global environmental solutions

Manganese Mine

near Hotazel

Northern Cap Province

Kudumane Manganese Resources (Pty) Ltd

Air Quality Impact Assessment

SLR Ref: 4AF.03471.00026

August 2014

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ACRONYMS AND ABBREVIATIONS

Below a list of acronyms and abbreviations used in this report.

Acronyms / Abbreviations	**Definition**
AQA	Air Quality Act
AQS	Air Quality Standard
CO	Carbon monoxide
DMP	Dust Management Plan
EF	Emission factor
EIA	Environmental Impact Assessment
EP	Equator Principles
IFC	International Finance Corporation
NO2 / NOx	Nitrogen dioxide / nitrogen oxide
NPI	National Pollution Inventory
PM10	particles of an aerodynamic diameter of less than 10 micrometers
ROM	Run-of-Mine
SANS	South African National Standards
SO2	Sulphur dioxide
SRTM	Shuttle Radar Topography Mission
TSF	Tailings Storage Facility
TSP	Total Suspended Particulates
US-EPA	United States Environmental Protection Agency
WB/IFC	World Bank/International Finance Corporation
WHO	World Health Organisation
WRD	Waste Rock Dump

1.0 INTRODUCTION

Kudumane Manganese Resources (Pty) Ltd (Kudumane), a South African mining company holds a mining right on the farms York A 279 (York) and Telele 312 (Telele) located approximately 3km south west of the town of Hotazel in the John Taolo Gaetsewe District Municipality in the Northern Cape.

The Environmental Impact Assessment (EIA) and Environmental Management Programme (EMP) submitted as part of the approved mining right application covers the opencast mining and infrastructure on the farm York and underground mining on the farm Telele under the DMR authorisation (NC 30/6/1/2/2/268 MR). In broad terms the approved EIA/EMP included the establishment of an opencast and future underground mining operation, associated residue handling and disposal facilities, a crushing and screening plant, water management facilities, rail and road transport infrastructure and various support infrastructure and service.

Kudumane now wishes to expand its mining operations and applied for a new mining right to include the farms Kipling 217 (Kipling), Devon 277 (Devon) and Hotazel 280 (Hotazel). In addition to adding new mining rights to its existing mining rights areas, Kudumane intends to establish additional infrastructure to what has already been approved.

This report presents an assessment of potential impacts of this project on air quality in the surrounding environment. The assessment describes the scope, relevant legislation, assessment methodology and the baseline conditions (both currently existing in the project area and with the already approved mine development). It then considers any potentially significant environmental affects the proposed facility would have on this baseline environment; the mitigation measures required to prevent, reduce or offset any significant adverse affects; and the likely residual impacts after these measures have been employed.

1.1 Brief Project Description

1.1.1 Existing Mining Rights Areas

Kudumane is currently operating under a mining right (NC 30/6/1/2/2/0268 MR) for the remainder of portion 1 of the farm Telele and the remainder of portion 2 of the farm York 279. The mining right was executed on the 26th April 2013. In broad terms the approved mining right and related EIA/EMP (Metago 2010) made provision for 1.9 million tons of run-of-mine (ROM) per annum through opencast mining and subsequent 1.7 million tons of run-of-mine (ROM) per annum through underground mining. Allowance was made for a crushing and screening plant, waste rock dumps (WRDs), topsoil stockpiles, manganese ore stockpiles, storage of hazardous substances, sewage treatment facilities, staff accommodation, administration facilities and transport, rail and conveyance infrastructure. Infrastructure has already been established on site, the main body of the EIS, lists those items completed and those yet to be constructed.

In addition to the approved infrastructure, Kudumane is also proposing the following changes in infrastructure within the existing mining rights areas:

- Telele - changes to surface infrastructure associated with underground mining; and
- York - additional surface infrastructure (additional WRDs, stockpile area, sewage treatment plants pollution control dam etc.)

1.1.2 New Mining Rights Area

Kudumane is proposing the following infrastructure on the new mining rights areas:

- Hotazel and Kipling - new opencast pit and associated infrastructure (WRDs, water management infrastructure, soil and overburden stockpiles) including linear infrastructure connecting the pit with the existing mining operations on York; and
- Devon - mining and removal of manganese ore from the historical pit and tailings storage facility (TSF).

1.2 Scope and Objectives

The scope of the air quality assessment focuses on particulate emissions, these having been identified as the primary pollutants associated with the proposed mining activities and most likely to have an effect on local air quality considering the potential magnitude of emissions.

Assessment of particulate emissions has been considered both in terms of suspended particulate and deposited dust, specifically

- particles of an aerodynamic diameter of less than 10 micrometers (PM_{10}) including manganese for which air quality standards have been developed for the protection of health; and
- dust deposition (or soiling) that is associated with nuisance.

The assessment has the following objectives:

- to qualify the ambient air quality baseline;
- to quantify all proposed emission sources in an emissions inventory;
- to determine the relevant meteorological conditions in the project area including wind speeds and direction;
- to model the dispersion of emissions to air;
- to assess the potential off-site impacts of the emissions (mitigated and unmitigated scenarios); and
- to compare these estimated impacts to relevant guideline standards and evaluate the impacts.

1.3 Report Outline

The remainder of the report is set out as follows:

- Section 2 presents the methodology adopted for the assessment;
- Section 3 presents a summary of the legislation and guidance directly relevant to air quality and the scope of this report;
- Section 4 presents a review of the relevant meteorological parameters relevant to this assessment;
- Section 5 presents a review of the existing baseline air quality and monitoring data;
- Section 6 presents the estimation of emissions derived on the basis of the proposed operations;
- Section 7 presents the assessment of predicted impacts;
- Section 8 presents recommendations; and
- Section 9 presents conclusions.

2.0 METHODOLOGY

The assessment of potential impact on the air quality environment from the proposed mine has been undertaken in the following steps:

- a review of relevant legislation, guidance and applicable air quality standards;
- a review of site baseline conditions, including location of sensitive receptors, existing air quality and prevailing meteorological conditions;
- compilation of source inventory on basis of site design and following international industry guidance on emission estimation techniques;
- atmospheric dispersion modelling of emissions using an advanced atmospheric dispersion model; and
- comparison of exposure against applicable air quality standards and evaluation against EIA 'Methodology for Assessing the Significance of Impacts'.

The sections below provide further details of the methods used for baseline characterisation, emission estimation, dispersion modelling and evaluation of significance of impacts.

2.1 Baseline Characterisation

2.1.1 Air Quality

Existing air quality in the area has been characterised on the basis of a review of emission sources based on surrounding land-uses, industry types and population centres. This has been supplemented with air quality monitoring data obtained from publicly available sources and from on-site monitoring undertaken by SLR. Details of monitoring locations and data collected are provided in Section 5.2.

The projected baseline (i.e. with the currently approved scheme) has been modelled using the same techniques as for assessing the potential impact of the proposed scheme (as described in Sections 2.2 and 2.3).

2.1.2 Meteorological conditions

The meteorological conditions at the site have been assessed using both measured and modelled data.

Measured climatic data for weather recording stations near the site was obtained from the South African Weather Service (SAWS), specifically from the Milner and Kuruman stations, 18km and 55km distant respectively.

Atmospheric dispersion modelling requires input of numerous meteorological parameters that are not routinely measured by all weather stations. In the absence of meteorological stations capable of monitoring all the parameters necessary for detailed atmospheric dispersion modelling modelled data is applied. Data has been supplied from the Numerical Weather Prediction (NWP) system known as the Global Forecast System (GFS) described in more detail in Section 2.3.

2.2 Emission Estimation

Emissions from the mining and ore processing operations have been based on:

- United States Environmental Protection Agency (US-EPA) AP-42 'Compilation of Air Pollutant Emission Factors'; and

- Australian Government Department of the Environment and Heritage National Pollutant Inventory 'Emission Estimation Technique Manual for Mining';

The emission factors are typically based on activity rate and account for the silt and moisture content and in some cases, surface wind speed. Size specific emission factors are provided for both PM_{10} and deposited dust. The emission estimation is described in more detail in Section 6.0.

2.3 Dispersion Modelling

Dispersion modelling has been undertaken using the US American Meteorological Society and Environmental Protection Agency Regulatory Model known as AERMOD[1]. The AERMOD dispersion modelling program is widely used and accepted internationally for undertaking such assessments and its predictions have been validated against real-time monitoring data by the United States Environmental Protection Agency[2] (US EPA). The model incorporates:

- the location of sources, structures and receptors defined within a Geographical Information System based on site plans and satellite imagery;
- topographical information; and
- meteorological data, processed for site specific details.

Details of the model set-up are provided in the following subsections.

Meteorological Data

Meteorological data used in this assessment comprised a 3-year (2011-2013) sequential hourly average dataset to comply with current modelling guidance. This accounts for inter-year variability in meteorological conditions, with the average of the 3-year data set being used.

The meteorological data used in this study is obtained from assimilation and short term forecast fields of the Numerical Weather Prediction (NWP) system known as the Global Forecast System (GFS). The GFS is a spectral model and data are archived at a horizontal resolution of 0.5 degrees. The GFS resolution adequately captures major topographical features and the broad-scale characteristics of the weather. Smaller scale topological features are included in the dispersion modelling by using specific modules in the dispersion model (i.e. AERMET).

The meteorological data was obtained (.met format) from the data supplier and converted to the required surface and profile formats for use in AERMOD using AERMET Pro. Details specific to the site location were used for the conversion, such as latitude, longitude and surface characteristics in accordance with the latest guidance[3]. The surface features within 1km of the proposed development are relatively uniform in nature and as such the surface characteristics were applied as shown in Table 2-1.

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[1] Software used: BREEZE AERMOD, v7.2.6.

[2] AERMOD: Latest Features and Evaluation Results. USEPA Report: EPA-454/R-03-003 June 2003, (http://www.epa.gov/scram001/dispersion_prefrec.htm#aermod).

[3] AERMOD Implementation guide. AERMOD implementation workgroup, USEPA. Last revised March 19, 2009.

Table 2-1
Met Data Preparation – Applied Surface Characteristics

Albedo	Bowen	Roughness
0.3275	4.75	0.2625

Topography

The model was run with site surveyed digital height contour data from the Shuttle Radar Topography Mission (SRTM). Data was processed by the AERMAP function within AERMOD to calculate terrain heights, and interpolate data to calculate terrain heights for sources, buildings and receptors.

Receptor Grids and Discrete Sensitive Receptors

The modelling has been undertaken using a receptor grid across a map of the study area. Pollutant exposure isopleths are generated by interpolation between receptor points and superimposed onto the map. This method allows the exposure at any receptor location in the study area to be determined and presented. A 12km by 12km receptor grid with a 400m resolution was applied. In addition discrete receptor locations at a number of residential properties were modelled (see Table 2-2 and Figure 2-1); the locations were selected in order to provide an assessment of the range of impacts and to facilitate the discussion of results.

Table 2-2
Modelled Discrete Receptors

ID	Description	X [(a)]	Y[(a)]
Hotazel 1	Residential adjacent to railway sidings (southern end)	-3321	-3012821
Hotazel 2	Residential adjacent to railway sidings (northern end)	-3483	-3012018
Hotazel 3	Residential south Hotazel, western boundary	-3800	-3010874
Hotazel 4	Residential central Hotazel, western boundary	-4004	-3010180
Hotazel 5	Residential north Hotazel, western boundary	-4911	-3010010
Devon 1	Residential to South of R31 (close to Devon Pit)	-504	-3012561
Devon 2	Residential to North of R31 (close to Devon Pit)	-631	-3012197
Botha 313	Residential to South West of TSF (currently unoccupied)	-6841	-3016485

Table Note: a) Projection: Transverse Mercator. Datum: Hartebeeshoek, Lo 23

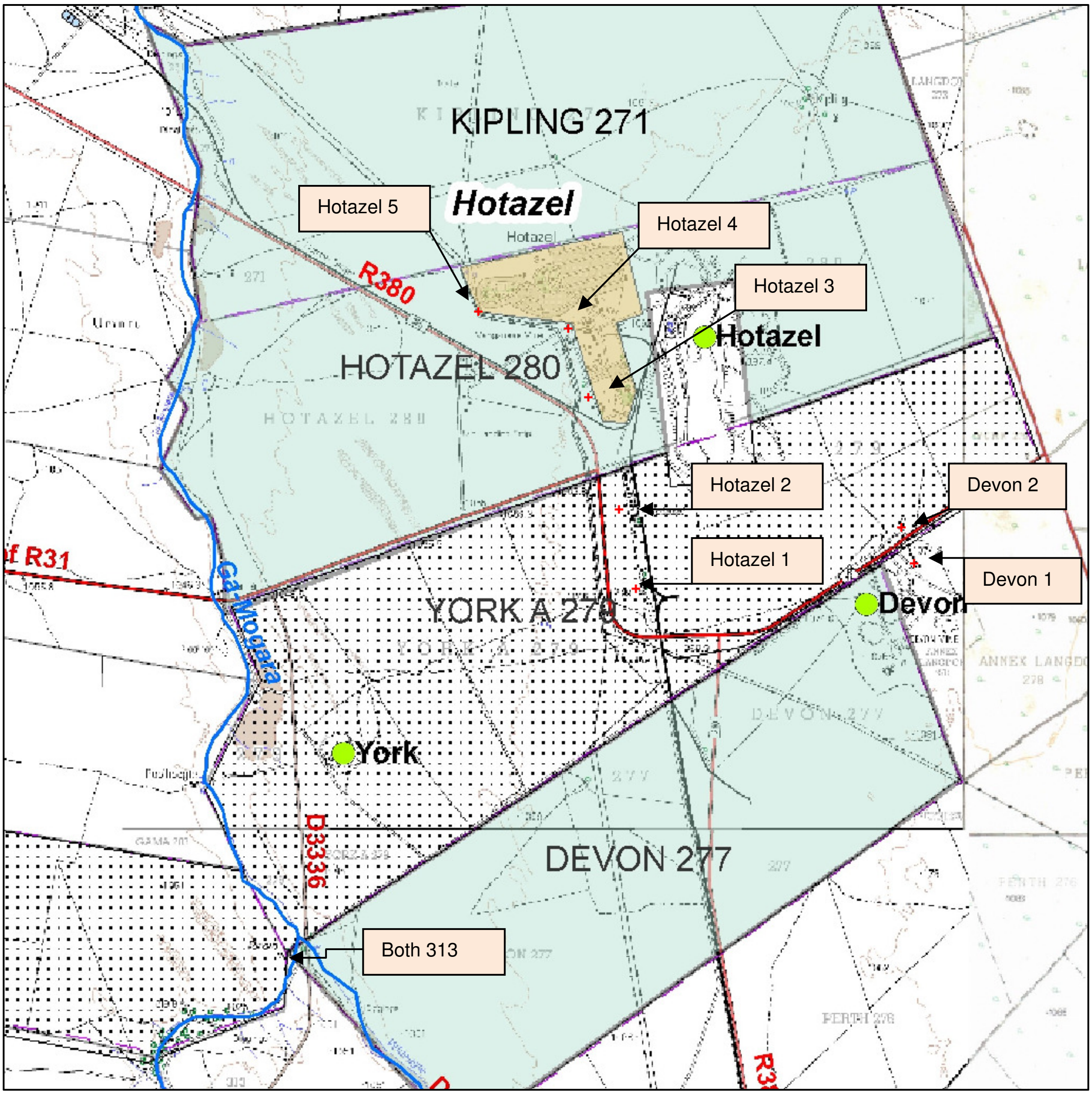

Figure 2-1
Modelled Discrete Receptors

Model Output

Model output was generated to allow comparison with environmental quality standards as presented in Table 2-3. Standards are described in more detail in Section 3.0.

Table 2-3
Model Output

Standard	Model Output
Annual Average PM_{10} and Manganese	Annual Average
24-hr Average PM_{10}	98.9th percentile of 24hour means (allowing for 4 exceedences)
Deposited dust	Monthly average to calculate daily deposition rate

2.4 Evaluation of Impact Significance

The significance of impacts was evaluated based on the EIA 'Methodology for Assessing the Significance of Impacts' as detailed in the matrix within the main EIA report. The method describes significance as a product of consequence and probability of the impacts. Consequence is a function of impact severity, spatial scale and duration.

2.5 Assumptions and Limitations

As with all assessment methodologies there are inherent limitations and a range of assumptions must be made. The most significant assumptions and limitations are described below:

- Emission estimations were based on process descriptions and mine layout available at the time of the assessment. Where detailed design of WRD layouts was not available (e.g. on Devon and Kipling) assumptions on areas have been made on the basis of known volumes/tonnages.
- Assumptions were made regarding silt content and particle size fractions based on experience from other mine sites and literature. It is likely that moisture, silt content and particle size fractions will vary across the site e.g. from roads to pits. As the site is developed further information can be collected.
- Fugitive dust releases driven by intermittent activity and meteorological conditions cannot be accurately represented in the dispersion model, e.g. dust from vehicle entrainment, or dust eroded and released by wind flow, the periodic abatement provided by rainfall, or the binding of particles due to crusting. As such steady state conditions in terms of emissions have been assumed (with the exception of blasting) and wind erosion.
- The minimum time-step of the model is 1-hour, as such short term releases such as from blasting cannot be accurately modelled. Blasting was accounted for in the modelling, simulated as if occurring for an hour every day.
- Combustion emissions would be released from mine vehicles and power generators. Considering the stand-off distance to local receptors from both generators and haulage routes, typically in excess of 1km, emissions are unlikely to be significant in comparison to particulate emissions which are the focus of this assessment.

3.0 POLICY, REGULATORY REQUIREMENTS AND GUIDANCE

3.1 National Environmental Management: Air Quality Act

The National Environmental Management: Air Quality Act (Act no.39 of 2004) (AQA) commenced on the 11th of September 2005. Sections omitted from the implementation are Sections 21, 22, 36 to 49, 51(1)(e),51(1)(f), 51(3),60 and 61. The sections previously omitted have come into effect on the 1st of April 2010 (Government Gazette, 26 March 2010).

The AQA required the establishment of:

- a National Framework for Air Quality Management;
- national, provincial and local ambient air quality and emissions standards;
- air quality management measures, such as Air Quality Management Plans and the declaration of Priority Areas; and
- regulation of industry via listing of activities that results in atmospheric emissions, licensing of Listed Activities and the setting of Minimum Emissions Standards for particular processes/activities.

3.2 The National Framework for Air Quality Management

The purpose of the National Framework is to provide a medium to long term plan for the practical implementation of the AQA. It provides mechanisms, systems and procedures to promote holistic and integrated air quality management through pollution prevention and minimisation at source, and through impact management with respect to the receiving environment from local scale to international issue.

In particular it sets out:

- the roles and responsibilities of the stakeholders in respect of air quality management, i.e. the roles of national government agencies, provincial environmental department and municipalities;
- guidelines for Air Quality Management Plans and designation of Priority areas;
- tools for management of air quality information e.g. the South African Air Quality Information System (SAAQIS);
- norms and standards for air quality monitoring;
- methods to establish national ambient air quality standards.

3.3 National Ambient Air Quality Standards

The National Ambient Air Quality Standards (AQS) set out in South African National Standard (SANS 1929:2011) '*Ambient air quality — Limits for common Pollutants*' for the pollutants of concern with regard to this assessment are detailed in Table 3-1 below.

Table 3-1
National Ambient Air Quality Standards for PM_{10}

Averaging Period	Concentration ($\mu g/m^3$)	Frequency of Exceedence	Compliance Date
24-hours	120	4	Immediate – 31st December 2014
24-hours	75	4	1st January 2015
1-year	50	0	Immediate – 31st December 2014
1-year	40	0	1st January 2015

3.4 Dust Deposition Limits

The South African National Standard (SANS 1929:2011) '*Ambient air quality — Limits for common Pollutants*' provides a 4-band scale used in the evaluation of dust deposition and target, action and alert thresholds based on the measuring reference method ASTM D1739 averaged over 30 days. The target, action and alert thresholds are reproduced in Table 3-2 below.

Table 3-2
Target, action and alert thresholds for dust deposition

Level	Dust fall rate ($mg/m^2/day$)	Averaging Period	Permitted frequency of exceeding dust fallout rate
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 exceedence requires remediation and compulsory report to relevant authorities.

