may, for example, not be considered offensive until a higher threshold is reached whereas odours from a waste disposal site or chemical facility may be considered offensive at lower thresholds.
- **Source characteristics** – emissions from point sources are more easily controlled that are diffuse sources, e.g. waste disposal sites

- **Health effects** – whether a particular odour is likely to be associated with adverse health effects. In general, odour from an agricultural operation is less likely to present a health risk than emissions from a waste disposal or chemical facility

Experience gained in NSW through odour assessments for proposed and existing facilities has indicated that an odour performance criterion of 7 OU/m³ is likely to represent the level below which "offensive" odours should not occur for an individual with a "standard sensitivity" to odours. The NSW EPA policy therefore recommends that, as a design criterion, no individual be exposed to ambient odour levels of greater than 7 OU/m3. Where a number of the factors listed above simultaneously contribute to making an odour 'offensive', odour criteria of 2 OU/m3 at the nearest sensitive receptor (existing or any likely future receptor) is appropriate. This is given as generally occurring for affected populations equal to or above 2000 people. A summary of the NSW EPA's odour performance criteria for various population densities is shown in Table 2-9.

Table 2-9: NSW EPA odour assessment criteria (NSW EPA, 2006)

Population of Affected Community	Odour Assessment Criteria (OU)
Rural single residence (≤2)	7.0
~ 10	6.0
~ 30	5.0
~ 125	4.0
~ 500	3.0
Urban area (≥ 2000) and/or schools and hospitals	2.0

The odour performance criteria specified by the NSW EPA is compared to that used in other jurisdictions in Table 2-10. It is evident that the odour performance criteria range specified by the NSW EPA includes the criteria stipulated in various other jurisdictions, the exception being the South Coast Air Quality Management District in the US which permits odour units of up to 10 OU in certain instances.

Table 2-10: Odour performance criteria used in various jurisdictions in the US and Australia

Jurisdiction	Odour Performance Criteria (given for application to odour units) (OU)
New South Wales EPA (NSW EPA, 2001a, 2001b)	2 to 7
California Air Resources Board (Amoore, 1999)	5
South Coast Air Quality Management District (SCAQMD) (CEQA, 1993)	5 to 10
Massachusetts (Leonardos, 1995)	5
Connecticut (Warren Spring Laboratory, 1990)	7
Queensland (Queensland Department of Environment and Heritage, 1994)	5

3. BASELINE CHARACTERISATION

3.1 Study Area

The land use within the study area mainly consists of agriculture with some industrial activity and residential developments. Industrial activity close to the proposed landfill site includes the Tutuka Power Station (~1.5 km to the east) and the New Denmark Colliery (~4.5 km to the northwest) (Figure 3-1). The closest residential development is the Thuthukani Township (~1.5km to the west-southwest) with a number of individual houses in the area (Table 3-1).

Figure 3-1: Study area for the current assessment and location of sensitive receptors and industrial activities

The proposed Tutuka GWDS is located approximately 1618 m above sea level. The study area is characterized by relatively flat terrain with rivers cutting through the landscape as the water erodes into the stream alluvium (Figure 3-2).

Table 3-1: Location of individual houses within 5km of the proposed Tutuka GWDS

Longitude	Latitude
29.296461°E	-26.759225°S
29.314939°E	-26.755556°S
29.315317°E	-26.794822°S
29.297669°E	-26.814656°S
29.328847°E	-26.802189°S
29.349119°E	-26.804758°S
29.360617°E	-26.797961°S

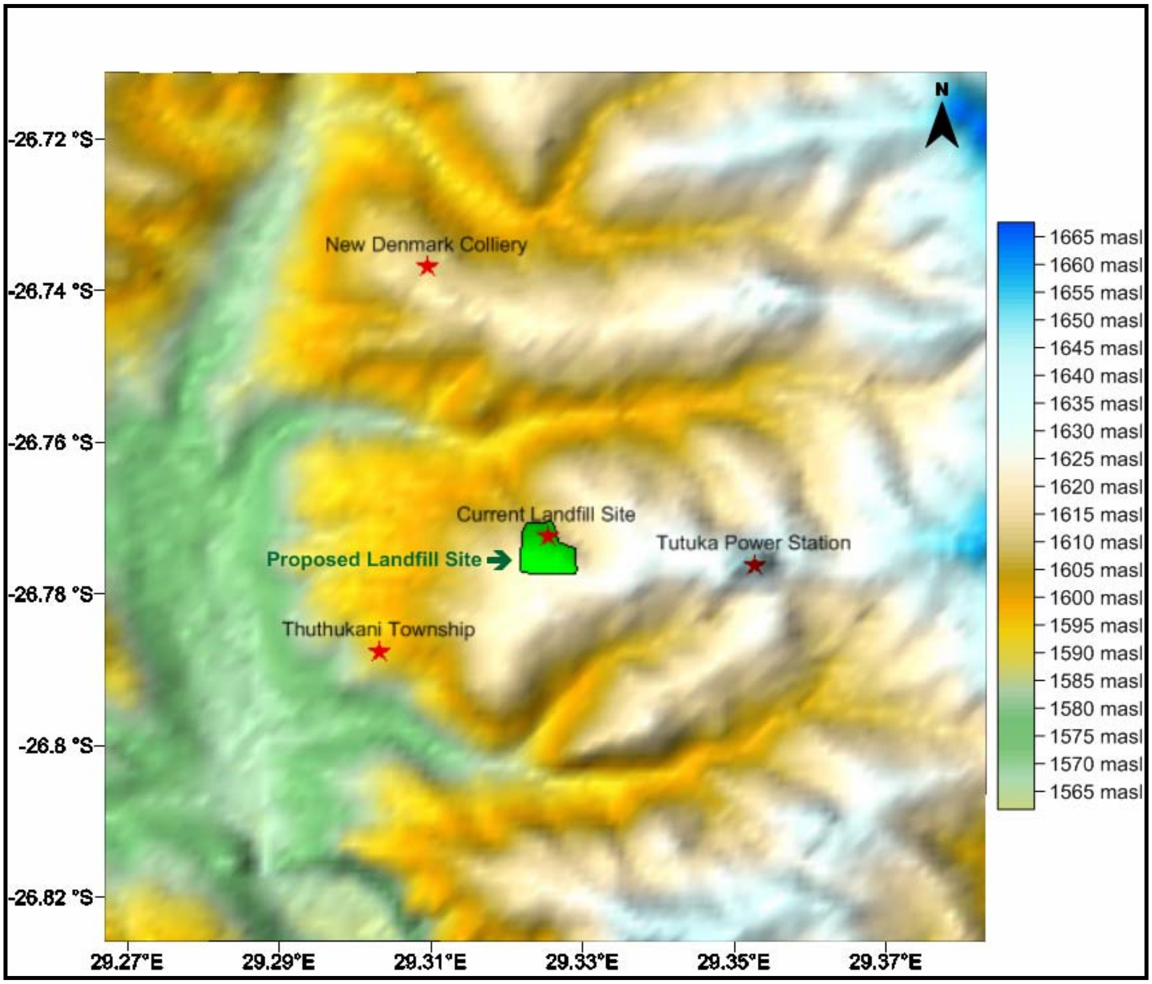

Figure 3-2: Topography of the study area.

3.2 Atmospheric Dispersion Potential

In the assessment of the possible impacts from air pollutants on the surrounding environment and human health, a good understanding of the regional climate and local air dispersion potential of a site is essential.

Meteorological mechanisms govern the dispersion, transformation and eventual removal of pollutants from the atmosphere (Pasquill and Smith, 1983; Godish, 1990). The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The vertical component is defined by the stability of the atmosphere and the depth of the surface mixing layer. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction, and the variability in wind direction, determines the general path pollutants will follow, and the extent of cross-wind spreading (Shaw and Munn, 1971; Pasquill and Smith, 1983; Oke, 1990).

Pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field. Spatial variations, and diurnal and seasonal changes, in the wind field and stability regime are functions of atmospheric processes operating at various temporal and spatial scales (Goldreich and Tyson, 1988). Atmospheric processes at macro- and meso-scales need therefore be taken into account in order to accurately parameterise the atmospheric dispersion potential of a particular area.

Parameters that need to be taken into account in the characterisation of meso-scale ventilation potentials include wind speed, wind direction, extent of atmospheric turbulence, ambient air temperature and mixing depth.