3.5 Guidance from the World Bank/International Finance Corporation

The Equator Principles (EPs) guidelines have been adopted by certain lending institutions to ensure that the projects they finance are undertaken '*in a manner that is socially responsible and reflects sound environmental management practices*'[4]. The EPs are based on the International Finance Corporation Performance Standards on social and environmental sustainability and on the World Bank Group Environmental, Health, and Safety Guidelines (EHS Guidelines).

The proposed project falls within the World Bank Group Category A projects. Accordingly requirements would need to be met by Kudumane should it require IFC finance.

The World Bank/International Finance Corporation (WB/IFC) EHS Guidelines[5] state:

> '*Projects with significant sources of air emissions, and potential for significant impacts to ambient air quality, should prevent or minimize impacts by ensuring that:*
>
> - *Emissions do not result in pollutant concentrations that reach or exceed relevant ambient quality guidelines and standards by applying national legislated standards, or in their absence, the current WHO Air Quality Guidelines or other internationally recognized sources;*
> - *Emissions do not contribute a significant portion to the attainment of relevant ambient air quality guidelines or standards. As a general rule, this Guideline suggests 25 percent of the applicable air quality standards to allow additional, future sustainable development in the same airshed'.*

The WHO air quality guidelines[6] for Manganese are presented in Table 3-3. National Ambient Air Quality Standards take priority over WHO limits and therefore WHO PM_{10} limits have not been reproduced and do not apply.

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[4] The Equator Principles June 2006 (July 2006) http://www.equator-principles.com/resources/equator_principles.pdf

[5] World Bank/International Finance Corporation, *Environmental, Health, and Safety (EHS) Guidelines,* (30th April 2007).

[6] WHO Air Quality Guidelines for Europe 2nd Edition (2000)

Table 3-3
WHO World Bank/IFC Targets

Pollutant	Averaging Period	Threshold value (µg/m^3)
Manganese	Annual	0.15

4.0 METEOROLOGICAL CONDITIONS

Weather conditions are a key aspect in undertaking an assessment of the potential effects on air quality of any process that emits pollutants to atmosphere. Local weather conditions are of direct relevance to modelling and the prediction of impacts, they determine not only the dispersion of pollutants in the atmosphere within the area of interest but also the generation of pollutants, e.g. dust release to atmosphere may increase as a result of dry windy conditions, but precipitation will suppress dust generation. The patterns and frequency of particular local weather conditions, for example, seasonality, are affected by synoptic scale atmospheric movements and therefore a broad understanding of their influence aid in the interpretation of potential impacts.

The most important meteorological parameters governing the atmospheric dispersion of pollutants, i.e. mesoscale, are wind direction and wind speed, and atmospheric stability.

- Wind direction determines the initial direction of the transport of emissions. Pollutants concentrations are probably more sensitive to wind direction than any other parameter for a point source emission[7].
- Wind speed will affect ground level concentrations of emissions by increasing the initial dilution of pollutants in the emission and the distance of downwind transport, causing stretching of the plume. The speed of the wind affects the extent of mechanical mixing or turbulence which increases dilution.
- Atmospheric stability (a measure of the vertical motions or turbulence present), is affected by both mechanical mixing (caused by obstacles on the earth’s surface) and thermal turbulence or buoyancy (caused by differential heating of the earths surface) will affect plume rise and vertical dispersion. There are a number of methods used to measure atmospheric stability, one is the Monin-Obukhov length, defined as the height at which turbulence is generated more by buoyancy than by wind shear. In an assessment such as this focussing on fugitive sources, atmospheric stability is of lesser importance, as opposed to modelling stack releases.

The project area falls within the Northern Steppe Climatic Zone, as defined by the South African Weather Bureau. This is a semi-arid region characterised by seasonal rainfall, hot temperatures in summer, and colder temperatures in winter.

4.1 Temperature

In terms of atmospheric dispersion air temperature is significant in terms of its effect on plume buoyancy, i.e. a greater differential will result in greater plume rise. Temperature may also be an important factor in driving thermal turbulence in the atmosphere. However with respect to assessing potential dust impacts, temperature is more important, along with air humidity in driving evaporation and causing drying of potential dust sources.

Table 4-1 presents the monthly average, maxima and minimum temperatures recorded at the Kuruman Weather Station. The seasonal profile demonstrates a variation in average temperature of approximately 15 degrees Celsius between the coldest month of June and July through to the warmest months of December and January.

[7] Daniel Vallero, Fundamentals of Air Pollution, 4th Ed. (2008)

Table 4-1
Temperature

Month	Maximum Temperature °C	Mean Temperature °C	Minimum Temperature °C
January	31.5	24.0	16.4
February	30.2	23.2	16.0
March	28.1	21.1	14.1
April	24.9	17.3	9.6
May	21.5	13.2	4.9
June	18.7	10.2	1.6
July	19.0	10.1	1.1
August	21.5	12.2	2.8
September	25.7	16.4	7.3
October	28.0	19.4	10.8
November	29.9	21.6	13.4
December	31.0	23.0	15.2

4.2 Surface Winds

Local wind direction and speed data has been obtained from the NWP 3-year data set.

Figure 4-1 presents a histogram of wind speed from the 3 year NWP dataset. This illustrates that wind speeds in the region are under 5m/s for 70% of the year. The average wind speed is 4.0m/s.

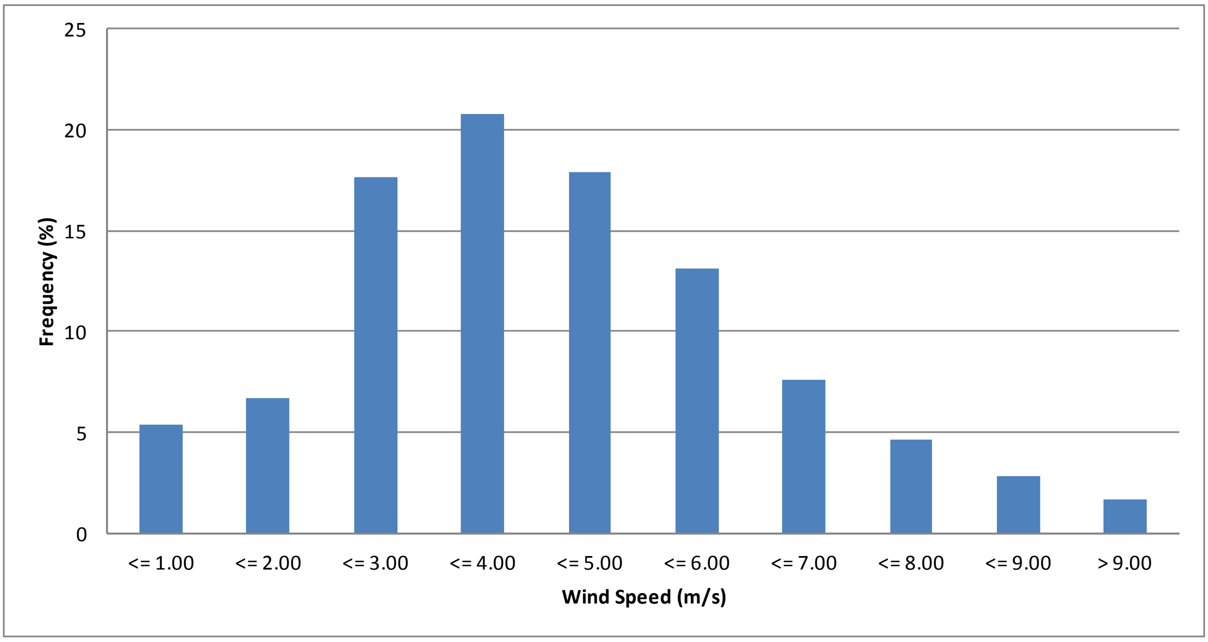


Figure 4-1
Wind Speed

The data (see Figure 4-2) illustrates the seasonal change. For the majority of the year north easterlies dominate with a marked change in wind pattern during September to November when for the period south westerlies occur with much greater frequency.

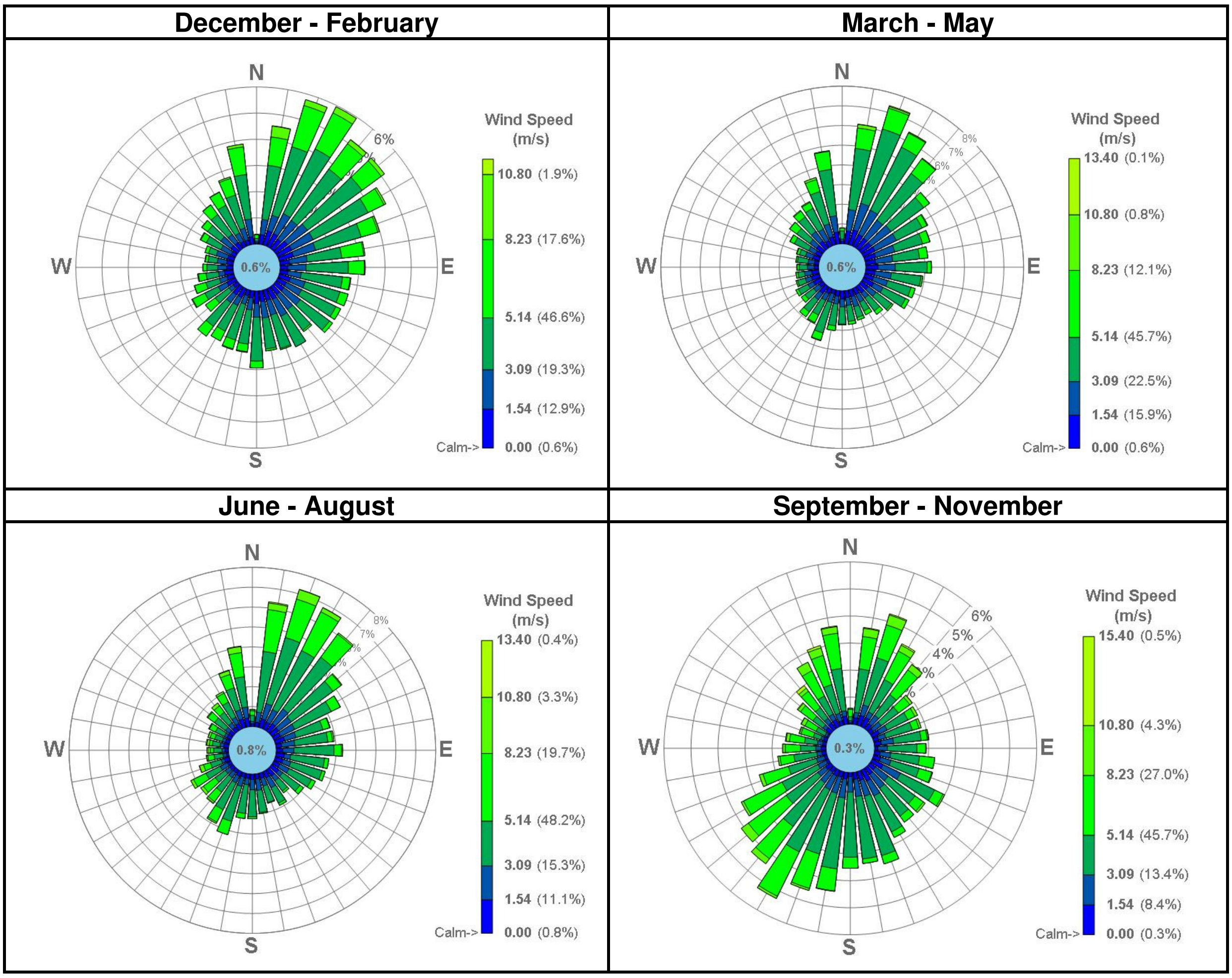


Figure 4-2
Windrose

4.3 Precipitation

Precipitation inhibits dust generation potential and represents a removal mechanism of pollutants from the atmosphere via wet deposition. Rainfall equal to or more than 0.25mm is considered to be sufficient to effectively suppress wind-blown dust emissions for some time[8] and is applied in the US-EPA AP-42 emission factors for unpaved haul roads to determine the level of natural attenuation.

Table 4-2 presents rainfall and evaporation data for the area and demonstrates that mean evaporation is greater than rainfall, making the project area a net water loss area for all months of the year.

Table 4-2
Precipitation and Evaporation

Month	Rainfall (mm)	Evaporation (mm)
January	66.1	259.0
February	61.4	208.4

[8] Report to The Mineral Industry Research Organisation (MIRO), *Management, mitigation and monitoring of nuisance dust and PM10 emissions arising from the extractive industries: an overview*, AEAT/ENV/R3141 Issue 1 (February 2011)

Month	Rainfall (mm)	Evaporation (mm)
March	66.4	161.3
April	35.5	122.3
May	16.1	113.2
June	6.0	82.5
July	1.9	99.1
August	4.2	131.2
September	6.2	188.5
October	19.0	236.3
November	32.0	243.6
December	46.6	272.7
Total	**361.6**	**2118.1**

5.0 EXISTING AIR QUALITY

Existing air quality in the area has been characterised on the basis of a review of emission sources based on surrounding land-uses, industry types and population centres. This has been supplemented with published air quality monitoring data from studies in the area and site specific monitoring undertaken by SLR. The review has focussed on those emissions with the potential for cumulative effects with potential emissions from the proposed mining activities.

5.1 Current mining operations

There are several mining-related activities located in the vicinity of the Kudumane Manganese Mine, however it should be noted that these mines are all in excess of 7km from the proposed project area.

Operational mines within 15km of the Kudumane project area include:

- Assmang's Gloria and Nchwaning mines (exclusively underground), which are located approximately 7km and 12km north of the Kudumane project area respectively;
- BHP Billiton's Wessels mine (exclusively underground), is located approximately 15km north-north west of site;
- The United Manganese of the Kalahari (UMK) Mine (opencast) is located approximately 10km south-west of the proposed project area; and
- Samancor's Mamatwan mine and Tshipi Borwa Mine (opencast) both located 15km south of the Kudumane project area.

Fugitive dust sources from the abovementioned mining operations may include wind blown dust from open areas, vehicle entrained dust from paved and unpaved roads, dust from materials handling operations, crushing and screening emissions, drilling and blasting emissions, as well as point source emissions.

There are also several closed/dormant manganese mines within proximity to the project area. These include the Hotazel mine, Annex Langdon-Devon mine, and the Perth and Smart mines. Dust may be generated from these mines as a result of wind erosion of un-restored areas such as pits, tailing storage and waste rock dumps (the location of the closest of these mines is indicated by a green dot on Figure 2-1).

5.1.1 Fugitive dust release – non mine related

Given the low level of rainfall in the region, sources such as agriculture, vehicle entrainment on sealed and unsealed roads and wind erosion of open areas may contribute to suspended particulate (PM_{10}) concentrations and dust deposition rates in the area. Farming in the area is predominantly livestock and game farming and as such is considered to present limited potential for dust generation. However, potential exists for localised and short-term elevated concentrations in proximity to roads as a result of vehicle entrainment of dust.

5.1.2 Biomass Burning

The burning of biomass as a result of the agricultural practice of burning vegetation for clearing and the domestic use of charcoal and wood as a fuel is considered of low significance in the area on the basis that:

- veld fires occur relatively infrequently in the region with any resultant air pollutant episodes being intermittent and of relatively short duration; and

- households in the local population centre of Hotazel predominantly have basic services and as such cooking and heating is unlikely to be sourced from charcoal and wood on a large scale.

5.1.3 Transportation Exhaust Emissions

The pollutants of most concern with regard to engine exhausts (both from road and rail transport) are nitrogen dioxide (NO_2) and particles (PM_{10}) in relation to human health and oxides of nitrogen (NOx) in relation to vegetation and ecosystems. Other pollutants of concern include carbon dioxide (in terms of global impact), carbon monoxide (CO), hydrocarbons (HCs), and sulphur dioxide.

Given the relatively low traffic volumes in the region, atmospheric emissions from transport activity are anticipated to be a relatively minor source of air pollution.

5.2 Baseline Monitoring Data

5.2.1 Measured Particulate Concentrations

The Air Quality Assessment[9] for the approved scheme included a collation and review of existing monitoring sets in the area. The review included suspended total particulate concentrations and ambient manganese concentrations recorded in the study region by the Counsel for Scientific and Industrial Research (CSIR). In addition, monitoring data obtained from the EMPRs for Wessels and Mamatwan mines was undertaken, however this is considered of little value in that monitoring was undertaken in close proximity (circa 20m) to sources at the mines.

The CSIR, on behalf of Assmang, conducted ambient monitoring of TSP and manganese levels within residential areas close to local mining operations near Black Rock and at two background sites in Kuruman and van Zylsrus (as documented in Wates, Meiring and Barnard, 2002, 2003). The data is reproduced in Table 5-1.

Table 5-1
Average Measured TSP and Manganese Concentrations

ID	TSP (µg/m^3)	Manganese in TSP (µg/m^3)	Manganese as % of TSP
Kuruman	22.3	0.095	0.43
Van Zylsrus	4.3	0.005	0.12
Black Rock Hostel	33.0	2.25	6.82
Black Rock Village	27.0	0.87	3.22
Schoonspruit Village	21.0	0.89	4.24

5.2.2 Dust Deposition Measurements

A baseline dust deposition monitoring survey was undertaken by SLR Consulting between June 2012 and February 2014. The monitoring has been undertaken at 5 locations in and around the proposed mine sites (descriptions and lat/long are provided in Table 5-2).

[9] Project done on behalf of Metago Environmental Engineers (Pty) Ltd. Air Quality Impact Assessment for the Proposed Kudumane Manganese Mining Project near Hotazel (Report No.: 09MEE02 - Rev 2). Airshed Planning professionals (Pty) Ltd : V von Reiche H Liebenberg-Enslin - September 2010

Table 5-2
Sampling Locations

ID	Description	Location
DB1	Dust fallout in the prevalent upwind direction near Hotazel	27° 14' 6.8"S 22° 56' 56.7'
DB2	Dust fallout in the prevalent downwind direction from the mine	27° 15' 16.5"S 22° 56' 38.4
DB3	Dust fallout as a result of ore processing, crushing operations and unpaved road emissions	27° 15' 34.2"S 22° 54' 29.6
DB4	Dust fallout levels north west of the open pit area (Directional Monitor)	27° 13' 38.9"S 22° 56' 01.5
DB5	Background dust fallout in the prevalent upwind direction. Dust fallout levels north of the mine	27° 14' 49.2"S 22° 56' 17.9

Results of dust deposition monitoring are summarised in Table 5-3 and illustrated in Figure 5-1 and Figure 5-2. Results have been compared to South African National Standards (SANS 1929:2011) however it should be noted that the monitoring locations do not represent sensitive receptors either residential or industrial. The average results are skewed by a small number of isolated events that exceeded the 'alert' threshold. In general average results are below the residential action level. A review of the data indicates that background dust deposition may be in the region of between approximately 200 and 500mg/m^2/day as a monthly average.

Table 5-3
Dust Deposition Summary (mg/m^2/day as a monthly average)

ID	Minimum (n=21)	Average (n=21)	Maximum (n=21)	No. > 1200 & <2400 (n=21)	No. > 2400 (Alert)(n=21)
DB1	70	**416**	912	0	0
DB2	104	**605**	3140	1	1
DB3	35	**230**	741	0	0
DB4N	64	**536**	2950	1	1
DB4S	79	**526**	3290	1	1
DB4E	83	**341**	817	0	0
DB4W	78	**346**	660	0	0
DB5	122	**393**	2609	0	1

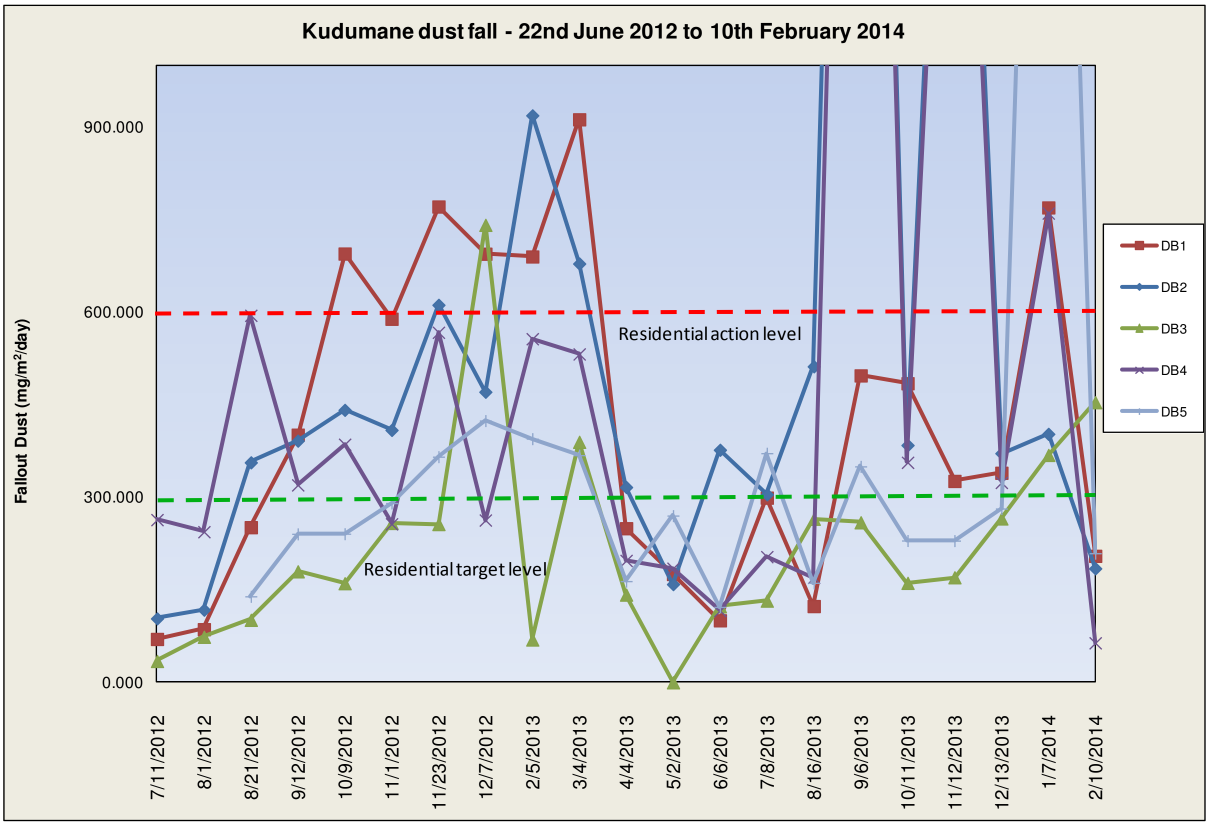


Figure 5-1
Dust Deposition (2012-2014)

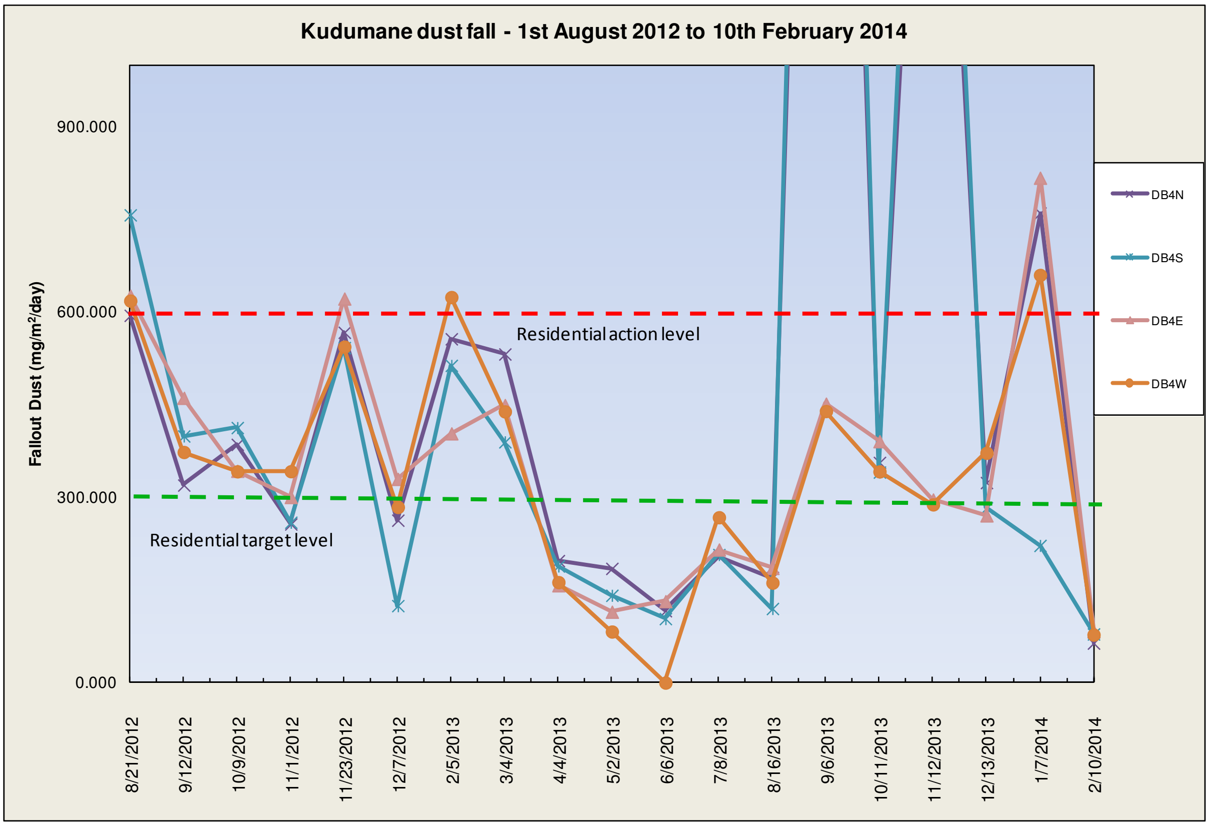


Figure 5-2
DB 5 Direction Gauge Dust Deposition (2012-2014)

6.0 EMISSION ESTIMATION

6.1 Construction Phase

The assessment of construction phase impacts has considered those elements of the infrastructure that are not included in the phased development of the mine. As such construction of TSF, sewage plant, workshops, ancillary buildings, admin blocks, permanent access roads and services are all considered in the construction phase. The phased development of the WRD's, pit areas and internal haul roads throughout the life of the mine are considered in the impact assessment of the operational phase.

The construction activities most likely to generate dust are:

- excavations;
- earthworks / landscaping;
- ground preparations prior to construction of the buildings;
- grading and levelling of the ground prior to construction of new roads;
- removal of spoil;
- storage of materials; and
- vehicles on haulage routes and public roads.

At the time of writing, limited information on the construction phase is available in terms of activity rates to generate a more detailed emission profile, i.e. loading/unloading tonnages, bull-dozers, compacting, motor grading etc.

For this reason the US EPA emission factor developed for 'heavy construction operations' have been used to estimate emission from the construction phase account for these activities. The quantity of dust emissions is assumed to be proportional to the area of land being worked and the level of construction activity. The emission factor is:

ETSP = 2.69 Mg/hectare/month of activity

This 'approximate' emission factor is used with caution as construction of any development will comprise a series of different operations at different times, each with its own duration and potential for dust generation. The guidance states '*the value is most applicable to construction operations with: (1) medium activity level, (2) moderate silt contents, and (3) semiarid climate*'. The emission factor is for TSP and therefore estimating PM_{10} as accounting for 50% is considered conservatively high.

Table 6-1
Construction Phase Emissions

Scenario	Area (Ha)	TSP (tpa)	PM_{10}(tpa)	TSP (tpa)	PM_{10}(tpa)
		Unmitigated		Mitigated	
Baseline (approved scheme)	88	852.2	426.1	426.1	213.0
Additions from Proposed Scheme	52	501.4	250.7	250.7	125.4
Total Proposed Scheme	**140**	**1353.6**	**676.8**	**676.8**	**338.4**

In terms of a comparison of the approved scheme with the proposed scheme; the level of additional construction is not large in terms of area with most of the construction taking place within the boundaries of the approved scheme. The assessment takes account of those construction areas outside of the approved scheme. Since approved works have already commenced at the mine only some elements of the construction phase of the approved scheme would occur concurrently with the proposed scheme. As such the assessment represents a hypothetical worst case scenario. The NPI indicates that between 50% and 70% control efficiency of dust generated from construction type activities can be achieved by spraying water, as such a 50% control efficiency has been applied to represent the mitigated scenario. The emission estimations are presented in Table 6-1.

6.2 Operational Phase Dust Emissions

Emissions from mining activities have been estimated using US-EPA AP-42 '*Compilation of Air Pollutant Emission Factors*' and Australian NPI '*Emission Estimation Technique Manual for Mining*'. Emission sources have been divided into the following categories and activities:

- Materials handling (loading / unloading from trucks and conveyors)
- Vehicle entrainment of dust on haul road
- Wind erosion on exposed areas (e.g. storage piles, TSF, WRD)
- Crushing and screening
- Drilling and blasting

The sections below describe the estimation of emissions from each activity.

The Life of Mine Schedule provides the activity rates, i.e. the predicted tonnages of ore and waste rock produced as the mine develops. The estimation of emissions and impact predictions has been based on consideration of the highest mining and processing rates and the proximity of receptors to particular phases of the scheme to provide a worst case assessment. To provide a precautionary assessment, in all scenarios the open pits, WRD and TSF have been assumed to be fully developed. As such the following scenarios have been investigated:

- Scenario 0: Projected Baseline – Open Pit mining of York and Processing Plant (1.9Mt/annum)
- Scenario 1a: Proposed Scheme – Steady State Underground Mining of Telele and York with Open Pit mining at Hotazel and Processing Plant (3.35Mt/annum). This scenario represents the latter stages of mining when all areas of Hotazel and WRDs are fully developed.
- Scenario 1b: Proposed Scheme - Steady State Underground Mining of Telele and York with Open Pit mining at Devon and Processing Plant (3.35Mt/annum). This scenario represents mining operations at their closest to sensitive receptors and a large quantity of waste rock haulage.

6.2.1 Materials Handling

Dust may potentially be generated as a result of truck tipping of top-soils, overburden and ore materials and conveying of ore materials. The amount of dust generated by these 'material handling' operations is a factor of the quantity of materials handled, it's moisture content, as well as climatic factors such as wind speed.

The following US-EPA equation has been used to estimate material handling emissions:

E = k (0.0016)((U/2.3)^1.3(M/2)^-1.4)

where:

- E = particle size-specific emission factor (kg/t handled)
- U = mean wind speed (m/s)
- M = material moisture content (%)
- k = particle size multiplier (PM_{10} 0.35, TSP 0.74)

A mean wind speed of 4.0m/s has been applied on the basis of meteorological data and an average moisture content of 2% assumed on the basis of previous assessment work.

Table 6-2 presents the estimation of emissions for each source, note materials handling associated with crushing and screening is assessed separately (see Section 6.2.3). A control factor for the use of sprays when required of 0.5 has been applied following Australian NPI guidance (refer to Table 4 of NPI guidance).

Table 6-2
Materials Handling

Source	Throughput (tpa)	PM_{10} Emissions (tpa)	TSP Emissions (tpa)	PM_{10} Emissions (tpa)	TSP Emissions (tpa)
		Unmitigated		Mitigated	
Scenario 0					
York Pit Excavation	2900000	3.4	7.2	1.7	3.6
York Pit Loading	2900000	3.4	7.2	1.7	3.6
Tipping at Stockpiles/WRDs	1000000	1.2	2.5	0.6	1.2
Tipping at ROM	1900000	2.2	4.7	1.1	2.3
Loading Crusher	1900000	2.2	4.7	1.1	2.3
Conveyor to Stockpile and Stacker	1900000	2.2	4.7	1.1	2.3
Reclaimer and Train Loading	1900000	2.2	4.7	1.1	2.3
Scenario 1a					
Kipling Pit Excavation	3119231	3.6	7.7	1.8	3.8
Kipling Pit Loading	3119231	3.6	7.7	1.8	3.8
Tipping at York Stockpiles/WRDs	1000000	1.2	2.5	0.6	1.2
Tipping at ROM	3350000	3.9	8.3	2.0	4.1
Loading Crusher	3350000	3.9	8.3	2.0	4.1
Conveyor to Stockpile and Stacker	3350000	3.9	8.3	2.0	4.1
Reclaimer and Train Loading	3350000	3.9	8.3	2.0	4.1
Tipping at Kipling Stockpiles/WRDs	2769231	3.2	6.8	1.6	3.4
Scenario 1b					
Devon Pit Excavation	8350000	9.7	20.6	4.9	10.3
Devon Pit Loading	8350000	9.7	20.6	4.9	10.3
Tipping at York Stockpiles/WRDs	1000000	1.2	2.5	0.6	1.2
Tipping at ROM	3350000	3.9	8.3	2.0	4.1
Loading Crusher	3350000	3.9	8.3	2.0	4.1
Conveyor to Stockpile and Stacker	3350000	3.9	8.3	2.0	4.1
Reclaimer and Train Loading	3350000	3.9	8.3	2.0	4.1
Tipping at Devon Stockpiles/WRDs	8000000	9.3	19.7	4.7	9.9

6.2.2 Vehicle Entrainment of Dust from Unpaved Haul Roads

Unpaved haul roads can lead to dust generation as a result of the pulverization of surface material caused by the wheels on the road surface, the particles are lifted into the air either by the rolling wheels or as a result of air currents from the turbulence cause by the passing of the vehicle.

The quantity of dust emissions from a given segment of unpaved road varies linearly with the volume of traffic. The other primary factors that affect dust generation on unpaved haul roads on industrial sites as opposed to general traffic include, silt content and vehicle weight, thus for vehicles travelling on unpaved surfaces at industrial sites, emissions are estimated from the following equation:

$$EF = k\ (s/12)^a (W/3)^b (281.9)$$

where k, a, b, are empirical constants given below and:

- EF = size-specific emission factor (g/VKT)
- k = 1.5 for PM_{10} and 4.9 for TSP
- s = surface material silt content (%)
- a = 0.9 for PM_{10} and 0.7 for TSP
- W = mean vehicle weight (tons)
- b = 0.45 for PM_{10} and 0.45 for TSP
- 281.9 = g/VKT to lb/VMT

In the absence of site specific road silt loading data, a mean silt content of 8.4% was used on the basis of AP-42 emission factor Table 13.2.2-1. This is considered a precautionary estimate on the basis that the AP-42 guidance states '*tests … show that road silt content is normally lower than in the surrounding parent soil, because the fines are continually removed by the vehicle traffic, leaving a higher percentage of coarse particles*'. The emissions rate has then been adjusted for the total number of wet days in the year to reflect natural mitigation (number of wet days / 365).

Trip profiles were determined for the ore and waste and the general destination on an annual basis, i.e. waste material to the WRD or ROM stockpile. Thus the annualised distance travelled was combined with the specific emission factor to derive site emissions (see Table 6-3).

Table 6-3
Unpaved Haul Road Emissions

	Kilometers per day	PM_{10} Emissions (tpa)	TSP Emissions (tpa)	PM_{10} Emissions (tpa)	TSP Emissions (tpa)
g/vkm		890	3121	445	1560
		Unmitigated		Mitigated	
Scenario 0					
York Pit to ROM	281	91	321	46	160
York Pit to WRD	296	96	337	48	169
Scenario 1a					
York/Telele UG to ROM	444	144	506	72	253
York/Telele UG to WRD	296	96	337	48	169
Kipling Pit to ROM	246	80	280	40	140
Kipling Pit to WRD	568	185	647	92	324
Scenario 1b					
York/Telele UG to ROM	444	144	506	144	506
York/Telele UG to WRD	296	96	337	96	337
Devon Pit to ROM	39	13	44	13	44
Devon Pit to WRD	770	250	877	250	877

Table Note: based on distances estimated from site plan and annual throughput from life of mine schedule.

6.2.3 Crushing and Screening

Crushing and screening leads to the emissions of dust as a result of mechanical action generating fine particles and then releasing them into the atmosphere. Dust fallout in the locality may then be re-suspended as a result of wind action or turbulence caused by vehicles.

Fugitive dust emissions from crushing have been quantified using the emissions factors from the Australian NPI guidance (i.e. 0.004kg/t and 0.010kg/t for PM_{10} and TSP respectively). Emission factors for crushing activities include emissions from loading, screens, the crusher, the hoppers, feeders, and transfer points that are integral to the crusher. Table 6-4 presents a summary of the predicted emissions.

Table 6-4
Estimation of Crushing Emissions

Scenario	Activity Rate	PM_{10} Emissions (tpa)	TSP Emissions (tpa)	PM_{10} Emissions (tpa)	TSP Emissions (tpa)
	(tpa)	Unmitigated		Mitigated	
Scenario 0	1900000	7.6	19.0	3.8	9.5
Scenario 1a and 1b	3350000	13.4	33.5	6.7	16.8

6.2.4 Wind erosion

Dust emissions may be generated by wind erosion of exposed surfaces on the TSF (i.e. beached tailings), ROM storage piles, WRD, and soil storage piles. The magnitude of dust emission is a factor of the total area and emission rate. The primary factors that affect the rate of emission of fugitive dust include the extent of surface compaction, moisture content, particle size distribution, wind speed and precipitation.

Emissions from exposed waste rock and tailings have been estimated on the basis of US-AP42 emission factors (Table 8.19.1-1 EPA, 1985). This was considered most appropriate on the basis of the sand like particle size of the tailings (i.e. predominantly a fine to medium sand). The emission factors are:

- EF_{PM10} = 0.16 kg/ha/hour
- EF_{TSP} = 0.08 kg/ha/hour

A control factor for the use of sprays when required of 50% has been applied following Australian NPI guidance for active areas (refer to Table 4 of NPI guidance), i.e. WRDs, TSF, storage piles, and active open pit mine areas.

Modelling Information

The areas for each source have been entered on the basis of site plans and the following assumptions have been made:

- Each WRD is modelled at capacity
- The ROM pile area is at capacity
- The Low Grade Stockpile area is at capacity
- The Beached Tailings account for 50% of the tailings area
- Annual emissions calculated on the basis of the emissions factors have been apportioned equally across hours when winds are >5m/s to calculate a specific emission rate ($g/m^2/s$) for those events.

The sources and emissions are presented in Table 6-5.

Table 6-5
Wind Erosion

Source	Area (ha)	PM_{10} Emissions (tpa)	TSP Emissions (tpa)	PM_{10} Emissions (tpa)	TSP Emissions (tpa)
		Unmitigated Scenario		Mitigated Scenario	
Scenario 0					
York Open Pit	57.8	40.5	81.0	20.2	40.5
Low Grade Stockpile	21.5	15.1	30.2	7.5	15.1
York Stockpile2	22.0	15.4	30.8	7.7	15.4
York Stockpile1	16.0	11.2	22.4	5.6	11.2
Product Stockpile	5.2	3.6	7.2	1.8	3.6
Stacker-Reclaimer Stockpile	2.6	1.8	3.6	0.9	1.8
ROM Stockpile	1.5	1.1	2.1	0.5	1.1
Scenario 1a					
York Open Pit	57.8	40.5	81.0	20.2	40.5
Low Grade Stockpile	21.5	15.1	30.2	7.5	15.1
Stockpile2	22.0	15.4	30.8	7.7	15.4
Stockpile1	16.0	11.2	22.4	5.6	11.2
Hotazel Pit	24.3	17.0	34.1	8.5	17.0
Hotazel WRD1	25.2	17.7	35.3	8.8	17.7
Hotazel WRD2	24.0	16.8	33.6	8.4	16.8
Kipling Pit	43.8	30.7	61.4	15.4	30.7
Kipling WRD1	67.9	47.6	95.1	23.8	47.6
Kipling WRD2	101.2	70.9	141.8	35.5	70.9
Product Stockpile	5.2	3.6	7.2	1.8	3.6
Stacker-Reclaimer Stockpile	2.6	1.8	3.6	0.9	1.8
ROM Stockpile	1.5	1.1	2.1	0.5	1.1
TSF	5.7	4.0	7.9	2.0	4.0
Scenario 1b (Scenario 1a sources +)					
Devon Open Pit	26.6	18.6	37.3	9.3	18.6
Devon WRD	41.0	28.7	57.4	14.4	28.7

6.2.5 Drilling and Blasting

Blasting occurs intermittently for short durations (i.e. seconds). The ability of the model to simulate releases from blasting is limited by the minimum 1-hour time-step of the model. As such blasting has been accounted for in the modelling, simulated as if occurring for an hour with the mass release averaged over the hour. However given the relatively minor contribution to overall emissions from mining operations, it is considered that the limitations in modelling and general assumptions about drilling and blasting rates are of low significance.