3.3 Meso-scale Climatology and Atmospheric Dispersion Potential

The analysis of meteorological data observed for the site provides the basis for the parameterisation of the meso-scale ventilation potential of the site. Parameters that need to be taken into account in the characterisation of meso-scale ventilation potentials include wind speed, wind direction, extent of atmospheric turbulence, ambient air temperature and mixing depth. Meteorological data for the period 2006 - 2008 was obtained for the closest South African Weather Service Station of Standerton. The meteorological equipment at Standerton was stolen in November 2008 and the station was discontinued.

3.3.1 Meso-Scale Wind Field

The vertical dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness.

Wind roses comprise 16 spokes which represent the directions from which winds blew during the period. The colours reflect the different categories of wind speeds, the grey area, for example, representing winds of 1 m/s to 3 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. For the current wind roses, each dotted circle represents 5% frequency of occurrence. The figure given in the centre of the circle described the frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s.

The period, day-time and night-time wind roses for Standerton are provided in Figure 3-3.

The dominant wind direction at Standerton for the period 2006 – 2008 is from the east (~14% frequency of occurrence) and from the west (~10% frequency of occurrence). Wind speeds are predominantly moderate (2-4 m/s) with relatively high calm condition (23.3%). Day-time conditions are characterised by an increase in westerly winds (~15% frequency of occurrence) with night-time conditions reflecting an increase in easterly winds and high calm conditions (33.7%).

Seasonal wind roses are provided in Figure 3-4. The seasonal wind roses at Standerton largely reflect the synoptic conditions with increase in easterly waves occurring during summer and spring and with the increase in westerly waves shown in the winter months. An increase in calm conditions are also characteristic of the winter and autumn months (>30%).

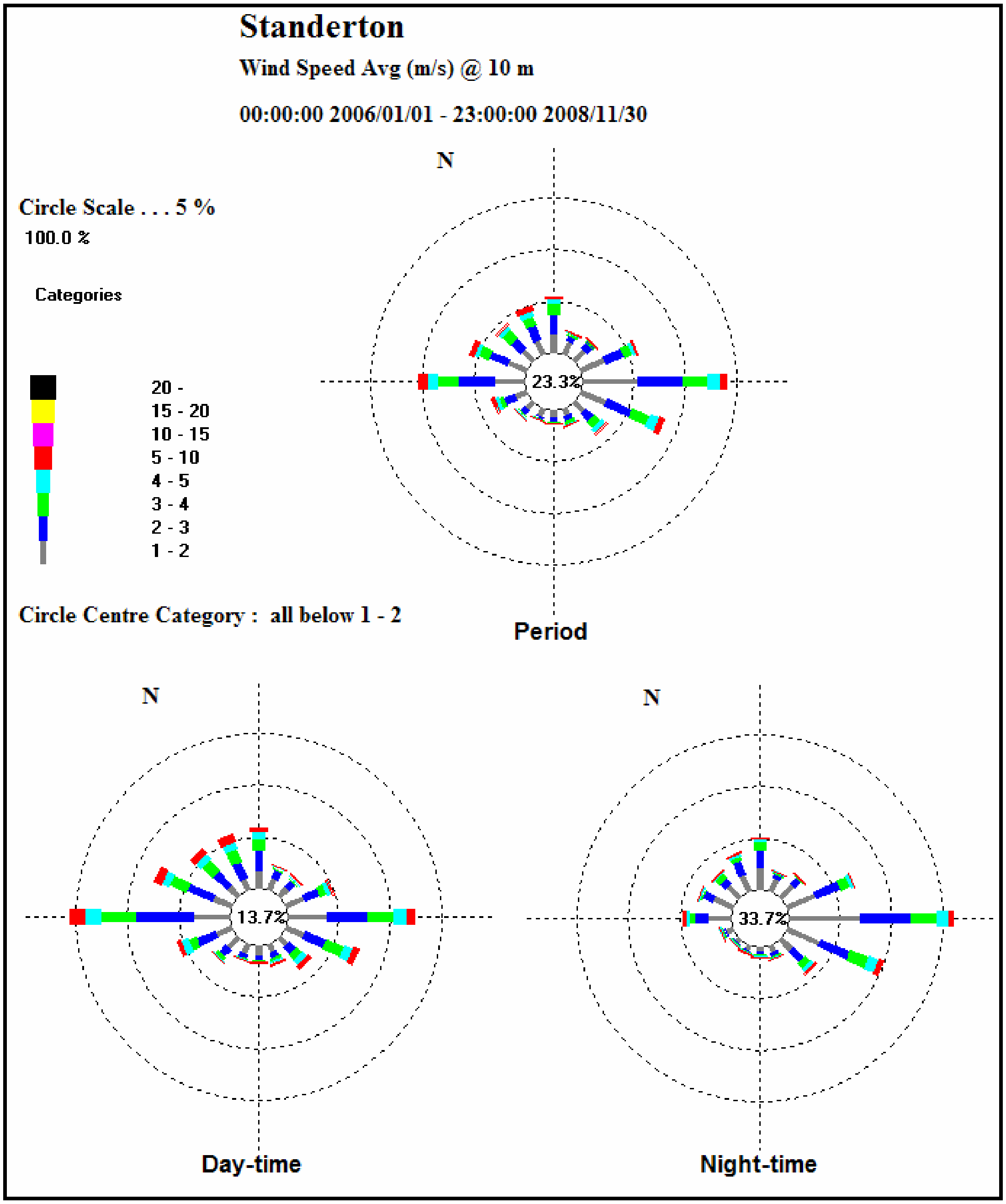

Figure 3-3: Period, day-time and night-time wind roses for Standerton (2006-2008).

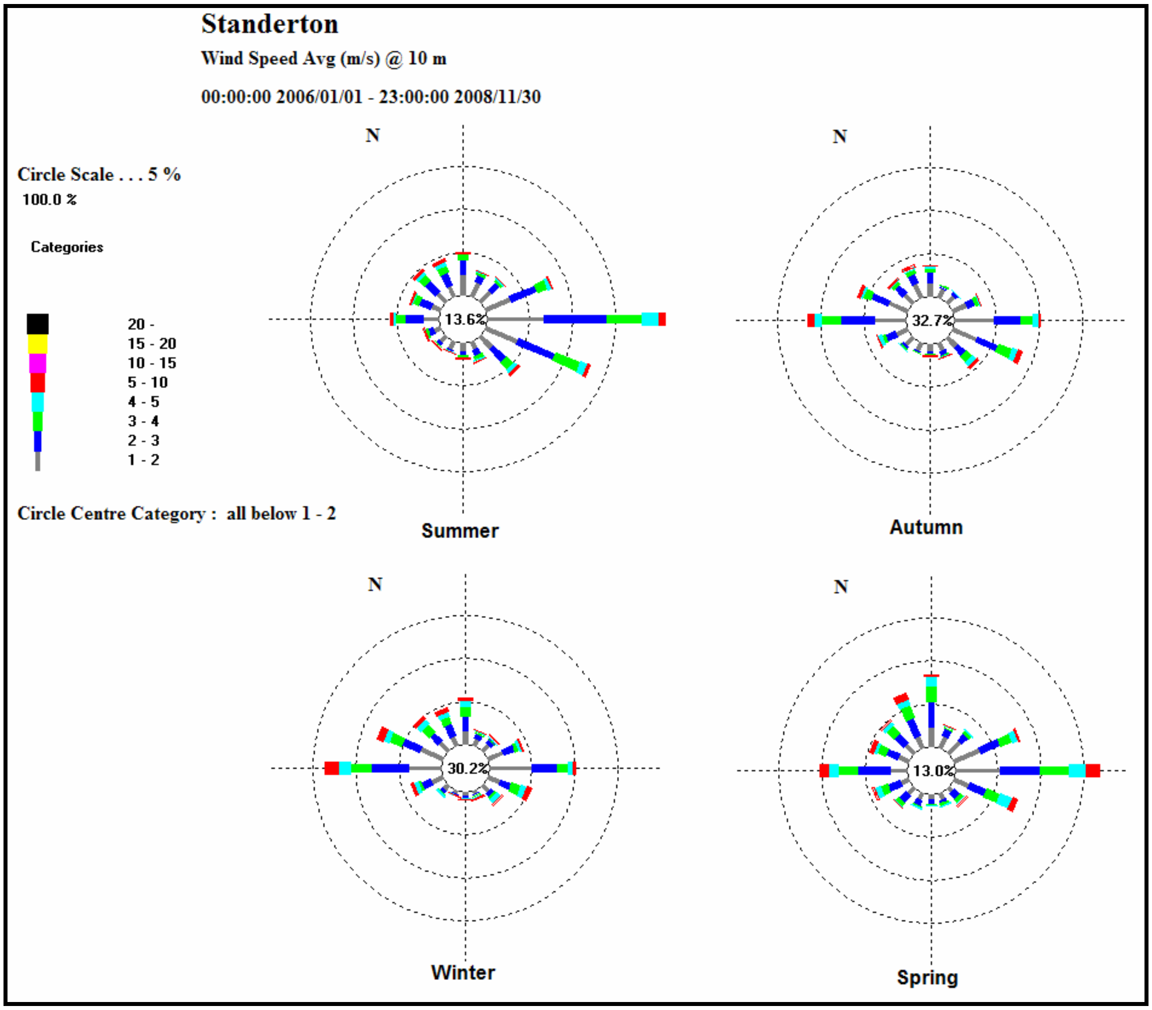

Figure 3-4: Seasonal wind roses for Standerton (2006-2008).