Drilling and blasting requirements will vary as the mining progresses dependent on the rock conditions encountered. Assumptions for drilling and blasting have been taken from the Air Quality Assessment for the approved scheme. There will 33 holes drilled per day and 2 blasts a week with an average area blasted of 3500m^2.

The blasting emission equations from the NPI have been applied as follows (A = area):

- E kg PM_{10} / blast = 0.000114 * A^1.5; and
- E TSP / blast = 0.00022 * A^1.5.

Drilling has been assumed to occur continually on a daily basis. Emissions from drilling have been estimated from the fixed emission factors from the NPI at:

- 0.31 kg/hole for PM_{10}; and
- 0.59 kg/hole for TSP.

Table 6-6
Blasting and Drilling

Source (all scenarios)	PM_{10} Emissions (tpa)	TSP Emissions (tpa)
Drilling	3.2	6.1
Blasting	8.6	16.6

6.3 Manganese Emissions

The manganese content of the ore is reported to be approximately 32%. To represent a precautionary assessment it has been assumed that the manganese fraction of the PM_{10} released from ore handling activities is also 32%. Manganese emissions have therefore been estimated from the following sources (with emission rates as 32% of the relevant PM_{10} emission detailed in the relevant sections above):

- Wind erosion of TSF
- Materials handling of ore and product
- Screening and Crushing
- Drilling and Blasting

6.4 Emission Summary and Source Contribution

A summary of estimated particulate emissions as a result of the approved (baseline) and proposed mine operations is presented in Table 6-7 below. The mitigated and unmitigated scenario source contributions are presented graphically in Figure 6-1 and Figure 6-2.

Table 6-7
Emission Summary and Source Contribution

Source Category	PM_{10} (tpa)	%	TSP (tpa)	%
			Scenario 0	
Wind Erosion	44.3	27.4%	88.7	11.1%
Materials handling	8.4	5.2%	17.8	2.2%
Screening and crushing	3.8	2.3%	9.5	1.2%
Roads	93.8	57.8%	657.9	82.6%
Drilling and Blasting	11.8	7.3%	22.7	2.8%
Total	**162.1**	**100%**	**796.6**	**100%**
			Scenario 1a	
Wind Erosion	146.7	34.0%	293.3	13.8%
Materials handling	13.7	3.2%	28.9	1.4%
Screening and crushing	6.7	1.6%	16.8	0.8%
Roads	252.5	58.5%	1771.4	83.0%
Drilling and Blasting	11.8	2.7%	22.7	1.1%
Total	**431.3**	**100%**	**2133.1**	**100%**
			Scenario 1b	

Source Category	PM_{10} (tpa)	%	TSP (tpa)	%
Wind Erosion	170.3	36.8%	340.7	15.5%
Materials handling	22.8	4.9%	48.2	2.2%
Screening and crushing	6.7	1.4%	16.8	0.8%
Roads	251.6	54.3%	1765.0	80.5%
Drilling and Blasting	11.8	2.5%	22.7	1.0%
Total	463.2	100%	2193.4	100%

The main contributor to dust emissions, accounting for more than 80% of total emissions, is predicted to be dust generated by vehicles hauling ore and waste rock. Other sources make only a minor contribution with wind erosion as the second largest sources accounting for between approximately 10% and 15% of PM_{10} and TSP respectively.

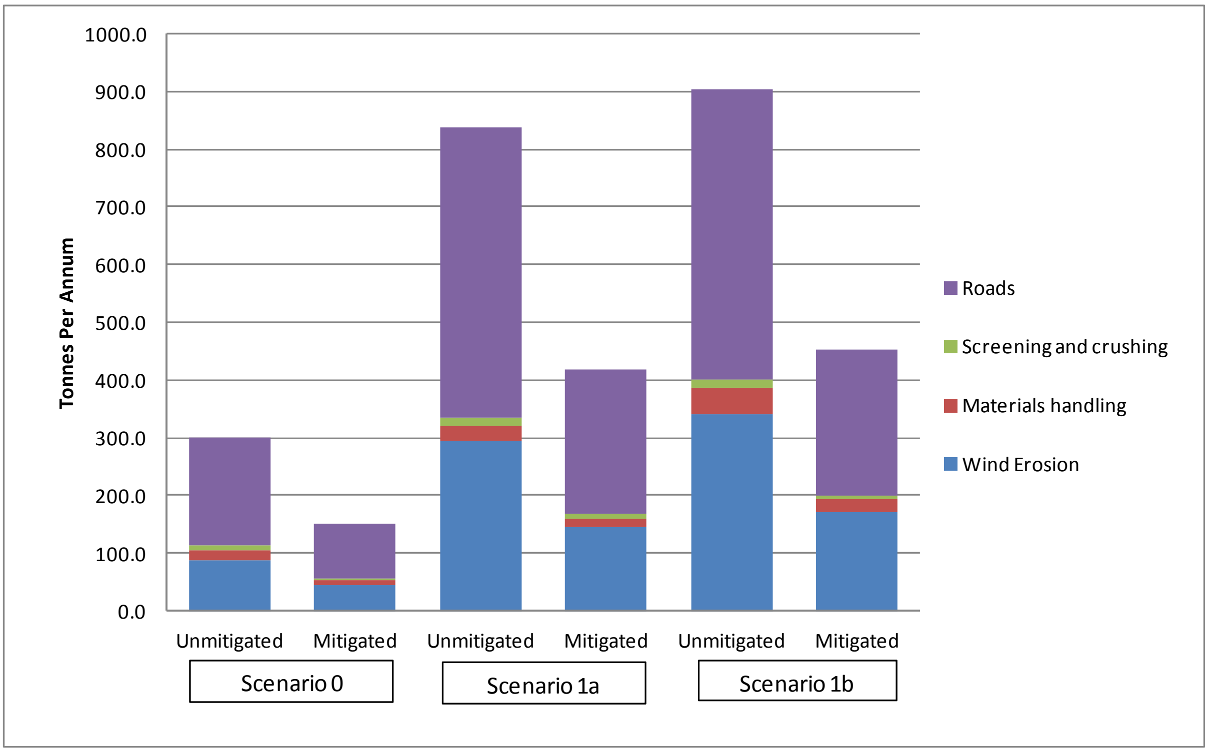


Figure 6-1
Source Contribution - PM_{10} Emissions

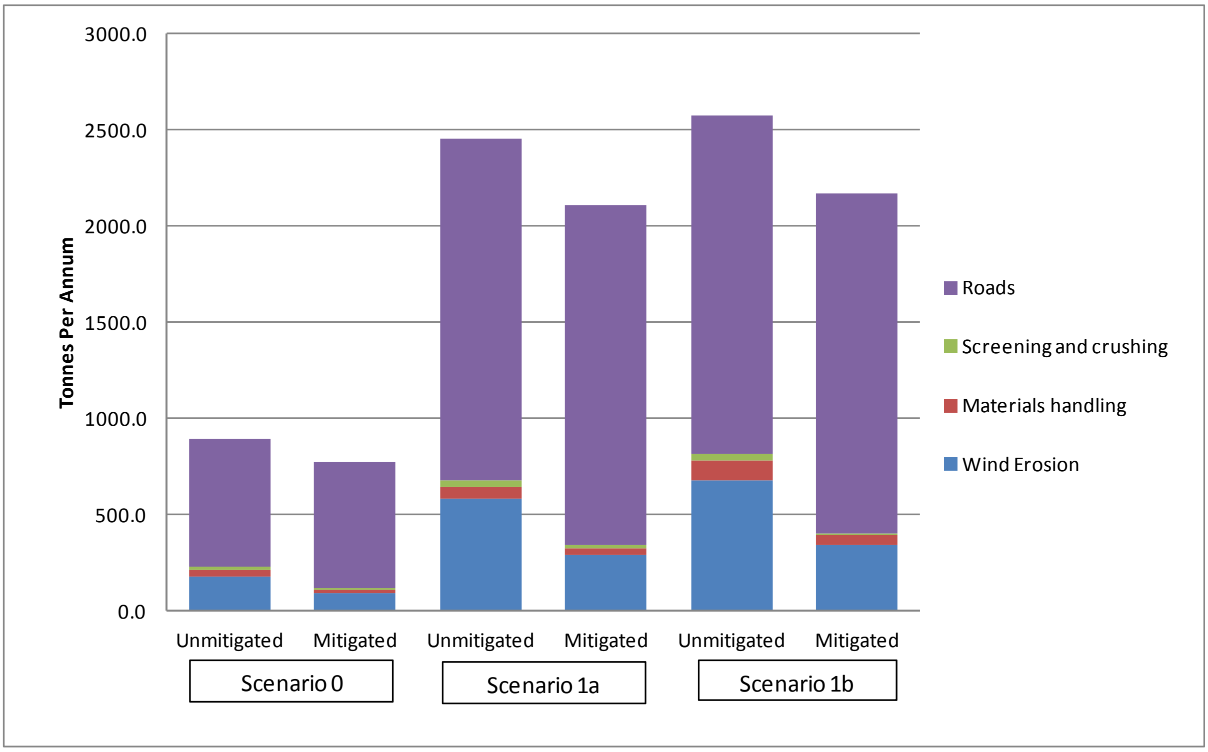


Figure 6-2
Source Contribution - TSP Emissions

7.0 IMPACT ASSESSMENT

This section presents the results of the dispersion modelling of estimated dust emissions from mine operations for PM_{10} and manganese concentrations and deposited dust. Figures that present concentration or deposition isopleths have been produced to illustrate the dispersion of emissions in the environment (see Appendix A) but it is the predicted exposure at human receptor locations that is the priority consideration in terms of protecting health and amenity. The predicted exposure at the selected receptor locations has been tabulated to facilitate the discussion of results.

7.1 Construction Phase

As discussed in Section 6.1, on the basis of the limitations in construction phase emission rate estimation, the model predictions are considered a likely over-estimate of exposure.

Table 7-1, Table 7-2, and Table 7-3 present the contribution of construction activities to annual mean PM_{10}, 24-hour mean PM_{10} and dust deposition. The findings of the assessment indicate:

- the proposed construction activities will result in an increase in contributions to the annual mean PM_{10} concentration, however the contribution is significantly below the AQS even without mitigation;
- the proposed construction activities will result in an increase in contributions to the 24-hour mean PM_{10} concentration. The modelling predicts exeedences would occur at the closest receptor in Botha 313, however this is un-occupied at the time of assessment and the construction dust emission factors is acknowledged to represent a very precautionary estimate likely to over predict impacts. As such increased attention is required to mitigation measures when construction activities are close to Botha 313 if occupied during construction of the TSF. Although not possible to represent in the modelling given the level of detail on construction activities, it is considered that with effective application of standard construction mitigation measures that exceedences could be mitigated; and
- the proposed construction activities will result in an increase in contributions to the dust deposition, however the contribution is significantly below the Residential Target Limit even without mitigation.

Figure A-1 to Figure A-6 present the dispersion of dust for the proposed scheme with and without mitigation.

Table 7-1
Construction Phase: Contribution to PM_{10} Annual Mean Concentration

Receptor	Approved Scheme ($\mu g/m^3$)	% of AQS	Proposed Scheme ($\mu g/m^3$)	% of AQS
Unmitigated				
Hotazel 1	2.2	5%	2.5	6%
Hotazel 2	0.9	2%	1.5	4%
Hotazel 3	1.1	3%	2.2	6%
Hotazel 4	1.1	3%	1.7	4%
Hotazel 5	1.5	4%	2.0	5%
Devon 1	1.7	4%	1.8	4%
Devon 2	1.5	4%	1.6	4%
Botha 313	8.8	22%	14.6	36%
Mitigated				

Receptor	Approved Scheme (µg/m³)	% of AQS	Proposed Scheme (µg/m³)	% of AQS
Hotazel 1	1.1	3%	1.3	3%
Hotazel 2	0.5	1%	0.8	2%
Hotazel 3	0.6	1%	1.1	3%
Hotazel 4	0.6	1%	0.9	2%
Hotazel 5	0.8	2%	1.0	3%
Devon 1	0.8	2%	0.9	2%
Devon 2	0.8	2%	0.8	2%
Botha 313	4.4	11%	7.3	18%

Table 7-2
Construction Phase: Contribution to PM_{10} 24-hour Mean Concentration (99th Percentile)

Receptor	Approved Scheme (µg/m³)	% of AQS	Proposed Scheme (µg/m³)	% of AQS
Unmitigated				
Hotazel 1	59.1	79%	59.1	79%
Hotazel 2	9.8	13%	22.0	29%
Hotazel 3	14.0	19%	64.4	86%
Hotazel 4	24.4	33%	26.3	35%
Hotazel 5	16.6	22%	43.5	58%
Devon 1	37.8	50%	38.1	51%
Devon 2	28.4	38%	28.9	38%
Botha 313	146.0	195%	223.1	297%
Mitigated				
Hotazel 1	29.5	39%	29.6	39%
Hotazel 2	4.9	7%	11.0	15%
Hotazel 3	7.0	9%	32.2	43%
Hotazel 4	12.2	16%	13.1	18%
Hotazel 5	8.3	11%	21.8	29%
Devon 1	18.9	25%	19.1	25%
Devon 2	14.2	19%	14.4	19%
Botha 313	73.0	97%	111.5	149%

Table 7-3
Construction Phase: Contribution to Dust Deposition

Receptor	Approved Scheme (µg/m³)	% of AQS	Proposed Scheme (µg/m³)	% of AQS
Unmitigated				
Hotazel 1	24.1	8%	26.8	9%
Hotazel 2	13.8	5%	16.8	6%
Hotazel 3	7.0	2%	13.5	4%
Hotazel 4	5.0	2%	9.7	3%
Hotazel 5	5.0	2%	8.8	3%
Devon 1	5.4	2%	7.3	2%
Devon 2	6.7	2%	8.3	3%
Botha 313	77.3	26%	104.5	35%
Mitigated				

Receptor	Approved Scheme (µg/m³)	% of AQS	Proposed Scheme (µg/m³)	% of AQS
Hotazel 1	12.1	4%	13.4	4%
Hotazel 2	6.9	2%	8.4	3%
Hotazel 3	3.5	1%	6.7	2%
Hotazel 4	2.5	1%	4.8	2%
Hotazel 5	2.5	1%	4.4	1%
Devon 1	2.7	1%	3.6	1%
Devon 2	3.3	1%	4.2	1%
Botha 313	38.7	13%	52.2	17%

7.2 Operational Phase

7.2.1 PM_{10} Impact

The predicted contribution to annual mean and 24-hour mean PM_{10} concentrations at receptor locations is presented in Table 7-4 below for both the unmitigated and mitigated scenario. It is evident that the application of dust abatement measures reduces predicted exposure significantly in terms of annual mean exposure. The proposed scheme (Scenarios 1a and 1b) represent an increase on the approved scheme (Scenario 0), however the process contribution remains below the AQS for all scenarios. Figure A-7 to Figure A-12 illustrate the dispersion of particulate and contribution to annual mean concentrations.

Due to the absence of reliable data at these receptor locations on existing annual mean PM_{10} concentrations from background sources (e.g. agricultural practices, transport, cooking etc) it is not possible to accurately predict what total exposure levels are likely to be, however the contribution from the mine emissions leaves significant headroom below the annual mean guideline values for emissions from these sources into the airshed. As such the risk of exceedences is predicted to be low.

Table 7-4
Process Contribution to PM_{10} Annual Mean Concentration

Receptor	Scenario 0 (µg/m³)	% of AQS	Scenario 1a (µg/m³)	% of AQS	Scenario 1b (µg/m³)	% of AQS
Unmitigated						
Hotazel 1	0.7	1.8%	1.5	3.7%	4.6	11.5%
Hotazel 2	0.6	1.6%	1.5	3.6%	3.8	9.4%
Hotazel 3	0.6	1.4%	1.5	3.8%	2.6	6.5%
Hotazel 4	0.5	1.3%	1.5	3.8%	2.1	5.2%
Hotazel 5	0.7	1.7%	2.4	6.0%	2.1	5.3%
Devon 1	0.3	0.7%	0.6	1.5%	14.5	36.3%
Devon 2	0.3	0.7%	0.6	1.5%	10.6	26.5%
Botha 313	4.0	10.0%	5.5	13.7%	5.6	14.1%
Mitigated						
Hotazel 1	0.4	0.9%	0.8	1.9%	2.4	5.9%
Hotazel 2	0.3	0.8%	0.8	1.9%	1.9	4.9%
Hotazel 3	0.3	0.7%	0.8	1.9%	1.3	3.4%
Hotazel 4	0.3	0.7%	0.8	2.0%	1.1	2.6%
Hotazel 5	0.4	0.9%	1.2	3.1%	1.1	2.7%
Devon 1	0.1	0.4%	0.3	0.8%	7.7	19.1%
Devon 2	0.1	0.4%	0.3	0.8%	5.6	13.9%

Receptor	Scenario 0 (µg/m³)	% of AQS	Scenario 1a (µg/m³)	% of AQS	Scenario 1b (µg/m³)	% of AQS
Botha 313	2.1	5.2%	2.8	7.1%	2.8	7.1%

The predicted contribution to 24-hour mean PM_{10} concentrations at receptor locations is presented in Table 7-5 below for both the unmitigated and mitigated scenario. Figure A-13 to Figure A-18 presents the dispersion of PM_{10} and the contribution to 24-hour mean concentrations (as a 99th percentile). The unmitigated scenario results in exceedences of the 24-hour mean AQS at receptors close to the Devon Pit for Scenario 1b, i.e. during the working of the Devon Pit, due to its close proximity to receptors. With mitigation the concentration is reduced to close to the AQS, however the levels still exceed the AQS. The predicted process contribution to 24-hour mean concentrations remains significantly below (less than 30%) the AQS for the other assessed operational scenarios.

Due to the absence of reliable data at these receptor locations on existing 24-hour mean PM_{10} concentrations from background sources it is not possible to accurately predict what total exposure levels are likely to be. The contribution from the mine emissions leaves significant headroom below the 24-hour mean guideline values for emissions from these sources into the airshed for the approved scheme (Scenario 0) and the proposed scheme (Scenario 1a), however the working of the Devon Pit is likely to lead to exceedences of the AQS given the reduced headroom. It should be noted that working of the Devon Pit is only proposed to take 1 year and as such the impact is of short duration.

Table 7-5
Process Contribution to PM_{10} 24-hour Mean Concentration (99th Percentile)

Receptor	Scenario 0 (µg/m³)	% of AQS	Scenario 1a (µg/m³)	% of AQS	Scenario 1b (µg/m³)	% of AQS
Unmitigated						
Hotazel 1	8.0	10.7%	19.3	25.8%	101.4	135.2%
Hotazel 2	6.4	8.6%	19.1	25.5%	76.5	101.9%
Hotazel 3	5.8	7.7%	19.2	25.6%	39.8	53.1%
Hotazel 4	5.2	6.9%	19.2	25.6%	30.7	40.9%
Hotazel 5	6.1	8.1%	27.2	36.3%	28.2	37.6%
Devon 1	3.7	5.0%	10.1	13.5%	166.0	221.3%
Devon 2	3.7	5.0%	8.9	11.9%	152.0	202.7%
Botha 313	29.9	39.9%	79.6	106.1%	80.3	107.1%
Mitigated						
Hotazel 1	4.3	5.8%	10.2	13.6%	62.6	83.4%
Hotazel 2	3.2	4.3%	9.8	13.1%	38.5	51.3%
Hotazel 3	2.9	3.9%	9.9	13.1%	20.1	26.8%
Hotazel 4	2.7	3.6%	9.8	13.1%	15.5	20.7%
Hotazel 5	3.1	4.2%	14.0	18.6%	14.2	19.0%
Devon 1	2.1	2.9%	5.2	6.9%	84.8	113.1%
Devon 2	2.0	2.7%	4.6	6.1%	76.4	101.9%
Botha 313	16.7	22.3%	41.7	55.6%	40.1	53.5%

7.2.2 Manganese Impact

The predicted process contribution to annual mean concentration of manganese is presented in Table 7-6 below. It is evident that the application of dust abatement measures reduces predicted exposure significantly in terms of annual mean exposure. The proposed scheme (Scenarios 1a and 1b) represent an increase on the approved scheme (Scenario 0).

Receptors close to Devon are at a risk of exeedences of the WHO limit value during the working of the Devon Pit with exceedences predicted at the closest receptors. As manganese is a constituent of the PM_{10} it follows the same patterns of dispersion as presented in the Figures for annual mean PM_{10} impact. It should be noted that working of the Devon Pit is only proposed to take 1 year and as such the impact is of short duration. The mitigated impact at all other receptors is predicted to be below the WHO limit value.

Table 7-6
Process Contribution to Manganese Annual Mean Concentration

Receptor	Scenario 0 (µg/m³)	% of WHO Limit	Scenario 1a (µg/m³)	% of WHO Limit	Scenario 1b (µg/m³)	% of WHO Limit
Unmitigated						
Hotazel 1	0.03	17.4%	0.03	23.3%	0.08	50.7%
Hotazel 2	0.02	14.2%	0.03	19.2%	0.07	45.1%
Hotazel 3	0.02	12.2%	0.02	15.9%	0.05	35.1%
Hotazel 4	0.02	11.0%	0.02	14.7%	0.04	26.1%
Hotazel 5	0.02	14.0%	0.03	19.7%	0.04	29.8%
Devon 1	0.01	6.5%	0.01	7.7%	0.27	179.8%
Devon 2	0.01	6.7%	0.01	7.6%	0.19	125.5%
Botha 313	0.18	118.6%	0.17	111.6%	0.21	139.0%
Mitigated						
Hotazel 1	0.02	10.9%	0.03	18.8%	0.05	32.5%
Hotazel 2	0.01	8.7%	0.02	15.6%	0.04	29.3%
Hotazel 3	0.01	7.2%	0.02	13.2%	0.03	21.8%
Hotazel 4	0.01	6.5%	0.02	12.6%	0.02	15.0%
Hotazel 5	0.01	8.4%	0.03	17.8%	0.03	17.3%
Devon 1	0.01	4.1%	0.01	6.2%	0.15	101.2%
Devon 2	0.01	4.3%	0.01	6.1%	0.12	82.3%
Botha 313	0.12	81.0%	0.11	75.2%	0.11	70.8%

7.2.3 Dust Deposition

The predicted contribution of mine emissions to dust deposition rates at receptor locations for both the mitigated and un-mitigated scenario is presented in Table 7-7 below. The proposed scheme (Scenarios 1a and 1b) represent an increase on the approved scheme (Scenario 0), however the process contribution remains below the Residential Target Value at all receptors for all scenarios.

Due to the absence of data at these receptor locations on existing dust deposition from background sources (e.g. agricultural practices, transport, etc) it is not possible to accurately predict what total deposition levels are likely to be, however considering an indicative background of 200 to 300mg/m^2/day total deposition is likely to be below the 'residential action level'.

Table 7-7
Predicted Dust Deposition (mg/m^2/day as a monthly mean)

Receptor	Scenario 0 (mg/m²/day)	% of Residential Target	Scenario 1a (mg/m²/day)	% of Residential Target	Scenario 1b (mg/m²/day)	% of Residential Target
Unmitigated						
Hotazel 1	4.3	1.4%	7.0	2.3%	14.0	4.7%

Receptor	Scenario 0 ($mg/m^2/day$)	% of Residential Target	Scenario 1a ($mg/m^2/day$)	% of Residential Target	Scenario 1b ($mg/m^2/day$)	% of Residential Target
Hotazel 2	4.1	1.4%	7.1	2.4%	13.4	4.5%
Hotazel 3	3.3	1.1%	7.8	2.6%	9.2	3.1%
Hotazel 4	2.7	0.9%	8.9	3.0%	8.5	2.8%
Hotazel 5	3.1	1.0%	15.9	5.3%	12.6	4.2%
Devon 1	1.1	0.4%	2.2	0.7%	119.9	40.0%
Devon 2	1.3	0.4%	2.5	0.8%	66.0	22.0%
Botha 313	32.4	10.8%	42.3	14.1%	40.8	13.6%
Mitigated						
Hotazel 1	2.2	0.7%	3.5	1.2%	7.0	2.3%
Hotazel 2	2.1	0.7%	3.6	1.2%	6.7	2.2%
Hotazel 3	1.6	0.5%	3.9	1.3%	4.6	1.5%
Hotazel 4	1.4	0.5%	4.5	1.5%	4.3	1.4%
Hotazel 5	1.6	0.5%	8.0	2.7%	6.4	2.1%
Devon 1	0.6	0.2%	1.1	0.4%	60.0	20.0%
Devon 2	0.7	0.2%	1.2	0.4%	33.0	11.0%
Botha 313	16.3	5.4%	21.3	7.1%	20.5	6.8%

Figure A-19 to Figure A-24 illustrate the spatial variation in dust deposition rates in the surrounding environment and indicates that the extent of the area where the Target Level of 300mg/m^2/day may be exceeded does not encompass any sensitive receptors.

7.3 Evaluation of Significance of Impacts

The potential impacts have been considered within the EIA matrix for assessment of significance, the judgement and reasoning for each category is presented in Table 7-8 below.

Table 7-8
Evaluation of Significance of Impacts

Category	Un-mitigated	Mitigated	Judgement and Reasoning
Severity	**High**	**High**	The judgement on severity has been based on the highest impact at a receptor location. The AQS for 24-hour mean PM_{10} and WHO Limit for manganese are predicted to be exceeded at locations close to the Devon Pit. There may potentially be an impact at the closest receptors on Botha 313 during the construction phase however the construction dust emission factors are considered likely to over-estimate impacts. Mitigation reduces the impacts but exposure remains just above the AQS and WHO limits. The severity at other receptor locations in Hotazel can be considered as Low with mitigation applied.
Duration	**Low**	**Low**	Although the potential for dust emissions will persist for the life of the mine (i.e. medium term) the impacts are primarily associated with impacts during the mining of Devon Pit. The duration of work in this area are only 1 year, significantly less than the life of the entire project. On cessation of all mining activities, even in the

Category	Un-mitigated	Mitigated	Judgement and Reasoning
			complete absence of a restoration programme, the cessation of mechanical disturbance, particularly on the haul roads, and the attenuation from natural re-vegetation of soil and waste piles on the level of dust raised by potential wind erosion will not result in impacts approaching the scale predicted during the operational phase.
Spatial Extent	**Medium**	**Medium**	The impacts are considered to be of medium spatial extent. Dust emissions will travel beyond the site boundary and result in concentrations or accumulations that exceed the AQS close to the Devon Pit. Dust travelling beyond the site boundary will not result in concentrations or accumulations that exceed the AQS in Hotazel.
CONSEQUENCE	**MEDIUM**	**MEDIUM**	
PROBABILITY	**Medium**	**Medium**	It is predicted that there would be possible/frequent exceedences of the 24-hour mean AQS for PM_{10} at receptors close to Devon Pit. The mitigation would reduce the frequency of exxedences but not to below the AQS. The probability of exposure above the AQS at the receptors in Hotazel is considered to be ‘low’, i.e. unlikely /seldom with the application of mitigation.
SIGNIFICANCE	**MEDIUM**	**MEDIUM**	On the basis of the consequence and probability of exposure the unmitigated and mitigated impacts are considered to be of ‘medium’ significance at receptors close to the Devon Pit. Mitigated impacts at the receptors in Hotazel are of ‘low’ significance.

8.0 RECOMMENDATIONS

The approved scheme is operated in accordance with Environmental Management Plan (DMR Ref: NC 30/5/1/2/2/268 MR, September 2010). The EMP includes dust management measures, contingency action and requirements for the air quality monitoring program.

The mitigation measures detailed in the EMP are likely to remain appropriate for the proposed scheme given that the types of operations being undertaken remain similar. An expanded scope within the dust management measures should consider:

- dust management at the TMF (during construction and operation); and
- dust monitoring including PM_{10}, with analysis of content of manganese, and dust deposition at locations in proximity to the Devon Pit and at receptor locations within the southern parts of Hozatel.

9.0 CONCLUSIONS

The conclusions of the assessment are that:

- the dust emissions from the proposed operations at Kudumane Mine are not predicted to result in exceedences of the National Ambient Air Quality Standards, WHO guidelines for manganese, or dust deposition limits at the identified sensitive receptor locations with the effective implementation of the dust mitigation measures; and
- the dust emissions from the proposed mining of the Devon Pit are likely to results in exceedences of the National Ambient Air Quality Standard for 24-hour PM_{10} and the WHO guidelines for manganese for those receptors close to the Devon Pit but not in Hotazel.

It is recommended that the management and control measures and monitoring detailed within the EMP continue to be implemented and the on-going monitoring is used as the basis of developing a programme of continual improvement with respect to managing emissions to the aerial environment.

10.0 CLOSURE

This report has been prepared by SLR Consulting Limited with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of Kudumane Manganese Resources (Pty) Ltd; no warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.

APPENDIX A: DISPERSION MODELLING FIGURES

Figure A-1 Construction Phase – Annual Mean PM_{10} Impact (Unmitigated)

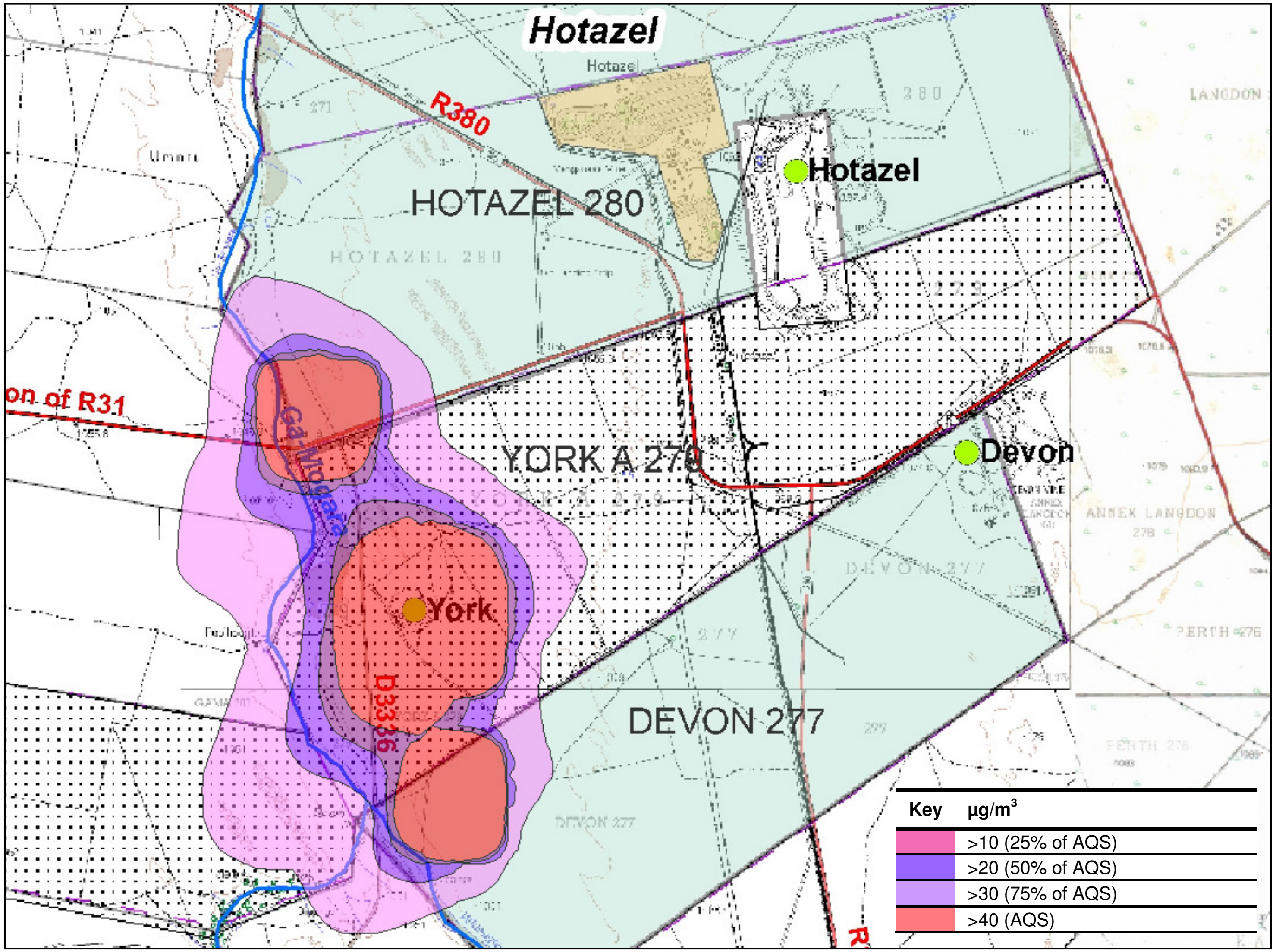


Figure A-2 Construction Phase – Annual Mean PM_{10} Impact (Mitigated)

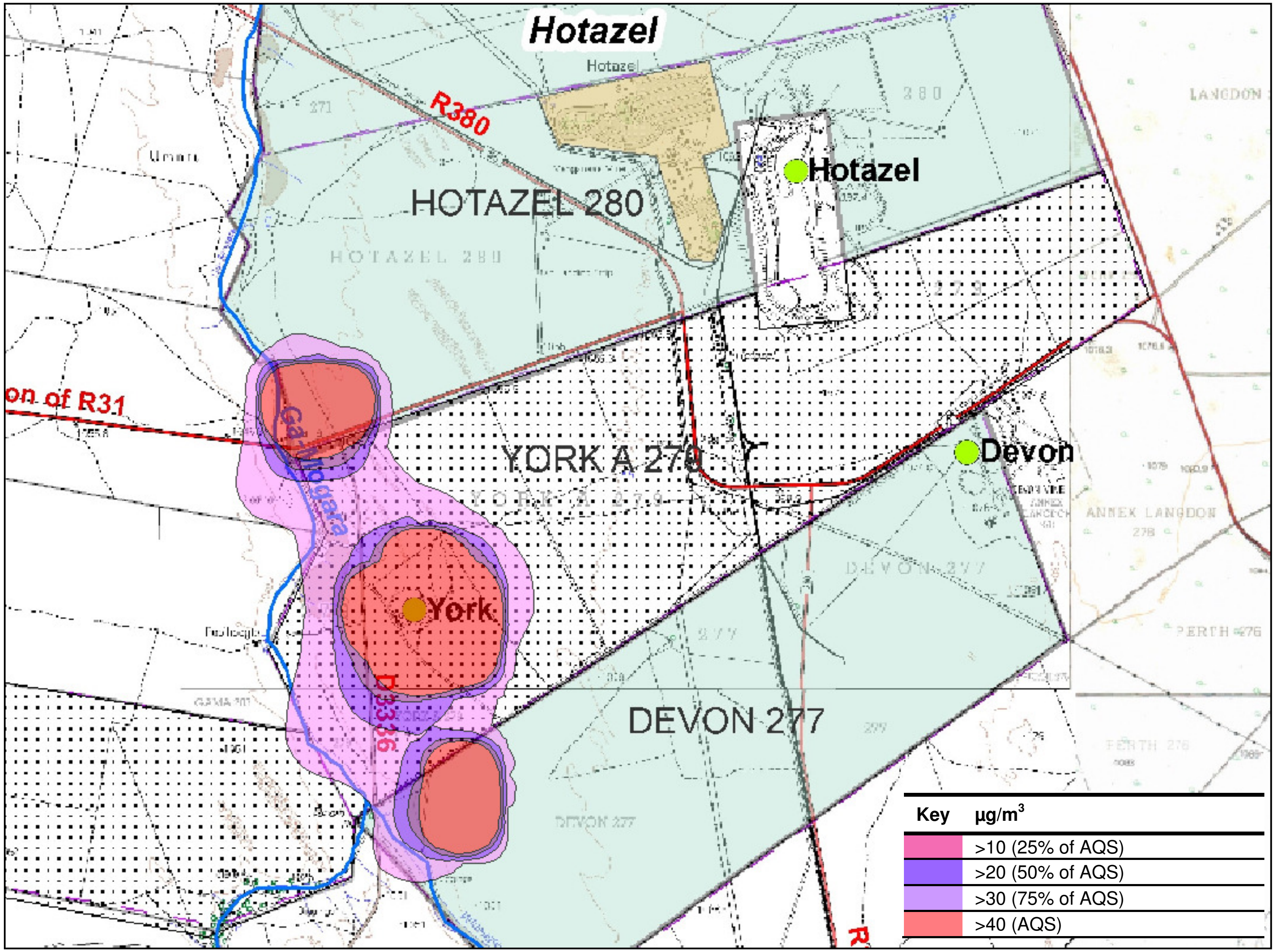


Figure A-3 Construction Phase – 24-hour Mean PM_{10} Impact (Unmitigated)

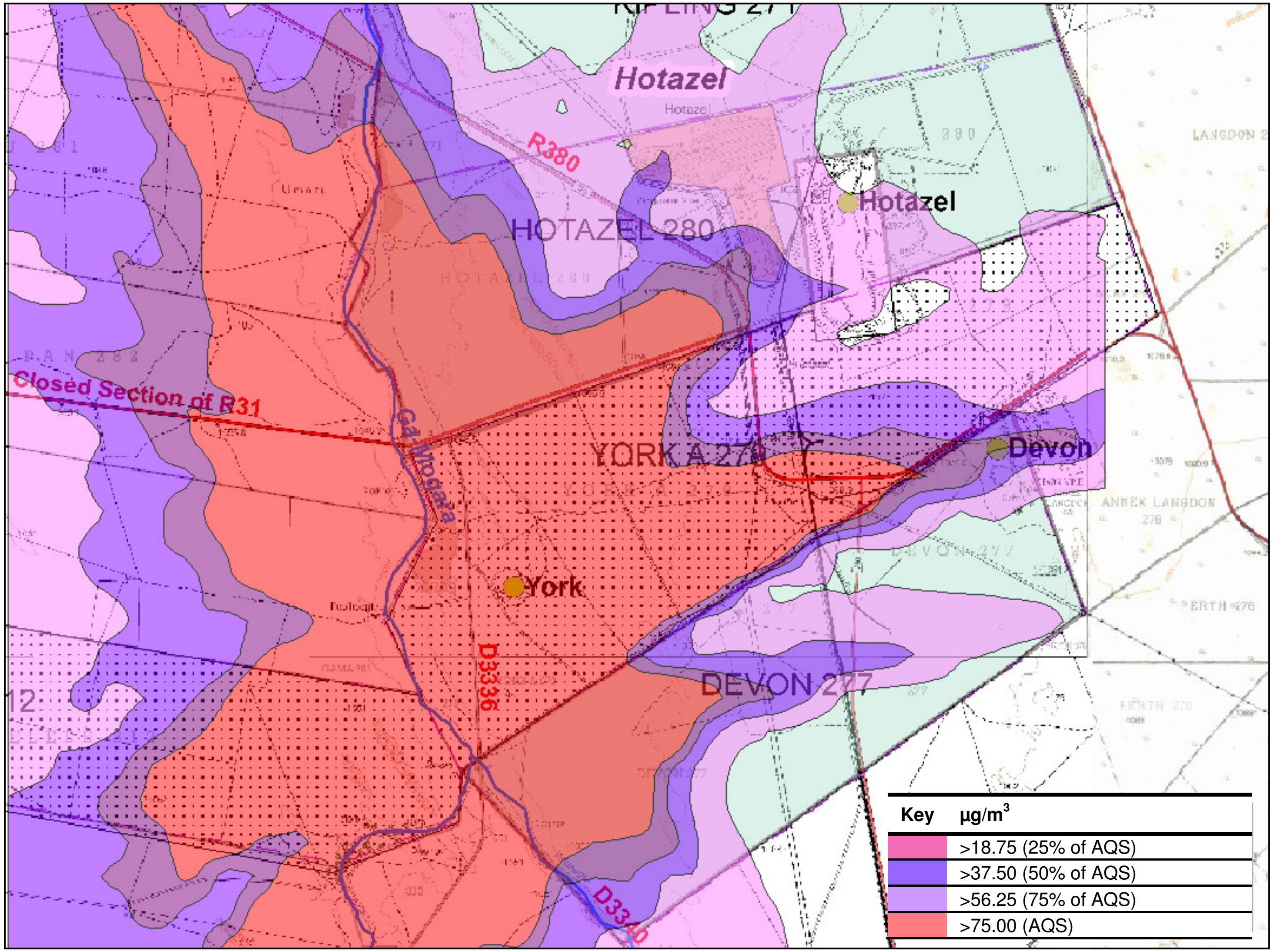


Figure A-4 Construction Phase – 24-hour Mean PM_{10} Impact (Mitigated)