3.3.2 Ambient Temperature

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume is able to rise), and determining the development of the mixing and inversion layers.

As the earth cools during night-time the air in direct contact with the earth's surface are forced to cool accordingly. This is clearly evident from Figures 3-5, reflecting the diurnal temperature profiles at the site. The coldest time of the day appears to be between 04:00 and 07:00, which is just before or after sunrise. After sunrise surface heating occurs and as a consequence the air temperature gradually increases to reach a maximum at approximately 14:00 in the afternoon.

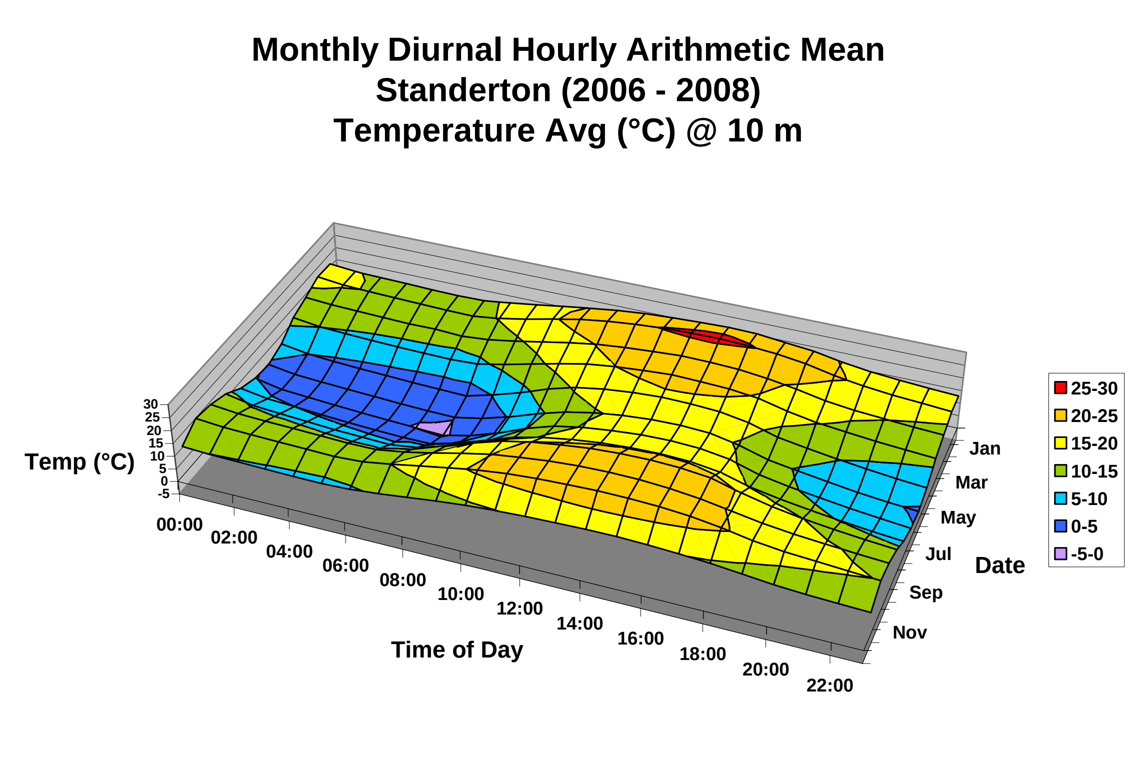

Figure 3-5: Diurnal and monthly variation of ambient air temperatures at Standerton for the period 2006-2008.

The annual average maximum, minimum and mean temperatures are given as 21.9°C, 8°C and 14.5°C respectively (Table 3-2). An average monthly maximum temperature of 25.6°C for Standerton was recorded during February for the period 2006-2008 and a minimum temperature of -0.6°C was recorded in July.

Table 3-2: Maximum, minimum and mean monthly temperatures at the Standerton monitoring station (2006-2008).

Temperature °C	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Monthly min (°C)	14.0	13.8	11.7	8.4	2.3	0.1	-0.6	2.6	6.5	11.2	12.8	13.7	8.0
Monthly mean (°C)	18.6	19.4	16.6	14.2	10.0	7.6	8.1	10.5	15.0	16.9	17.9	18.7	14.5
Monthly max (°C)	24.1	25.6	22.7	21.5	19.1	17.1	17.8	19.5	24.0	23.5	23.5	24.1	21.9

3.3.3 Atmospheric Stability

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. This layer is directly affected by the earth's surface, either through the retardation of flow due to the frictional drag of the earth's surface, or as result of the heat and moisture exchanges that take place at the surface. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the extension of the mixing layer to the lowest elevated inversion. Radiative flux divergence during the night usually results in the establishment of ground based inversions and the erosion of the mixing layer.

Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 3-2. The hourly standard deviation of wind direction, wind speed and predicted solar radiation were used to determine hourly-average stability classes.

The atmospheric boundary layer is normally unstable during the day as a result of the turbulence due to the sun's heating effect on the earth's surface. The thickness of this mixing layer depends predominantly on the extent of solar radiation, growing gradually from sunrise to reach a maximum at about 5 to 6 hours after sunrise. This situation is more pronounced during the winter months due to strong night-time inversions and slower developing mixing layer. During the night a stable layer, with limited vertical mixing, exists. During windy and/or cloudy conditions, the atmosphere is normally neutral.

For elevated releases, the highest ground level concentrations would occur during unstable, daytime conditions. The wind speed resulting in the highest ground level concentration depends on the plume buoyancy. If the plume is considerably buoyant (high exit gas velocity and temperature) together with a low wind, the plume will reach the ground relatively far downwind. With stronger wind speeds, on the other hand, the plume may reach the ground closer, but due to increased ventilation, it would be more diluted. A wind speed between these extremes would therefore be responsible for the highest ground level concentrations. In contrast, the highest concentrations for ground level, or near-ground level releases would occur during weak wind speeds and stable (night-time) atmospheric conditions.

Table 3-3: Atmospheric Stability Classes.

Designation	Stability Class	Atmospheric Condition
A	Very unstable	calm wind, clear skies, hot daytime conditions
B	Moderately unstable	clear skies, daytime conditions
C	Unstable	moderate wind, slightly overcast daytime conditions
D	Neutral	high winds or cloudy days and nights
E	Stable	moderate wind, slightly overcast night-time conditions
F	Very stable	low winds, clear skies, cold night-time conditions

The variation of stability with wind direction for Standerton (for the period 2006 – 2008) is given in Figure 3-6. It is noted that the winds are more frequent from the east and then from the west. A high frequency of very stable conditions occurs from the east with a high frequency of unstable conditions from the west.

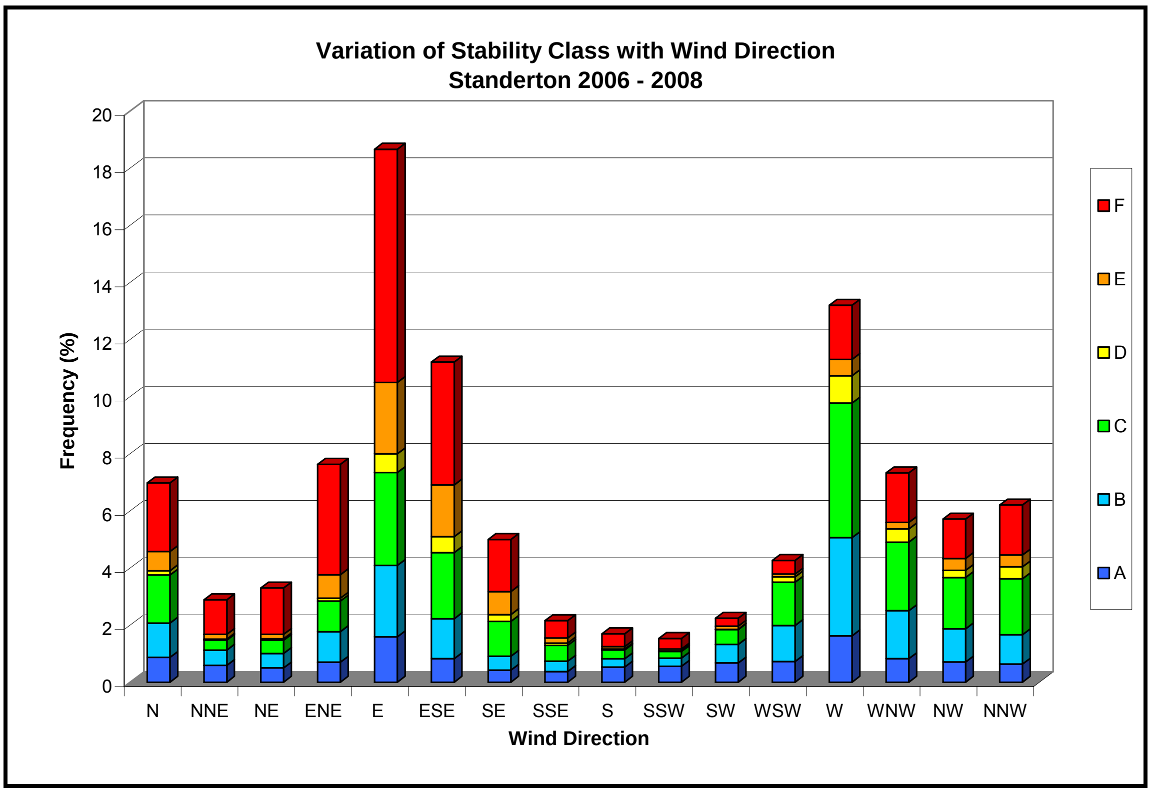

Figure 3-6: Variation of stability with wind direction for Standerton (2006 – 2008)

3.4 Existing Air Quality Sources and Possible Pollutants

The contribution of various sources of emission to ambient particulate concentrations within the proposed Tutuka GWDS is of interest given the potential for elevated concentrations in the area. The most significant sources located in close proximity to the proposed Tutuka GWDS include:

- Stack, vent and fugitive emissions from industrial operations - industrial emissions include various criteria pollutants (as SO_2, NO_x, CO and particulates), greenhouse gases (CO_2 and CH_4), volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), various heavy metals and other toxins. The closest industrial activity to the proposed Tutuka GWDS includes the Tutuka Power Station (~1.5km to the east). Sources of emission at these operations typically include boiler stack emissions (i.e. particulates, NO_x, SO_2, VOCs, CO and CO_2), and fugitive emissions from wind blown sources (i.e. ash dump) and vehicle entrainment.

- Fugitive emissions from mining operations - comprising mainly dust releases, with small amounts of NO_x, CO, SO_2, methane, CO_2 being released during blasting operations and vehicle exhaust. The closest mining operations to the proposed Tutuka GWDS are the New Denmark Colliery (~4.5km to the northwest).

- Vehicle tailpipe emissions - significant primary pollutants emitted by motor vehicles include CO_2, CO, hydrocarbons (HCs), SO_2, NO_x, particulate matter and lead. The regional road R38 runs to the east of the Tutuka Power Station.

- Household fuel combustion (coal, wood) - coal burning emits a large amount of gaseous and particulate pollutants including SO_2, heavy metals, total and respirable particulates including heavy metals and inorganic ash, CO, polycyclic aromatic hydrocarbons (PAHs), NO_2 and various toxins such as benzo(a)pyrene. Pollutants from wood burning include respirable particulates, NO_2, CO, PAHs, particulate benzo(a)pyrene and formaldehyde. Particulate emissions from wood burning have been found to contain about 50% elemental carbon and about 50% condensed hydrocarbons. The Thuthukani Township where domestic fuel burning may take place is ~1.5km to the west-southwest of the proposed Tutuka GWDS.

- Biomass burning - major pollutants from veld fires are particulates, CO and VOCs. The extent of NO_x emissions depends on combustion temperatures, with minor sulphur oxides being released.

- Various miscellaneous fugitive dust sources, including: agricultural activities, wind erosion of open areas, vehicle-entrainment of dust along paved and unpaved roads.

The pollutants listed above are released directly by sources and are therefore termed 'primary pollutants'. 'Secondary pollutants' which form in the atmosphere as a result of chemical transformations and reactions between various compounds include: NO_2, various photochemical oxidants (e.g. ozone), hydrocarbon compounds, sulphur acid, sulphates, nitric acid and nitrate aerosols.

Ambient air pollutant concentrations within the region occur not only due to local source but also as a result of emissions from various remote sources. Regionally- transported air masses comprising well mixed concentrations of 'aged' (secondary) pollutants are known to represent a significant component of ambient fine particulate concentrations within the South African interior. Such air masses contain pollutants released from various remote sources including elevated releases from distant industrial operations and power generation facilities and large scale biomass burning in neighbouring countries. Typical pollutants which circulate within such regionally-transported polluted air masses include nitrates, ammonium nitrate and sulphates.

The quantification of background particulate concentration, which is of particular importance given the nature of the proposed development, is complicated due to the large number of sources of this pollutant. Sources of particulates also include a significant proportion of fugitive emissions from diffuse sources (e.g. vehicle-entrained dust from roadways, wind-blown dust from stockpiles and open areas, dust generated by materials handling) which are more difficult to quantify than are emissions from a point source.

The characterisation of existing air quality is crucial for assessing the potential for cumulative impacts due to the emissions of a proposed development. As part of the Highveld Air Quality Monitoring Network, ambient monitoring stations have been placed over the Highveld region to monitor the ambient air quality. The closest monitoring station to the proposed Tutuka GWDS is located at Standerton. Although permission to obtain this data from the Department of Economic Development, Environment and Tourism was requested, the data was not provided to date and thus could not be included in the current study.

4. QUALITATIVE IMPACT ASSESSMENT

4.1 Description

A landfill is a facility for the disposal of waste materials by burial and is usually classified according to the type(s) of waste material deposited. Modern landfills are generally very complex systems where various chemical and biological processes occur simultaneously. These processes, including bacterial decomposition, volatilization and chemical reactions, produce a number of different landfill gases. The rate and volume of landfill gas produced depend on landfill characteristics such as waste composition, the age of the refuge, the presence of oxygen in the waste, the moisture content of the waste and temperature. The gases generated within the landfill will follow the path of least resistance and may move upward through the landfill surface if it is less dense than air (e.g. methane), or migrate horizontally to other areas if upward movement is prohibited. Gas denser than air (e.g. CO_2) tends to collect in subsurface areas.

A number of adverse air quality impacts such as explosion hazards, asphyxiation hazards, odours and low-level chemical exposures, could occur as a result of landfill operations. It is therefore essential that gaseous landfill emissions be quantified in order to assess the potential for hazards, health risk and nuisance impacts.

The waste that requires disposal on the proposed Tutuka GWDS originates from four main sources:

- Tutuka Power Station domestic and garden waste;
- Tutuka Power Station contractor domestic and building rubble waste;
- Thuthukani township domestic waste; and
- New Denmark Colliery domestic and garden waste.

The volumes of waste vary from month-to-month. Table 4-1 provides the average volumes of waste received by the existing disposal site for 2008 and 2009 to date. It is anticipated that the proposed Tutuka GWDS will have to take the same types of waste for the estimated life of the Tutuka Power Station, which is estimated for another 50 years.

It was assumed that operations at the proposed Tutuka GWDS will generally include the following activities:

(a) Domestic waste delivery by trucks;
(b) Cover and capping of filled areas;
(c) Final rehabilitation of the entire capped landfill area.