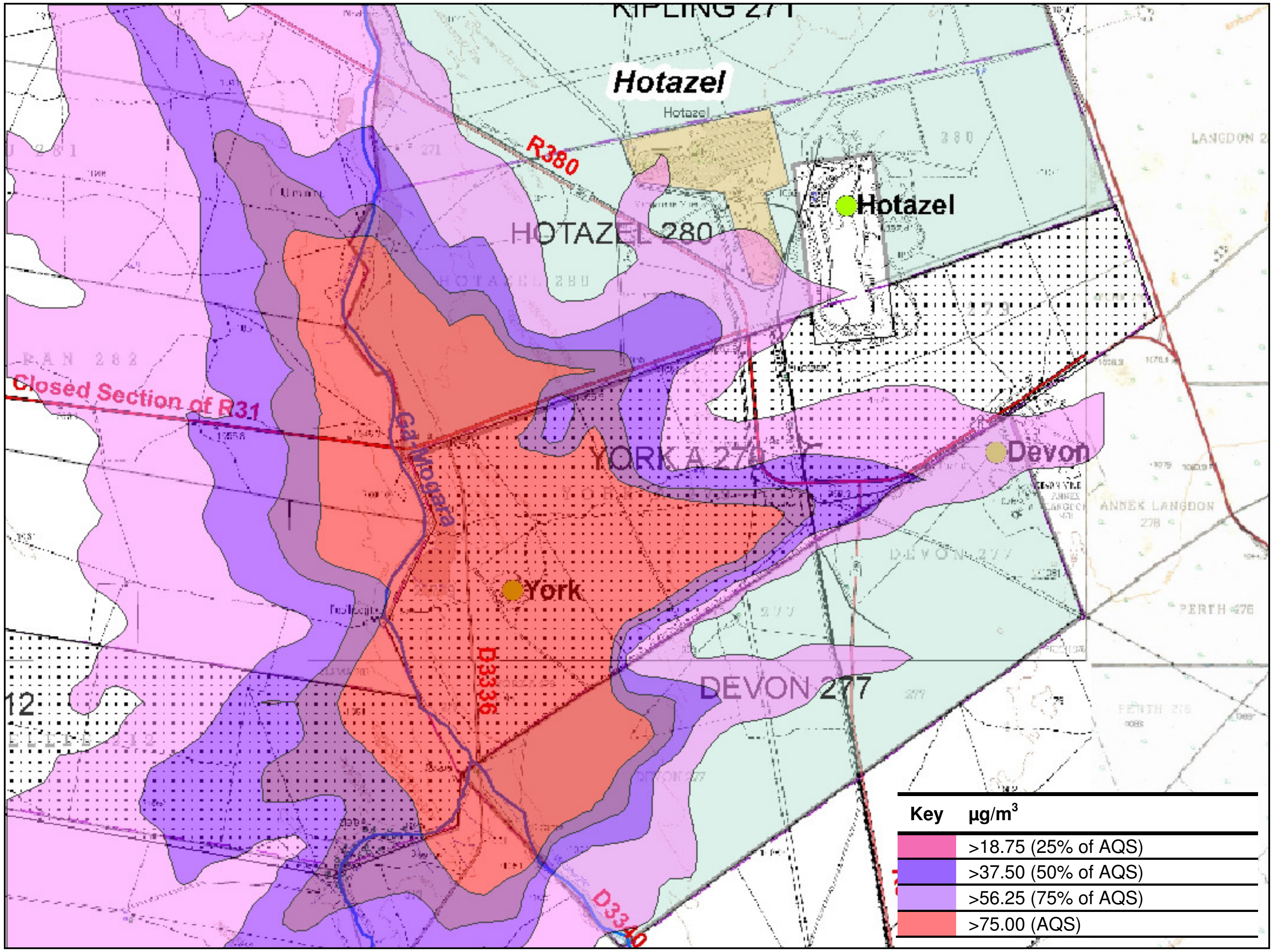


Figure A-5 Construction Phase – Dust Deposition Impact (Unmitigated)

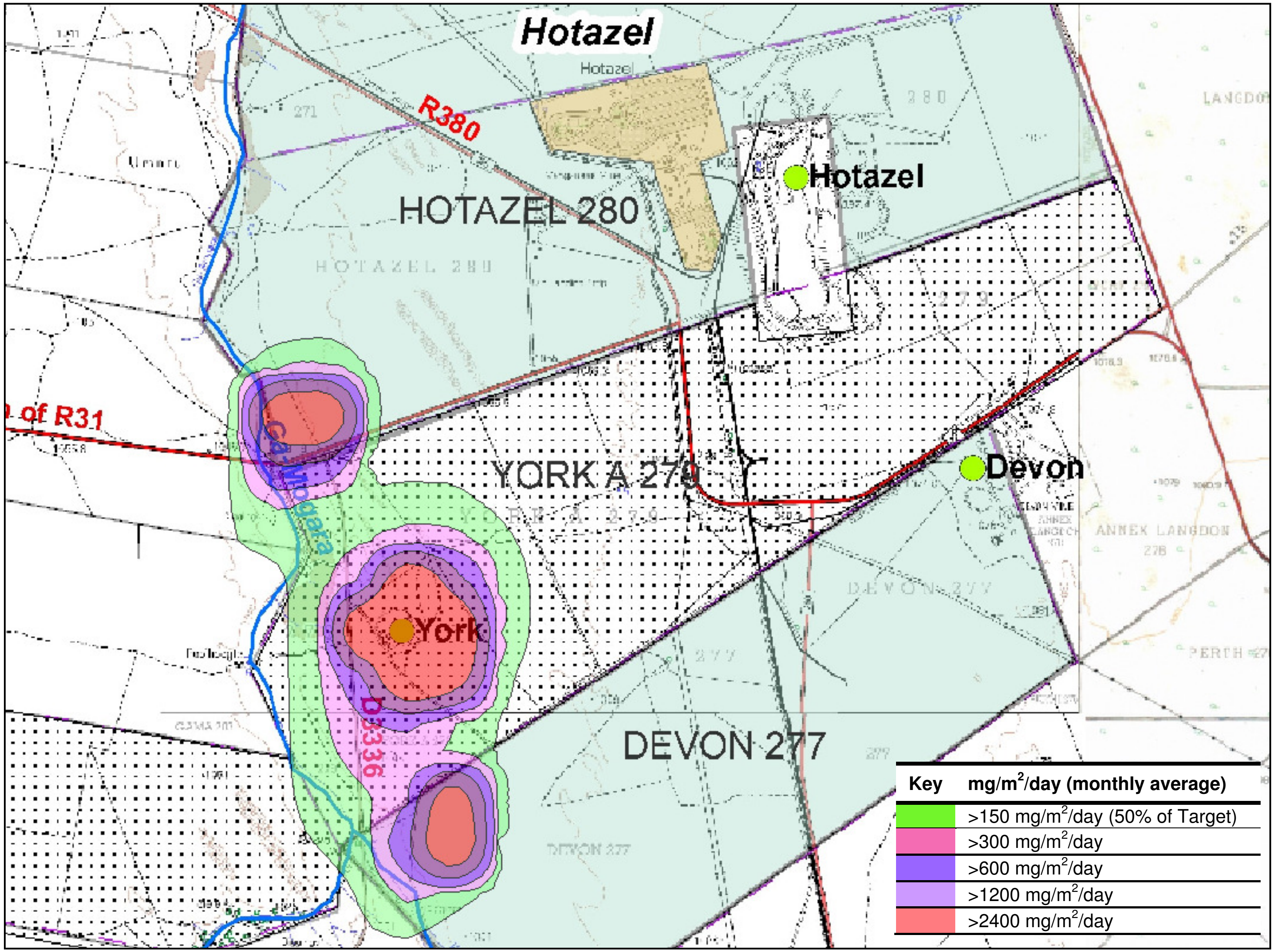


Figure A-6 Construction Phase – Dust Deposition Impact (Mitigated)

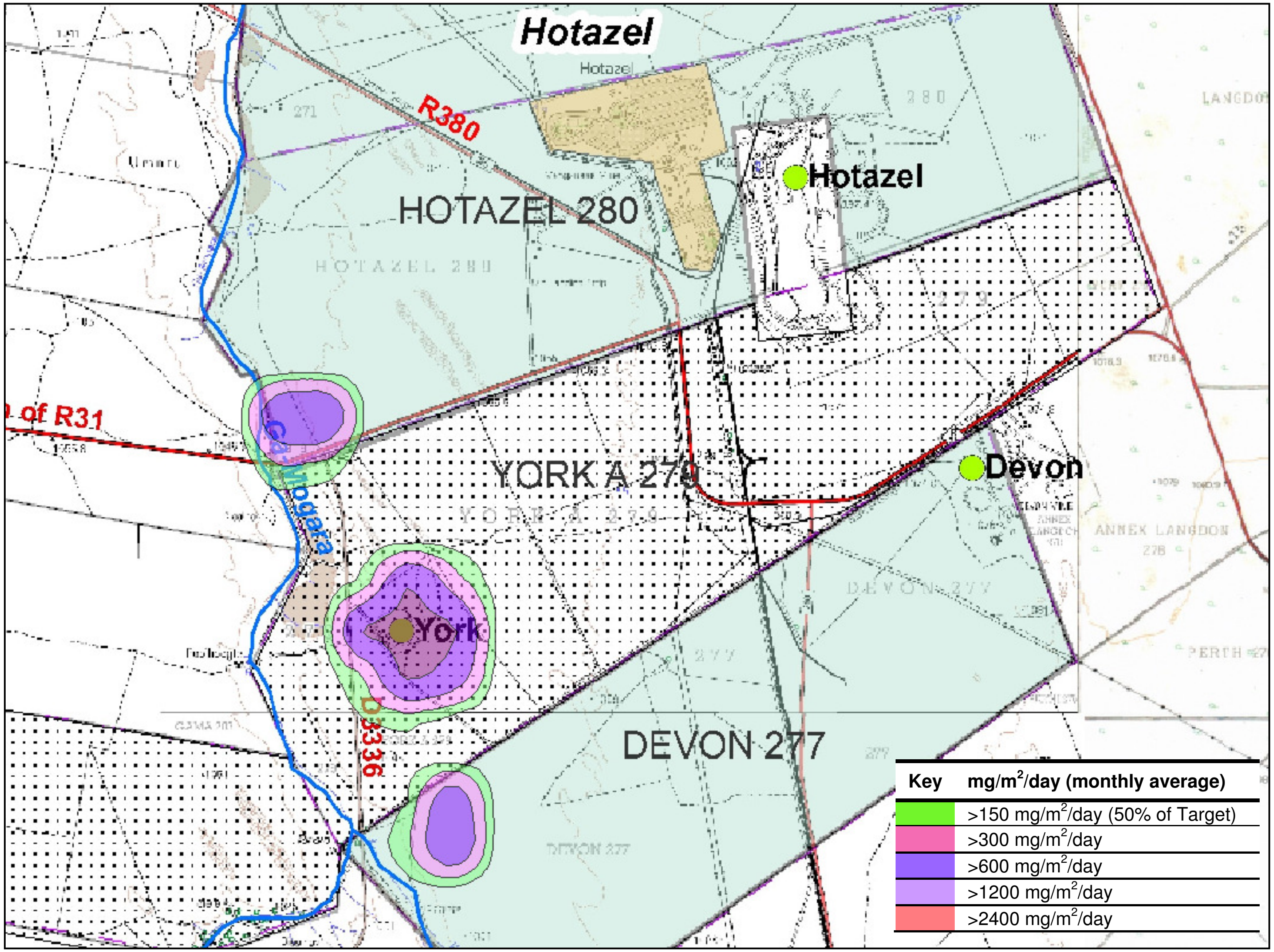


Figure A-7 Scenario 0 – Annual Mean PM_{10} Impact (Unmitigated)

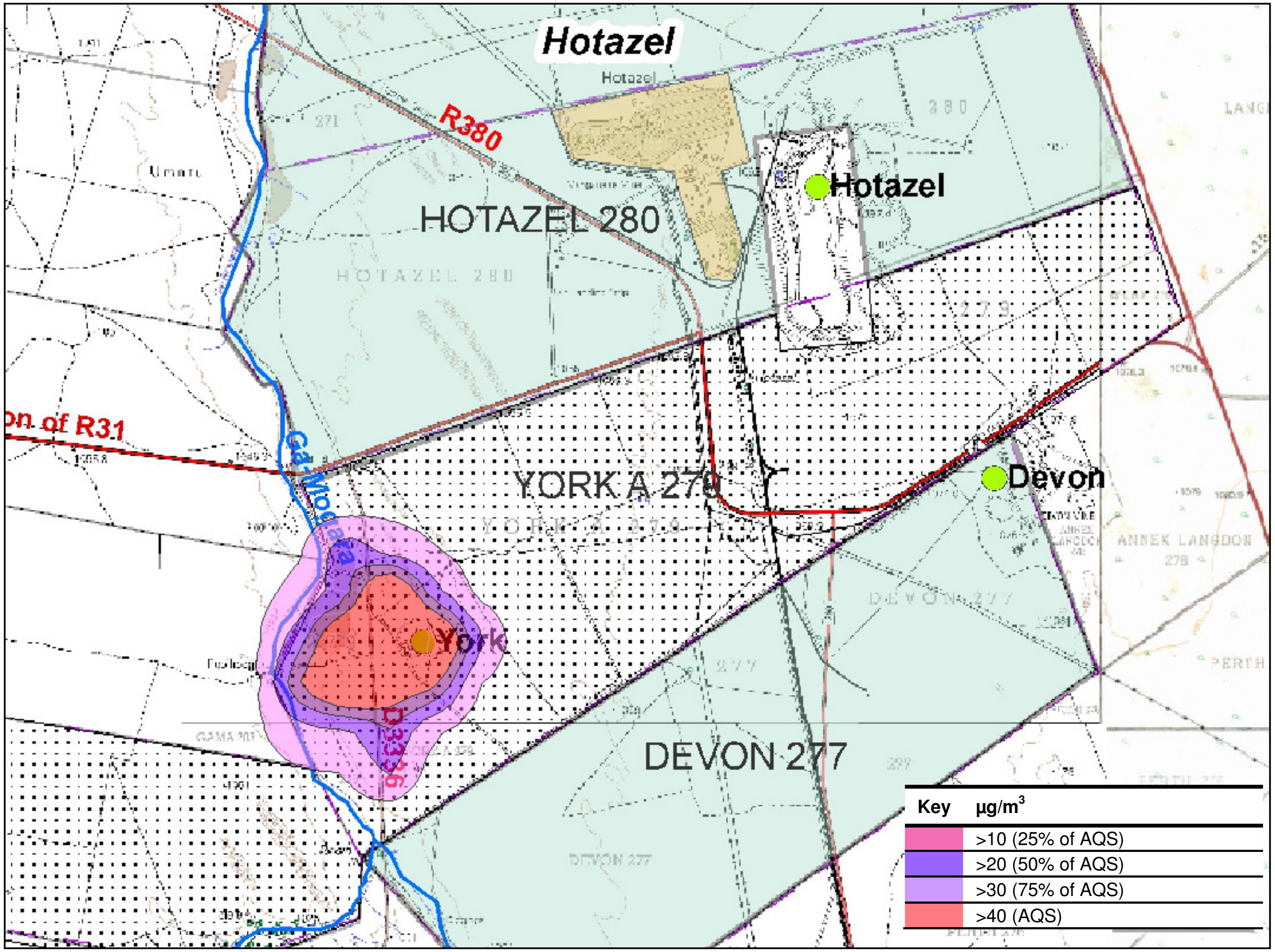


Figure A-8 Scenario 1a – Annual Mean PM_{10} Impact (Unmitigated)

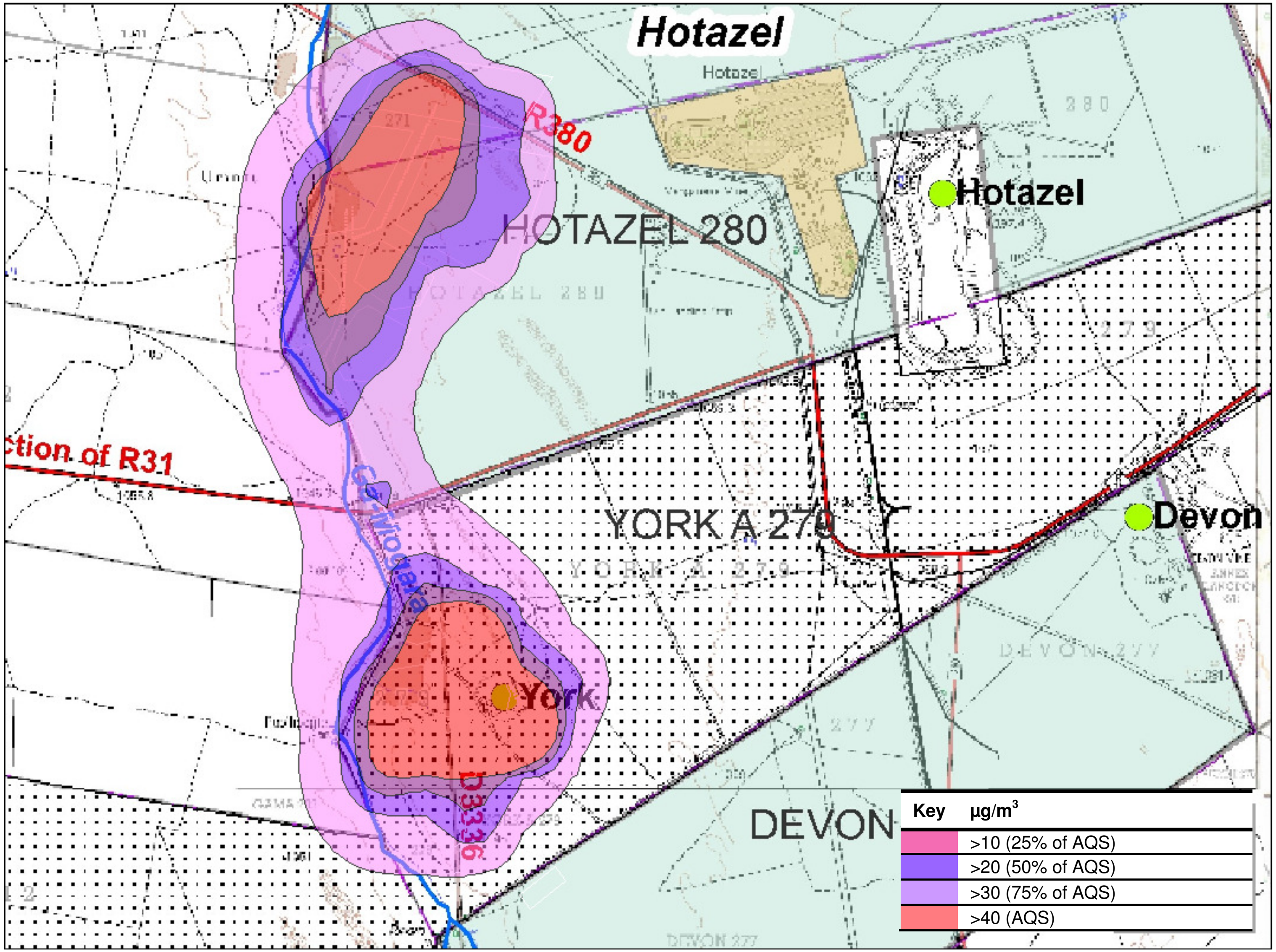


Figure A-9 Scenario 1b – Annual Mean PM_{10} Impact (Unmitigated)