Table 4-1: Percentage split of the different waste streams received at the current landfill site for 2008 and 2009

Waste Type	2008	2009	Measurements
Domestic Waste	396	425	Monthly average tonnes
Garden Waste	256	166	
Building Waste	101	46	

4.2 Construction Phase

Atmospheric emissions represent the environmental aspects of concern in the current study. For the construction phase such aspects were identified as the clearing of the proposed Tutuka GWDS area, construction of buildings and vehicle entrainment.

Various components of the bio-physical and socio-economic environment may be impacted by the atmospheric emissions associated with the construction phase of the proposed Tutuka GWDS. Such components include:

- Ambient air quality;
- Local residents and neighbouring communities;
- Employees;
- The aesthetic environment; and
- Possibly fauna and flora

Unmitigated construction activities provide the potential for impacts on local communities, primarily due to nuisance and aesthetic impacts associated with fugitive dust emissions. On-site dustfall may also represent a nuisance to employees.

General Construction

The construction phase will comprise of land clearing and site development operations at the site. In order to determine the significance of the potential for impacts it is necessary to quantify atmospheric emissions and predicted airborne pollutant concentrations and dustfall rates occurring as a result of such emissions.

The construction phase will comprise a series of different operations including land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, (etc.). Each of these operations has its own duration and potential for dust generation. It is anticipated therefore that the extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions. This is in contrast to most other fugitive dust sources where emissions are either relatively steady or follow a discernible annual cycle. It is therefore often necessary to estimate area wide construction emissions, without regard to the actual plans of any individual construction process. Should detailed information regarding the construction phase be available, the construction process would have been broken down into component operations for emissions quantification and dispersion simulations. Due to the lack of detailed information (e.g. number of dozers to be used, size and locations of raw materials stockpiles and temporary roads, rate of on-site vehicle activity), emissions were instead estimated on an area wide basis. The quantity of dust emissions is assumed to be proportional to the area of land being worked and the level of construction activity.

The US-EPA documents emissions factors which aim to provide a general rule-of-thumb as to the magnitude of emissions which may be anticipated from construction operations. Based on field measurements of total suspended particulate, the approximate emission factors for construction activity operations are given as:

$$\mathbf{E = 2.69\ Mg/hectare/month\ of\ activity\ (269\ g/m^2/month)}$$

These emission factors are most applicable to construction operations with (i) medium activity levels (including blasting operations), (ii) moderate silt contents, and (iii) semiarid climates.

PM10 is assumed to represent ~35% of the TSP emissions given that this is the approximate PM10 component of vehicle-entrainment releases and such releases are anticipated to represent the most significant source of dust during construction operations.

4.3 Operational Phase

4.3.1 Landfill Emissions

Under standard operating practices, the proposed Tutuka GWDS is expected to be characterised by the following sources of atmospheric emissions:

- Gaseous emissions from the working surface and covered portions of the landfill; and,
- Fugitive particulate emissions as a result of vehicles travelling on unpaved road surfaces.

4.3.1.1 Gaseous Emissions from Working Surfaces and Covered Portions of the Landfill

The nature of emissions emanating from the proposed landfill site is dependent on the following factors:

(a) the composition of the waste to be received at the site;
(b) the design and operational practices (e.g. treatment policies);
(c) the chemical reactions within the landfill; and
(d) the stage of the landfill gas generation process

The key odorous, toxic components and indicator species of the landfill gas are listed in Table 4-2.

The generation of gas, primarily due to microbial decomposition, climatic conditions, refuse characteristics and land-filling operations, represents an inevitable consequence of the waste disposal in landfills. Numerous factors affect the ultimate rate with which gases may be released from the covered portions of the landfill. Such factors include advection, diffusion, accumulation, generation, adsorption, biodegradation, leaching, capillary action and evaporation.

Table 4-2: Key odourous, toxic components and indicator species of landfill gas

1'1'1'2-tetrafluorochloroethane	cymenes	MTBE
1'1'1-trichlorotrifluoroethane	decane	naphthalene
1'1'2-trichloroethane	dibromomethane	n-butyl acetate
1'1-dDichloroethane	Dichlorodifluoromethane	Nitric acid
1'1-dichloroethene	dichlorofluoromethane	nitrogen oxides (reported as NO_2)
1'1-dichlorotetrafluoroethane	dichloromethane	nitropentane
1'2-dibromo-3-clhoropropane	diethyl disulphide	n-nonane
1'2-dibromoethane	diethyl disulphide	n-octane
1'2-dichloropropane	diethyl ether	n-propanol
1'2-dichlorotetrafluoroethane	dimethyl disulphide	n-propyl benzene
1'2-dichlorotetrafluoroethylene	dimethyl disulphide	odour Units (Predicted)
1'3-dichlorobenzene	dimethyl sulphide	para-dichlorobenzene
1-chloro-1'1-difluoroethane	dimethyl sulphide	pentachloroethane
1-chlorobutane	dioxins and furans	pentane
2-chloro-1'1'1-trifluoroethane	dodecane	pentene (all isomers)
2-hexanone	ethane	perflourocarbons (PFCs) (Total)
2-methyl heptane	ethanethiol	pinene
2-Propanol	ethanethiol (ethyl mercaptan)	PM10s
acetalehyde (ethanal)	ethanol	propane
acetone	ethyl toluene (all isomers)	propanethiol
acrylonitrile	ethylbenzene	propanethiol

benzene	ethylene	propionitrile
benzo(a)pyrene (PAH)	ethylene dibromide	styrene
benzyl chloride (chlorobenzene)	ethylene dichloride	sulphide - with H2S
bromodichloromethane	fluorotrichloromethane	sulphide - without H2S
bromoethane	formaldehyde (methanal)	sulphur reduced (reported as SO2)
bromoform	freon 113	t-1'2-dichloroethene
bromomethane	halons	t-1'3-dichloropropane
butadiene (as 1'3-Butadiene)	heptane	tetrachloroethane
butane	hexachloro1'3-butadiene	tetrachloroethylene (tetrachloroethene)
butene isomers	hexachlorocyclohexane	tetrahydrofuran
c-1'2-dichloroethene	hexachloroethane	toluene
c-1'3-dichloropropane	hexane	total chloride (reported as HCl)
carbon disulphide	hydrochloroflourocarbons	total fluoride (reported as HF)
carbon monoxide	hydroflourocarbons (HFCs)	total non-methane VOCs
carbon tetrachloride	hydrogen sulphide	trichlorobenzene (all isomers)
carbonyl sulphide	hydrogen sulphide	trichloroethylene
chloro ethyl vinyl ether	limonene	trichlorofluoromethane
chlorobenzene	mercury	trichlorotrifluoroethane
chlorodibromomethane	methanethiol	trimethylbenzene (all isomers)
chlorodifluoromethane	methanethiol (methyl mercaptan)	trimethylpentane
chloroethane	methyl acrylate	undecane
chloroflourocarbons (CFCs)	methyl chloride (chloromethane)	vinyl acetate
chlorofluoromethane	methyl chloroform	vinyl chloride (chloroethene chloroethylene)
chloroform (trichloromethane)	methyl ethyl ketone	xylene (all isomers)
chlorotrifluoromethane	methyl isobutyl ketone	
cumene	methyl methacrylate	
cyclohexane	methylcyclohexane	

4.3.1.2 Fugitive Dust Emission

Fugitive dust emissions at waste landfill sites occur as a result of vehicle entrainment, materials handling, bulldozing operations and wind erosion of open areas. Vehicle entrainment from on-site unpaved haul roads generally the most significant source of fugitive dust at waste disposal sites.

In assessing the impact of fugitive dust emissions a distinction need be made between Total Suspended Particulates (TSP) and respirable particulates. Although TSP may be defined as all particulates with an aerodynamic diameter of less than 100 µm, an effective upper limit of 30 µm aerodynamic diameter is frequently assigned. Respirable particulates are generally defined as particulate matter with an aerodynamic diameter of less than 10 µm (PM10).

PM10 has health implication since it represents particles of a size that would be deposited in, and damaging to the lungs. In the quantification of TSP and PM10 emissions, use is generally made of emission factors published by the US Environmental Protection Agency (US-EPA) in its AP-42 document Compilation of Air Pollution Emission Factors.

Vehicle-Entrained Dust from Roads

Vehicle-entrained dust emissions have been found to account for the greatest portion of fugitive dust emissions from many local waste disposal operations. The force of the wheels of vehicles travelling on unpaved roadways causes the pulverisation of surface material. Particles are lifted and dropped from the rotating wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. The quantity of dust emissions from unpaved roads varies linearly with the volume of traffic. The US-EPA emission factor used in the quantification of this fugitive emission source is given in Appendix A.

The main access road to the proposed Tutuka GWDS will link the site with one of the existing roads in the area. The US-EPA recommends a silt loading of 32 g/m² (upper range) for paved road surfaces at waste disposal sites. Mean silt content for unpaved roads given by the US-EPA as being typical for disposal routes at municipal solid waste landfills is 6.4%. The road silt loading range is given by the US-EPA as 2.2% to 21%.

It was provided that waste of 753 tpm and 637 tpm was transported to the current waste disposal site for the period 2008 and 2009 respectively. Taking the average waste for these two years and assuming the same waste throughput to the proposed Tutuka GWDS, it was calculated that ~6 trucks (with an average weight of 10.55 ton) would be required per day.

4.3.2 Impact Zones due to General Waste Landfills

Representative extents of health and nuisance impact zones were based on two quantitative studies undertaken by Airshed Planning Professionals (Pty) Ltd for general waste landfill sites (i.e. the proposed Waterval Waste Disposal Site and the Chloorkop Waste Disposal Site). These predicted impact zones provide an indication of the extent of health and nuisance impact zones that can be expected from General Waste Disposal Sites (Table 4-3).

The particulate matter impacts due to the operational phase of the landfill are due mainly to the vehicle activity at the facility. The Chloorkop and Waterval Landfill sites predicted ~400 trucks per day and ~159 trucks per day respectively to transport waste to the facilities. The proposed Tutuka GWDS is predicted to require ~6 trucks per day to transport the waste to the facility, considerably less than that of the Chloorkop and Waterval waste disposal sites. It is therefore expected that the particulate matter impact area at the proposed Tutuka GWDS will be less than that of the Chloorkop and proposed Waterval disposal facilities. The Chloorkop Landfill is ~ 24 ha with the proposed Waterval Landfill ~67 ha. Although the predicted impact areas due to gaseous landfill emissions at the Chloorkop and proposed Waterval landfill sites varied, the maximum predicted impacts distances were similar. Without undertaking a quantitative assessment of the proposed Tutuka GWDS it is assumed that maximum impact distances (due to gaseous landfill emissions) at this facility will be similar to the predicted impact distances at Chloorkop and proposed Waterval landfill facilities.

Table 4-3: Predicted impact zones from General Waste Disposal Sites

Study	Health/nuisance impact	Defining parameter used to determine impact zone	Criteria used to define impact zone	Maximum distance of impact from landfill site
Proposed Waterval General Waste Disposal Site [(a)]	Health	Proposed SA PM10 standard for daily average exposure	75 µg/m³	~300 m
		Total cancer risk	1 in 100 000 due to various carcinogens	~110 m
		Combined chronic hazard rating	Greater than 1 for non-carcinogenic health impacts	~50 m
	Nuisance	Odour impacts	Based on 2 OU/m³ (NSW criteria for Urban areas with >2000 people residing) for the highest odour impacts	~1250 m
		Dust fallout	250 mg/m²/day	~110 m

Study	Health/nuisance impact	Defining parameter used to determine impact zone	Criteria used to define impact zone	Maximum distance of impact from landfill site
			given by DEA for slight dust fallout	
Chloorkop General Waste Disposal Site [(b)]	Health	Proposed SA PM10 standard for daily average exposure	75 µg/m³	~200 m
		Total cancer risk	1 in 100 000 due to various carcinogens	~110 m
		Combined chronic hazard rating	Greater than 1 for non-carcinogenic health impacts	~50 m
	Nuisance	Odour impacts	Based on 2 OU/m³ (NSW criteria for Urban areas with >2000 people residing) for the highest odour impacts	~1720 m
		Dust fallout	250 mg/m²/day given by DEA for slight dust fallout	~500 m

Notes:

(a) Reference: von Gruenewaldt and Burger, 2009. This report is currently available as a draft for public comment. The Waterval WDS is proposed to be ~67ha with a waste throughput of 650 tpd.

(b) Reference: Scorgie, *et al*, 2006. The Chloorkop WDS is ~24ha with a waste throughput of 880 tpd.

4.4 Closure Phase

It is anticipated that the proposed Tutuka GWDS will be compacted and capped with soil material in order to cover the waste and to allow vegetation to re-establish on the site. The potential for impacts during this phase will depend on the extent of rehabilitation efforts during closure.

5. BUFFER ZONE DELINEATION

Buffer zones, or set back distances, represent separations between a registered landfill site boundary and any adjacent residential areas or sensitive developments. Such buffer zones are established to ensure that a landfill operation does not have an adverse impact on quality of life and/or public health. The establishment and maintenance of buffer zones is enforceable in terms of the Health Act, 1997 (Act 63 of 1977), which makes provision for measures necessary to prevent any nuisance, unhygienic or offensive condition that is harmful to health (DWAF, 1998).

Although the width of the buffer zone is prescribed for communal and small landfills, such zones need to be independently defined for all other landfills based on the classification of the landfill and on site-specific factors which may influence the landfill's impact on the environment (DWAF, 1998). The extent of gaseous emission is largely dependent on the composition of the waste accepted at the landfill and the waste treatment and management methods applied. The amount of vehicle activity at the site, and the control efficiency of fugitive dust abatement measures implemented determine the particulate emission rate. The atmospheric dispersion of gaseous and particulate emissions is a function of the macro-, meso- and micro-scale ventilation potentials characterising the site.

It is recommended by the Department of Water Affairs and Forestry (1998) that scientific investigations be undertaken to determine the width of buffer zones for large and hazardous waste landfills. Buffer zone widths are ultimately approved by the relevant government departments, on the basis of the investigations undertaken and following consultation with interested and affected parties.

The basis for determining buffer zones, given predicted odour and health impact zones, has been a point of contention. During consultations with DWAF representatives responsible for managing landfills in Gauteng it was recommended that a distinction be made between:

- Management zones - indicative of the odour and dust impact areas, with reductions in the extent of such impact areas requiring the implementation of emission reduction measures at the landfill site.
- Buffer zones - delineated exclusively on the basis of health impact zones and of crucial importance in terms of determining land use potentials.

5.1 General Criteria for Determining Buffer Zones

It is well established that human health and well-being are affected by air pollution, which has both acute and chronic impacts. The impact of air pollution on the natural environment is also an important factor that should be considered (Fenger et al. 1998). The main aim for spatial development is to avoid any adverse effects on public health and the environment.

Increasingly environmental indicators are used in Environmental Land Use Planning and Management to simplify environmental assessments. Indicators are defined as a single measure of a condition of an environmental element that represents the status or quality of that element. An index is a combination of a group of indicators to measure the overall status of an environmental element, and a threshold is the value of an indicator or index (Randolph, 2003).

5.1.1 Health Criteria

Limit values based on adverse health effects associated with air pollution (i.e. PM10 and gaseous pollutants from landfills) are the most important criteria for determining buffer zones within an environment. Of particular concern is the need to protect the most vulnerable citizens from the effects of air pollution. Effects on vulnerable groups were explicitly taken into account in the development of the WHO guidelines on which EU air quality objectives are based (COM, 2001). The ambient air quality guideline values indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality guidelines and standards are normally given for specific averaging periods.

The health criteria used in the determination of suitable buffer zones can be based on the following listed in order of importance:

- Frequency of Exceedance of Limit Values – allowable number of times per year that air quality limit values can be exceeded;
- Alert thresholds – refer to levels beyond which there is a risk to human health from brief exposure (requires immediate action) - only available for a few criteria pollutants;
- LOAEL – the lowest level at which adverse effects for a specific pollutant have been observed;
- Single Exceedance of Limit values – limit values are based on scientific knowledge, with the aim of avoiding, preventing or reducing harmful effects on human health and the environment as a whole.

5.1.2 Nuisance Criteria

Odour criteria are population dependent, reflecting the differing environmental nuisance or environmental harm associated with increasing potential for community exposure to the odour. Based on similar studies completed, odour impacts can generally be for distances up to 3000m but can be as far from the source as 5000m depending on the dispersion potential of the site and the type of landfill (EPA Australia, 2000). Typically the absolute odour detection threshold (50%) is used as guideline criteria.