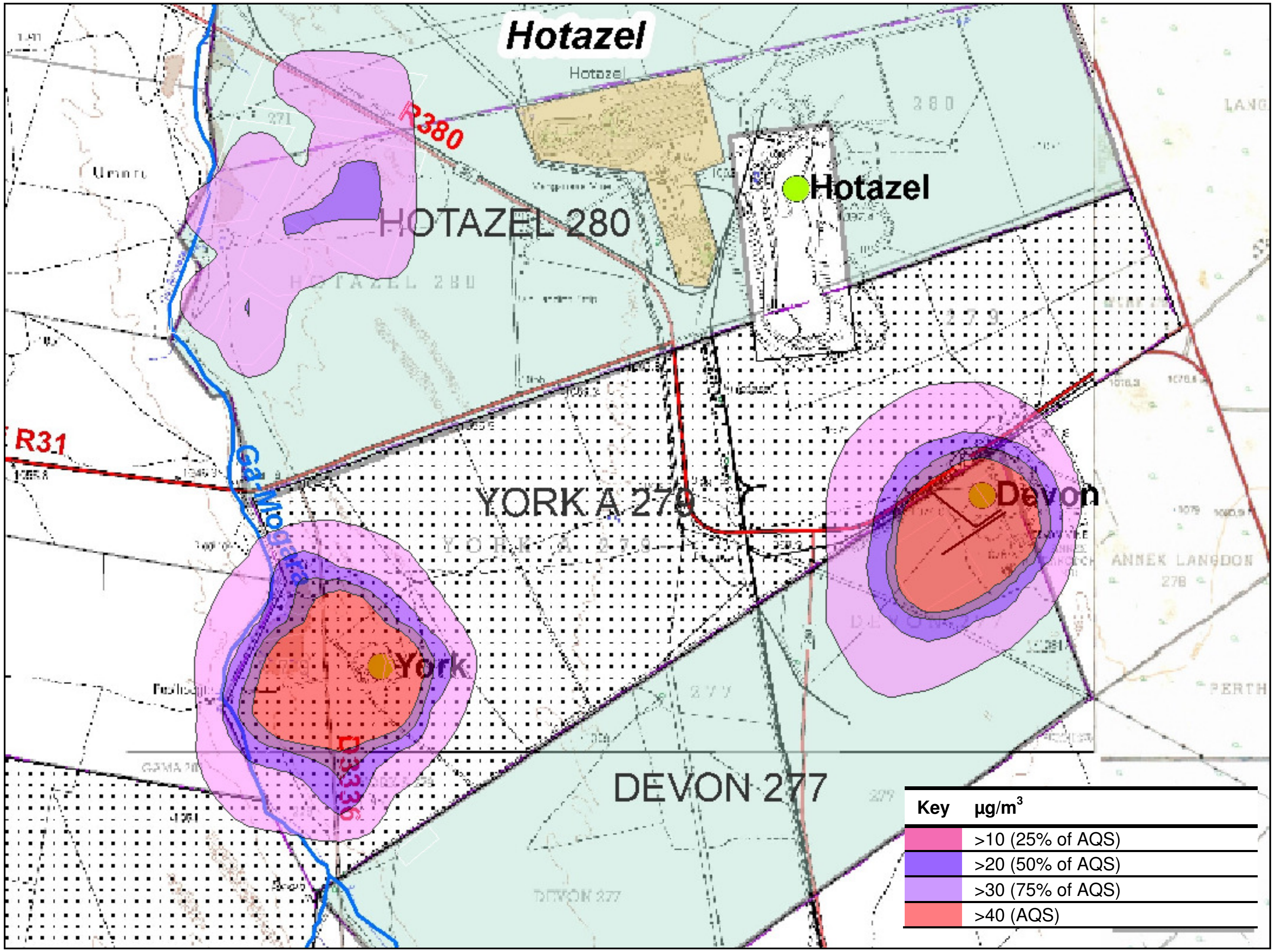


Figure A-10 Scenario 0 – Annual Mean PM_{10} Impact (Mitigated)

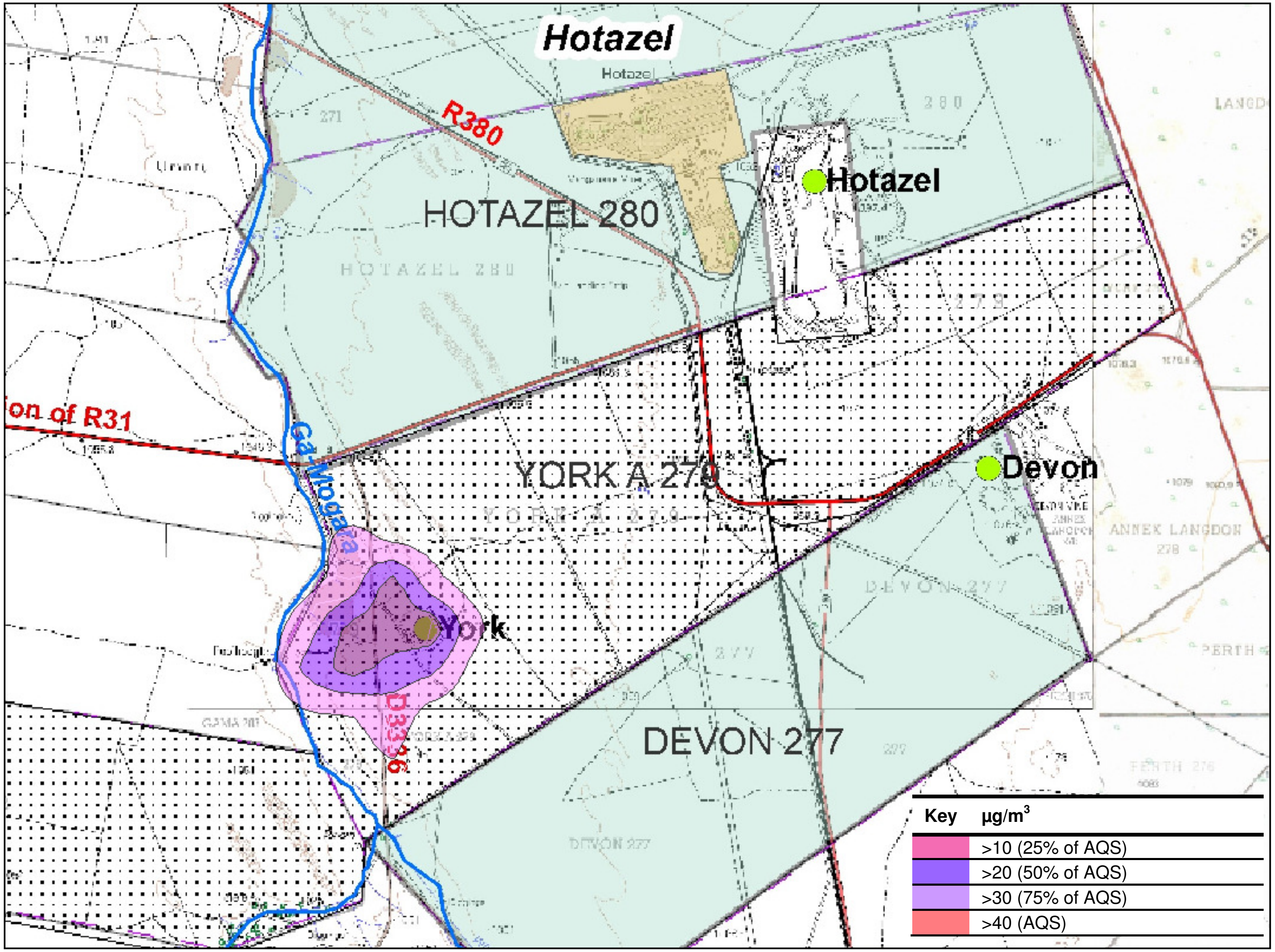


Figure A-11 Scenario 1a – Annual Mean PM_{10} Impact (Mitigated)

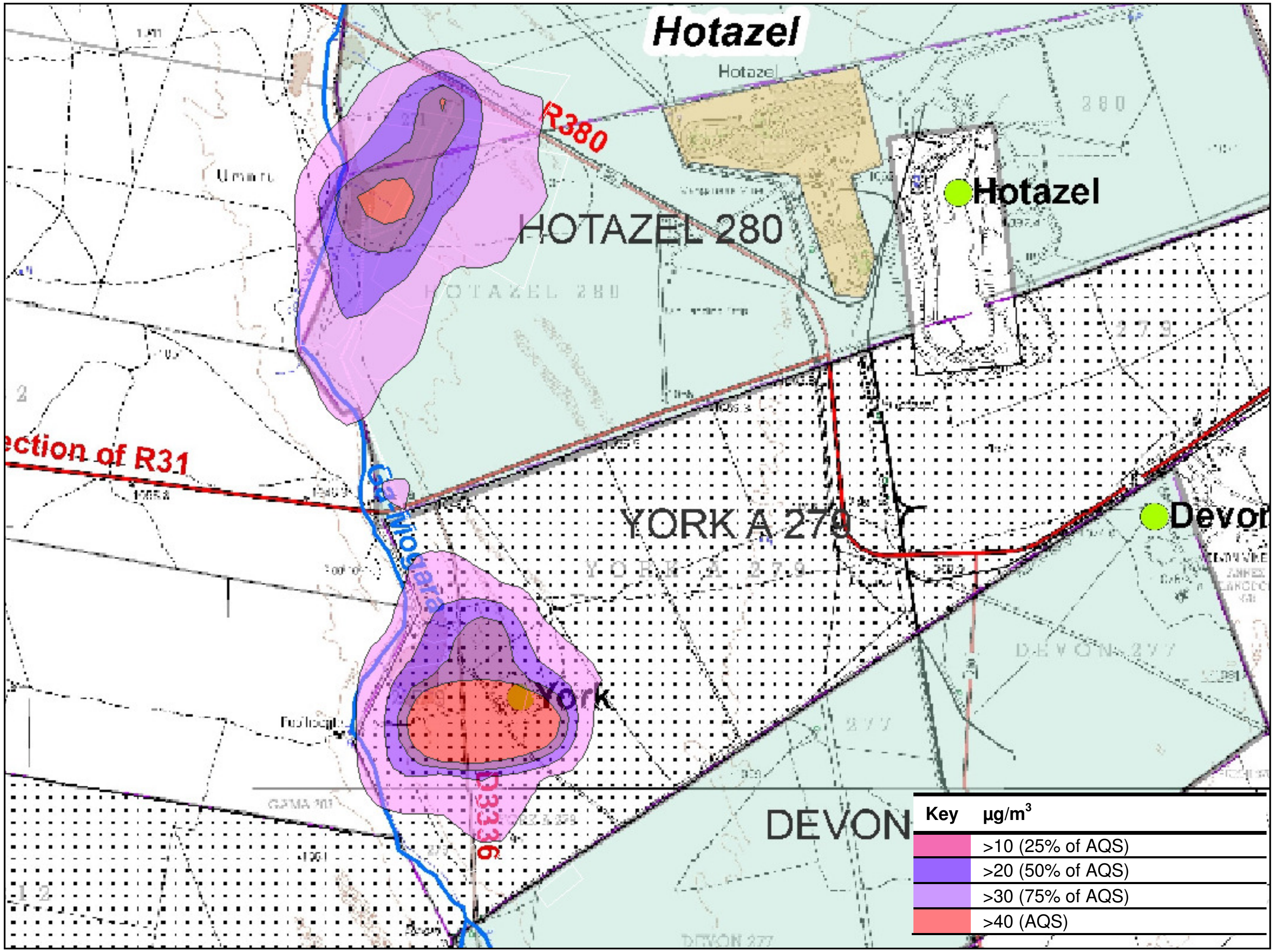


Figure A-12 Scenario 1b – Annual Mean PM_{10} Impact (Mitigated)

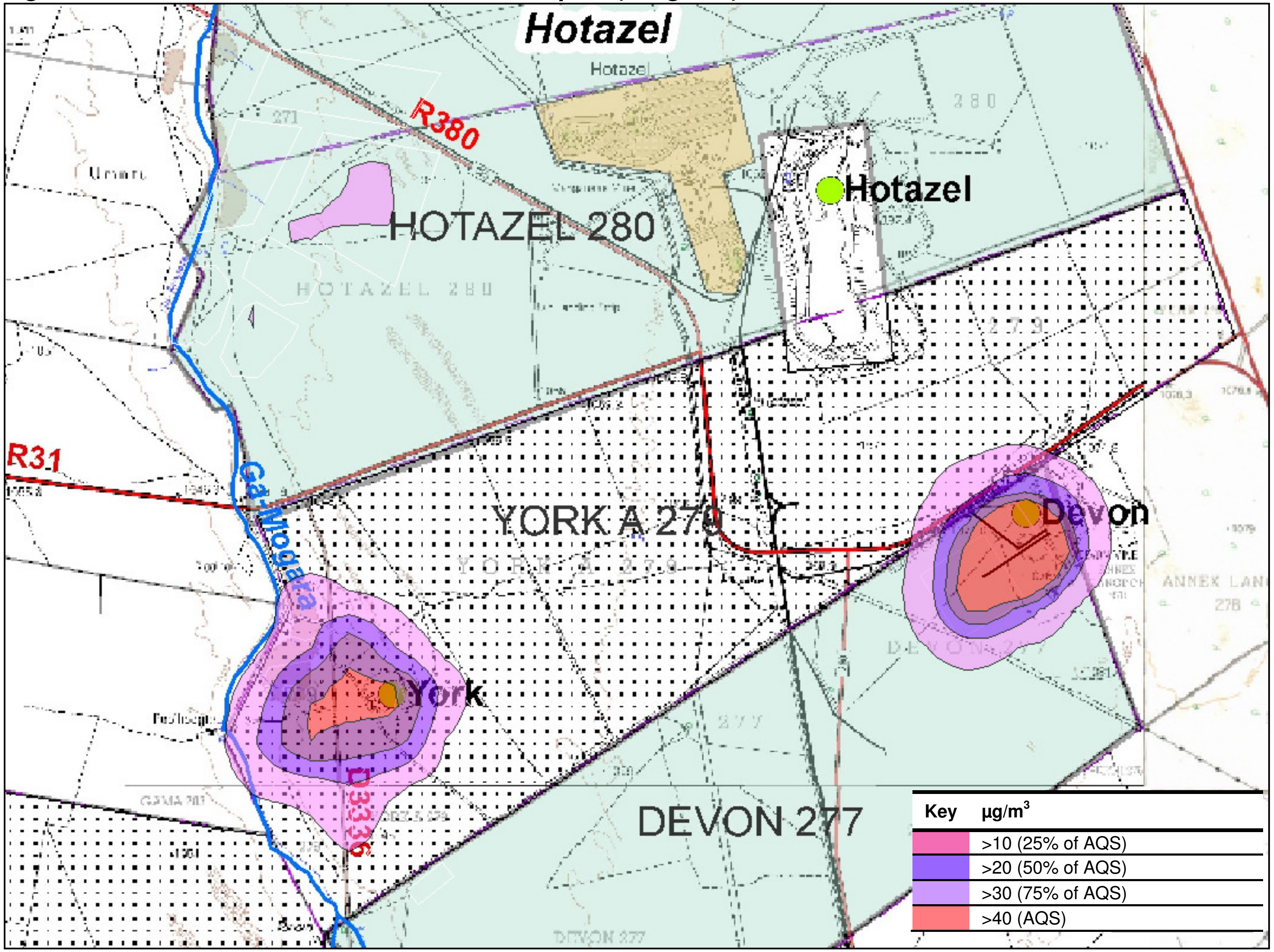


Figure A-13 Scenario 0 – 24-hour Mean 99th Percentile PM_{10} Impact (Unmitigated)

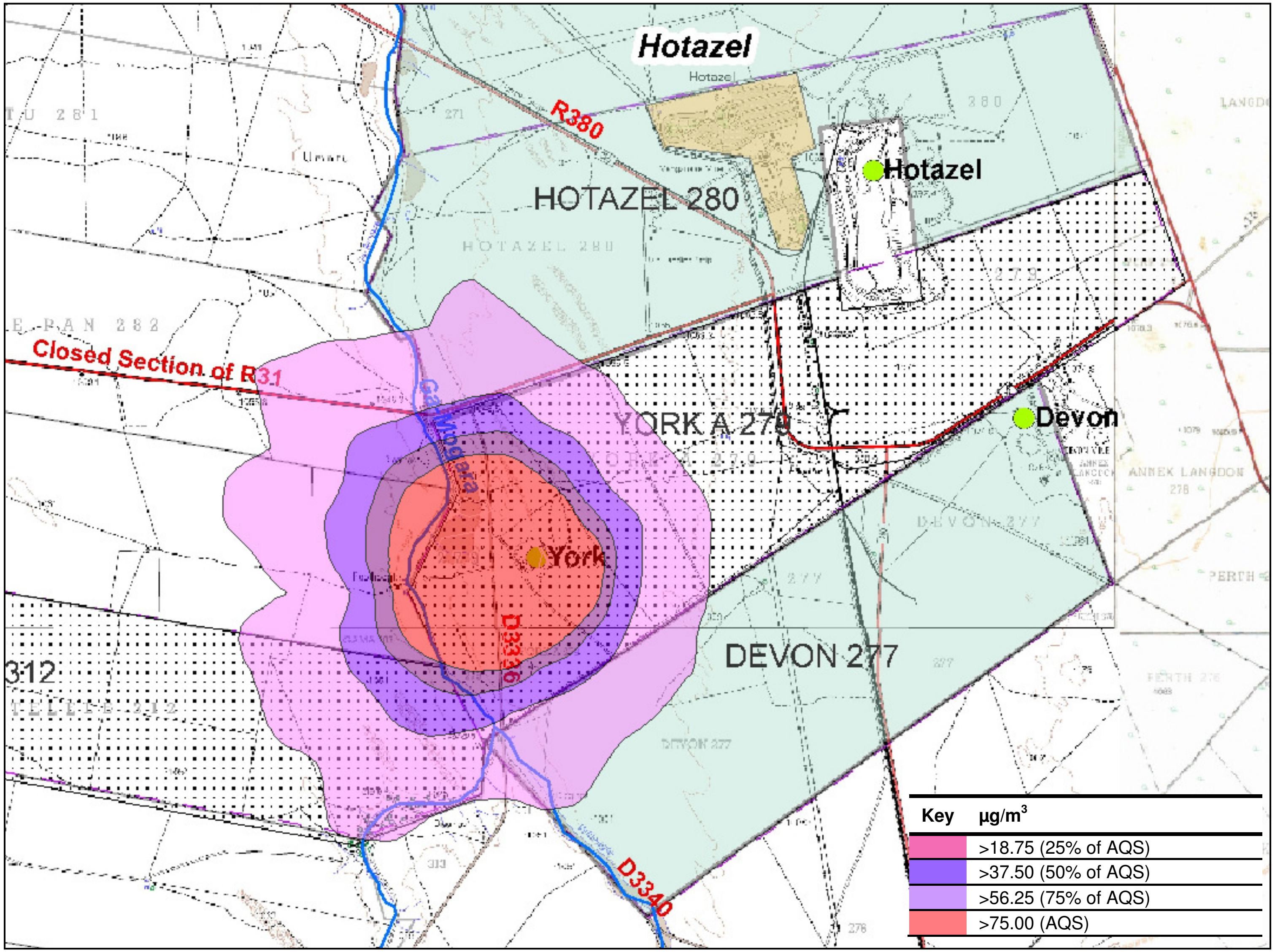


Figure A-14 Scenario 1a – 24-hour Mean 99th Percentile PM_{10} Impact (Unmitigated)