5.1.3 Other Criteria

The Australian EPA in their draft Guidelines for Separation Distances includes visual impacts and nuisance from dust as criteria to define suitable buffer zones around waste facilities (EPA Australia, 2000).

Poor visibility is a side effect of atmospheric pollution caused by the attenuation, scattering, and absorption of light by the polluted air. It is usually easily recognisable with the unaided eye merely in the reduction of the number of objects that can be seen and the clarity of the objects (Fenger et al. 1998).

Nuisance impacts due to dust are associated with dustfall and soiling impacts and with reductions in visibility. Atmospheric particulates change the spectral transmission, thus diminishing visibility by scattering light. The scattering efficiency of such particulates is dependent upon the mass concentration and size distribution of the particulates. Various costs are associated with the loss of visibility, including: the need for artificial illumination and heating; delays, disruption and accidents involving traffic; vegetation growth reduction associated with reduced photosynthesis; and commercial losses associated with aesthetics. The soiling of building and materials due to dust frequently gives rise to damages and costs related to the increased need for washing, cleaning and repainting. Dustfall may also impact negatively on sensitive industries, e.g. bakeries or textile industries.

5.2 Current Buffer Zone Projection Methodology

Buffer zone projection is a tool to assist development proposals to ensure that incompatible land uses are located in such a way so that impacts caused by odour and polluting air emissions are minimised.

When considering buffer zone projection health, odour and nuisance impacts from the proposed development are taken into account. The distances of exceedance of the various health and odour criteria as a result of emissions from the proposed development are compared and the maximum distance of exceedance applied as the buffer zone.

For the proposed Tutuka GWDS the health risk impacts are expected to extend ~200 m - 300 m (maximum distance from landfill) based on qualitative studies undertaken for General Waste Disposal Sites. The nuisance impact areas are expected to extend ~1250 m to 1720 m. As no quantitative assessment was undertaken for the proposed Tutuka GWDS, it is recommended to implement as good practice a buffer zone around the proposed site based on South Australian EPA's draft document on "Guidelines for Separation Distances" (as a minimum).

A buffer zone is that area defined by the application of a separation distance from the activity boundary (EPA Australia, 2000). The Australian EPA regards sensitive land uses such as:

- Caravan parks;
- Community centres;
- Consulting rooms;
- Detached dwellings;
- Educational establishments;
- Childcare centres;
- Hospitals;
- Hotels;
- Motels;
- Multiple dwellings;
- Nursing homes;
- Offices;
- Residential flat buildings;
- Row dwellings;
- Parklands, recreational areas or reserves;
- Semi-detached dwellings; and,
- Zones (whether developed or not) designed in a Development Plan which list any sensitive land use listed above as complying development.

According to the Australian EPA in their guidelines for Separation Distances (August 2000), the recommended distance from a landfill site is between 200m and 3000m. This, however, assumes that Best Available Technology Economically Achievable (BATEA) is implemented. More specifically, the Australian EPA recommends minimum separation distances for new major solid waste landfill depots as stipulated in Table 5-1.

In terms of ***air quality*** the recommended separation distance as provided by the Australia EPA is given as 500 m from residential developments for odour, dust and gas migration problems. The proposed Tutuka GWDS meets the recommended separation distances of 500 m from residential developments (with the Thuthukani Township ~1.5km to the west-southwest).

It is therefore recommended that a buffer zone (delineation exclusively on the basis of health impact zones) be a minimum distance of 500 m from the proposed Tutuka GWDS. Based on odour impacts from previous quantitative studies undertaken for General Waste Disposal Sites, it is recommended that the management zone (delineation based on nuisance issues, i.e. odour impacts and dust fallout) be a distance of ~1500m from the proposed Tutuka GWDS.

Table 5-1: Recommended separation distances for new solid waste landfill depots (EPA Australia, 2000)

Sensitive Land Use	Objectives	Proposed separation distance from operations area
Urban residential development	Protection of residential and visual amenity, e.g. minimise odour, dust, noise, seepage, gas migration problems	500m
Highways and arterial road networks	Protection of safety & visual amenity, e.g. ensure safe monitoring, minimise dust & litter migration.	500 m
Rural township	Protection of residential and visual amenity, e.g. minimise odour, dust, noise, seepage, gas migration problems	500 m
Flood plain/ surface water	Protection of waters from pollution; users of surface waters not compromised; no significant impacts on fauna and flora, maintenance of ecological value of water	500 m minimum from limit of 100 ARI[(a)] flood plain / surface water
Airport	Protection of air traffic from bird hazards	3000 m to runway (turbojet aircraft)

Notes:

(a) 100 ARI flood plain means the area which would be inundated by the occurrence of a flood having an average recurrent interval of 100 years

6. IMPACT SIGNIFICANCE RATING

The significance of the identified impacts is determined using the approach outlined below. This incorporates two aspects for assessing the potential significance of impacts, namely occurrence and severity, which are further sub-divided as follows:

Occurrence		Severity	
Probability of occurrence	Duration of occurrence	Magnitude (severity) of impact	Scale/extent of impact

To assess each of these factors for each impact, the following four ranking scales are used:

Probability	Duration
5 – Definite/don't know	5 – Permanent
4 – Highly probable	4 – Long-term
3 – Medium probability	3 – Medium term (8-15 years)
2 – Low probability	2 – Short-term (0-7 years)
1 – Improbable	1 – Immediate
0 – None	
Scale	**Magnitude**
5 – International	10 – Very high/don't know
4 – National	8 – High
3 – Regional	6 – Moderate
2 – Local	4 – Low
1 – Site only	2 – Minor
0 – None	

Once these factors are ranked for each impact, the significance of the two aspects, occurrence and severity, is assessed using the following formula:

SP (significance points) = (magnitude + duration + scale) x probability

The maximum value is 100 significance points (SP). The impact significance will then be rated as follows:

SP>60	**High** environmental significance
SP 30-60	**Moderate** environmental significance
SP<30	**Low** environmental significance

For the purposes of assessing the impacts identified, the proposed project will be divided into four phases from which impacting activities have been identified:

- Construction Phase,
- Operational Phase, and
- Decommissioning Phase.

The activities arising from each phase will be included in an assessment table so as to facilitate the identification of those activities which require certain management actions to mitigate the impacts arising from them.

6.1 Construction Phase

Only particulate impacts due to wind erosion on open surfaces, materials handling due to earthworks to shape the floor to an even grade and vehicle entrainment are predicted to be related to construction phase. Possible air quality impacts associated with these emissions are health risks associated with predicted inhalable particulate matter and nuisance impacts as a result of predicted dustfall levels.

Table 6-1: Impact significance rating due to construction phase

Impact	Duration [(a)]	Spatial Scale[(b)]	Probability [(c)]	Magnitude [(d)]	Significance Points (SP)	Significance [(e)]
PM10	Short-term (2)	Localised (2)	Medium probability (3)	Low (4)	24	LOW
Dustfall	Short-term (2)	Localised (2)	Medium probability (3)	Low (4)	24	LOW

NOTES:

(a) Short-term duration of impacts for the construction period. These are short-term impacts on the affected system(s) or party(ies) that could be mitigated.

(b) Localised particulate impacts (from a few hectares in extent) are expected due to the constructional phase.

(c) The probability is given as medium as exceedances of the particulate ambient standards may occur off-site due to the constructional phase.

(d) As the impacts are expected to be in the vicinity of the proposed site (<1 km), the magnitude is given as low.

(e) Impacts are rated as LOW.

6.2 Operation Phase

This impact assessment addressed emissions from the operational phase of the landfill. Emissions associated with the operational phase of the landfill include the following:

- Fugitive dust emissions from vehicle entrainment; and
- Landfill gas emissions

Possible air quality impacts associated with these emissions are:

- Health risks associated with predicted inhalable particulate and landfill gas concentrations;
- Cancer risks associated with predicted landfill gas concentrations;
- Odour impacts associated with predicted landfill gas concentrations; and
- Nuisance impacts as a result of predicted dustfall levels.

Table 6-2: Impact significance rating of the operational phase at the proposed Tutuka GWDS

Impact	Duration [(a)]	Spatial Scale[(b)]	Probability [(c)]	Magnitude [(d)]	Significance Points (SP)	Significance [(e)]
PM10	Long-term (4)	Localised (2)	Medium probability (3)	Low (4)	30	MODERATE
Dustfall	Long-term (4)	Localised (2)	Medium probability (3)	Low (4)	30	MODERATE
Health Risk	Long-term (4)	Localised (2)	Medium probability (3)	Low (4)	30	MODERATE
Cancer Risk	Long-term (4)	Localised (2)	Medium probability (3)	Low (4)	30	MODERATE
Odour	Long-term (4)	Localised (2)	Medium probability (3)	Low (4)	30	MODERATE

NOTES:

(f) The impacts are given as long-term as the particulate and gaseous emissions from the landfill will continue during the entire operation of the proposed Tutuka GWDS.

(g) Localised particulate and gaseous impacts (from a few hectares in extent) are expected due to the operational phase.

(h) The probability is given as medium as exceedances of the particulate ambient standards as well as health criteria for non-carcinogenic pollutants and carcinogenic pollutants as well as odour impacts may occur off-site due to the operational phase.

(i) As the impacts are expected to be in the vicinity of the proposed site (<1 km), the magnitude is given as low.

(j) Impacts are rated as MODERATE.

6.3 Decommissioning Phase

Only landfill gas emissions are associated with the decommissioning (post-closure) phase. No particulate emissions are expected since no materials handling or vehicle activities will be present and all exposed areas are expected to be closed and rehabilitated.

Possible air quality impacts associated with the decommissioning phase are:

- Health risks associated with predicted landfill gas concentrations;
- Cancer risks associated with predicted landfill gas concentrations; and
- Odour impacts associated with predicted landfill gas concentrations.

Table 6-3: Impact significance rating of the decommissioning (post-closure) phase

Impact	Duration [(a)]	Spatial Scale[(b)]	Probability [(c)]	Magnitude [(d)]	Significance Points (SP)	Significance [(e)]
Health Risk	Long-term (4)	Localised (2)	Medium probability (3)	Low (4)	30	MODERATE
Cancer Risk	Long-term (4)	Localised (2)	Medium probability (3)	Low (4)	30	MODERATE
Odour	Long-term (4)	Localised (2)	Medium probability (3)	Low (4)	30	MODERATE

NOTES:

(a) The impacts are given as long-term as the gaseous emissions from the landfill will continue for some time after the operational phase of a landfill.

(b) Localised gaseous impacts (from a few hectares in extent) are expected during the decommissioning phase.

(c) The probability is given as medium as exceedances of the health criteria for non-carcinogenic pollutants and carcinogenic pollutants as well as odour impacts may occur off-site due to the decommissioning phase.

(d) As the impacts are expected to be in the vicinity of the proposed site (<1 km), the magnitude is given as low.

(e) Impacts are rated as MODERATE.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Principal Findings

A qualitative air quality impact assessment has been undertaken for the proposed Tutuka GWDS aimed at assessing associated impacts with the proposed operations and to determine delineated buffer and management zones. The main findings can be summarised as follows:

- **Dispersion potential of the site:** The dispersion potential for the site was determined by assessing meteorological data from the closest SAWS station of Standerton. The dominant wind direction at Standerton for the period 2006 – 2008 was from the east (~14% frequency of occurrence) and from the west (~10% frequency of occurrence). Day-time conditions were characterised by an increase in westerly winds (~15% frequency of occurrence) with night-time conditions reflecting an increase in easterly winds and high calm conditions (33.7%).

- **Atmospheric stability:** A high frequency of very stable conditions occurs from the east with a high frequency of unstable conditions from the west. For ground level, or near ground-level releases, the highest ground level concentrations would occur during weak wind speeds and stable (night-time) atmospheric conditions.

- **Ambient air quality in the vicinity of the site:** Sources that may contribute to the ambient air quality within the vicinity of the proposed Tutuka GWDS include industrial activities (i.e. Tutuka Power Station), mining operations, vehicle emissions, domestic fuel burning, farming activities, and biomass burning.

- **Buffer and management zone delineation:** In terms of air quality the recommended separation distance for landfill sites as provided by the Australia EPA is given as 500 m from residential developments for odour, dust and gas migration problems. The proposed Tutuka GWDS meets the recommended separation distances of 500 m from residential developments (with the Thuthukani Township ~1.5km to the west-southwest). Based on health impacts from previous quantitative studies for General Waste Disposal Sites the maximum impact distance was ~200m – 300m. Based on odour impacts from previous quantitative studies undertaken for General Waste Disposal Sites, the impact distance (assuming the odour criteria of

2OU/m³ for residential areas of greater than 2000 residents) ranges from ~1250 m – 1720 m.

7.2 Recommendations

- It is recommended that the proposed Tutuka GWDS be operated according to the Minimum Requirements for Waste Disposal by Landfill (Second Edition 1998).

- As the Minimum Requirements currently do not provide recommended buffer zone distances for landfill sites it is recommended that a buffer zone (delineation exclusively on the basis of health impact zones) be a minimum distance of 500 m from the proposed Tutuka GWDS as stipulated by the Australia EPA. Based on odour impacts from previous quantitative studies undertaken for General Waste Disposal Sites, it is recommended that the management zone (delineation based on nuisance issues, i.e. odour impacts and dust fallout) be a distance of ~1500m from the proposed Tutuka GWDS. It should be noted, however, that these recommended buffer and management zone delineations are based on previous studies undertaken. In order to more accurately understand the delineated zones required for the proposed Tutuka GWDS, a quantitative assessment should be undertaken.

- Ambient PM10 concentrations and dust fallout measurements should be undertaken in the vicinity of the proposed Tutuka GWDS prior to its operation in order to establish background ambient air quality. Once the proposed Tutuka GWDS is in operation, the ambient measurements will provide an indication of impacts due to the General Waste Disposal Site.

- The proposed Tutuka GWDS operator should control on-site fugitive dust emissions by effective management and mitigation due to the potential cumulative impacts of this pollutant in the study area.

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APPENDIX A – FUGITIVE DUST EMISSION FACTORS AND EQUATIONS

Vehicle Entrained Dust from Unpaved Roads

Vehicle-entrained dust emissions have been found to account for a great portion of fugitive dust emissions from open pit mining operations. The force of the wheels of vehicles travelling on unpaved haul roads causes the pulverisation of surface material. Particles are lifted and dropped from the rotating wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. The quantity of dust emissions from unpaved roads varies linearly with the volume of traffic.

The unpaved road size-specific emission factor equation of the US-EPA, used in the quantification of emissions, is given as follows:

$$E = k\left(\frac{s}{12}\right)^{a} \cdot \left(\frac{W}{3}\right)^{b} \cdot 281.9$$

Where,

E	=	*emissions in lb of particulates per vehicle mile travelled (g/VKT)*
K	=	*particle size multiplier (dimensionless);*
S	=	*silt content of road surface material (%);*
W	=	*mean vehicle weight (tons)*

The particle size multiplier in the equation (k) varies with aerodynamic particle size range and is given as 1.5 for PM10 and 4.9 for total suspended particulates (TSP). The constants a and b are given as 0.9 and 0.45 respectively for PM10 and as 0.7 and 0.45 respectively for TSP.

Vehicle Entrained Dust from Paved Roads

Particulate emissions will result from the entrainment of loose material from the paved road surface due to vehicle traffic (Cowhert and Engelhart, 1984, 1985; Jones and Tinker, 1984). The extent of particulate emissions from paved roads is a function of the "silt loading" present on the road surface. In return, the silt loading is affected by the mean speed of vehicles on the road, the average daily traffic, the number of lanes and to a lesser extent of the average weight of vehicles travelling on the road (Cowhert and Engelhart, 1985; EPA, 2006). Silt loading (sL) refers to the mass of silt-size material (i.e. equal to or less than 75 microns in diameter) per unit area of the travel surface.

The quantity of dust emitted from vehicle traffic on paved roads was estimated based on the following equation (EPA, 2006):

$$E = k(\frac{sL}{2})^{0.65}(\frac{W}{3})^{1.5} - C$$

where,

E = particulate emission factor in grams per vehicle km traveled (g/VKT)
K = basic emission factor for particle size range and units of interest
sL = road surface silt loadings (g/m^2)
W = average weight (tons) of the vehicles traveling the road
C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear.

The particle size multiplier (k) is given as 4.6 for PM10, and as 24 for TSP. The emission factor (C) is given as 0.1317 g/VKT for PM10 and TSP.