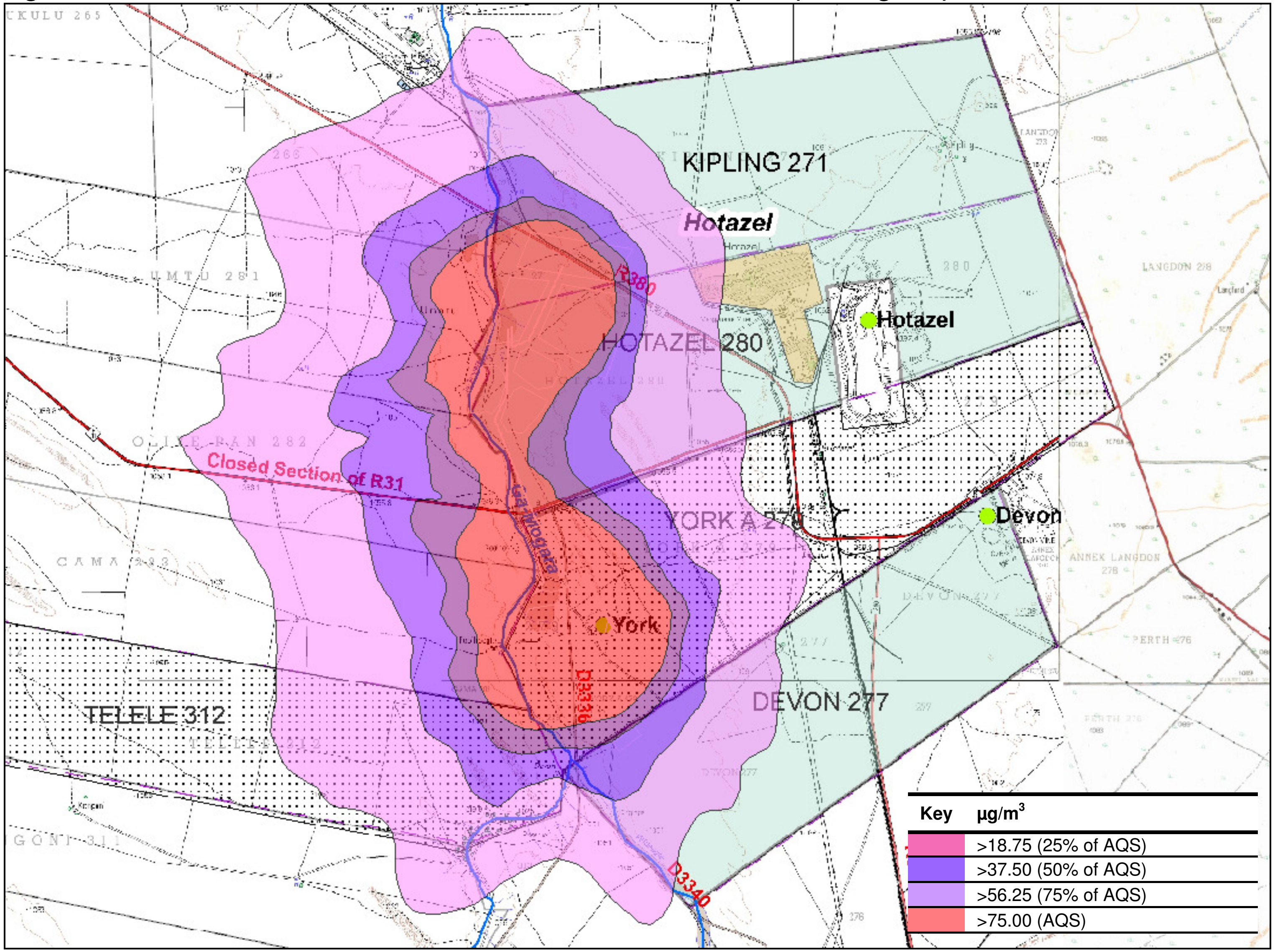


Figure A-15 Scenario 1b – 24-hour Mean 99th Percentile PM_{10} Impact (Unmitigated)

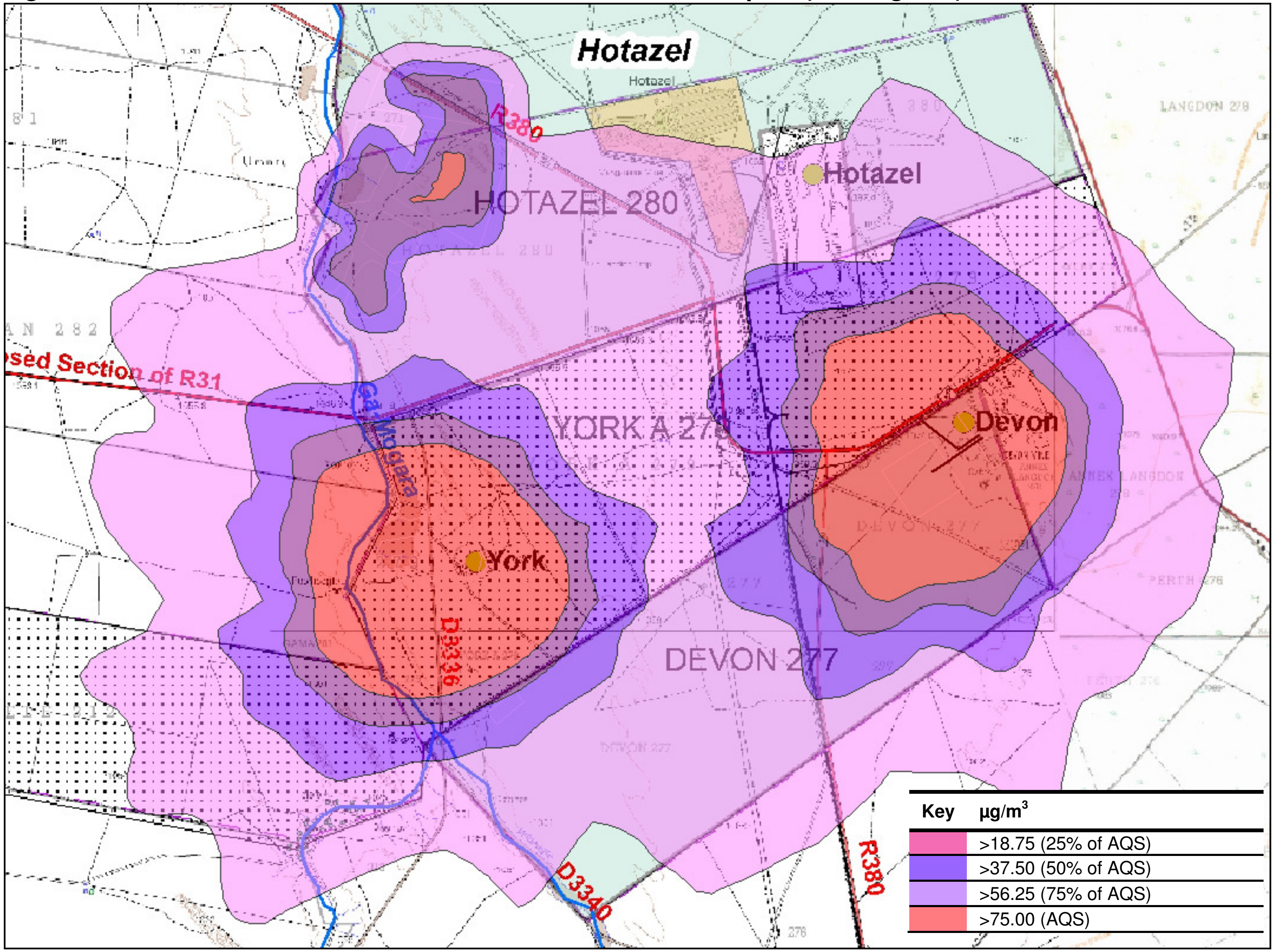


Figure A-16 Scenario 0 – 24-hour Mean 99th Percentile PM_{10} Impact (Mitigated)

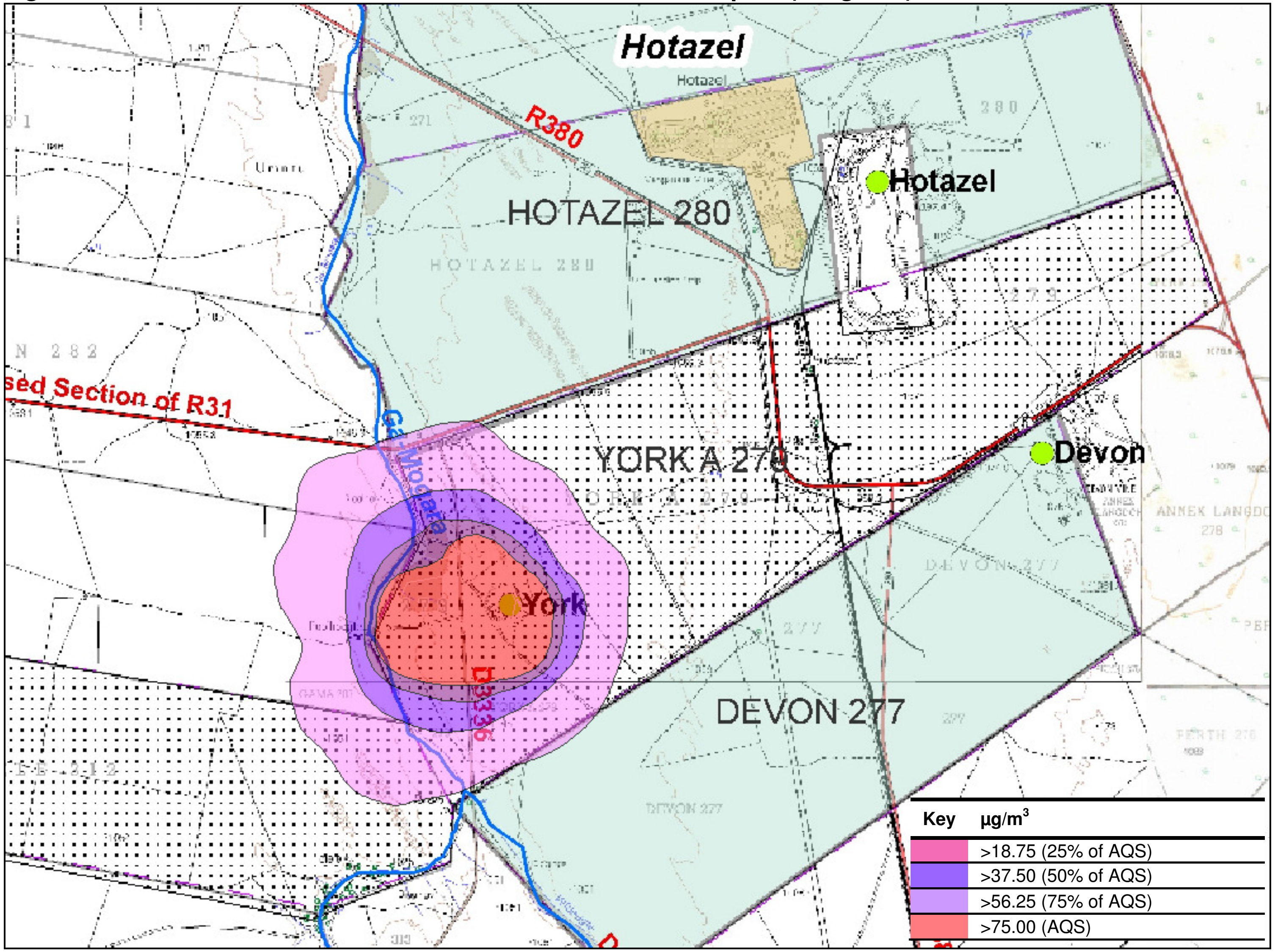


Figure A-17 Scenario 1a – 24-hour Mean 99th Percentile PM_{10} Impact (Mitigated)

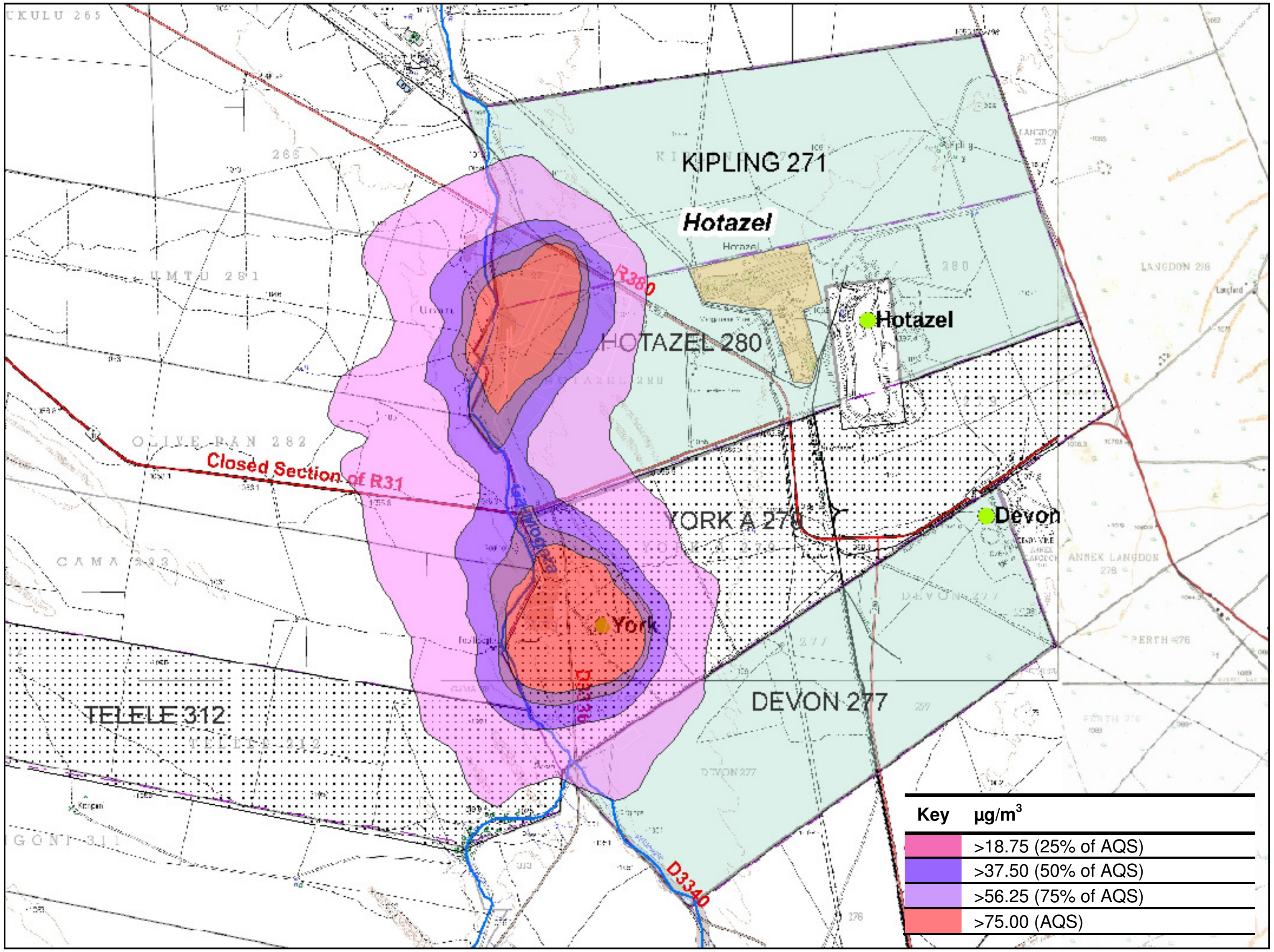


Figure A-18 Scenario 1b – 24-hour Mean 99th Percentile PM_{10} Impact (Mitigated)

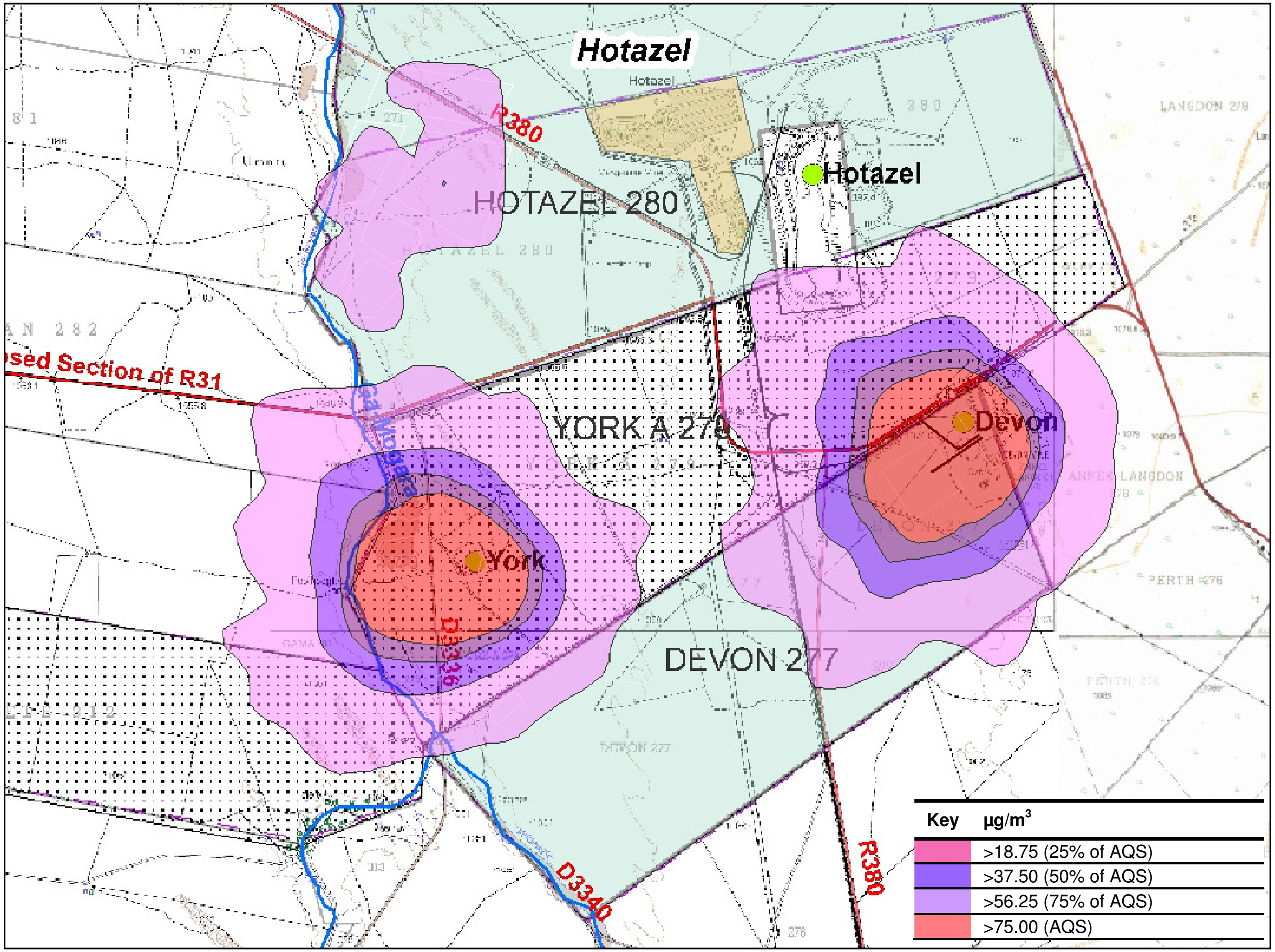


Figure A-19 Scenario 0 – Dust Deposition Impact (Unmitigated)

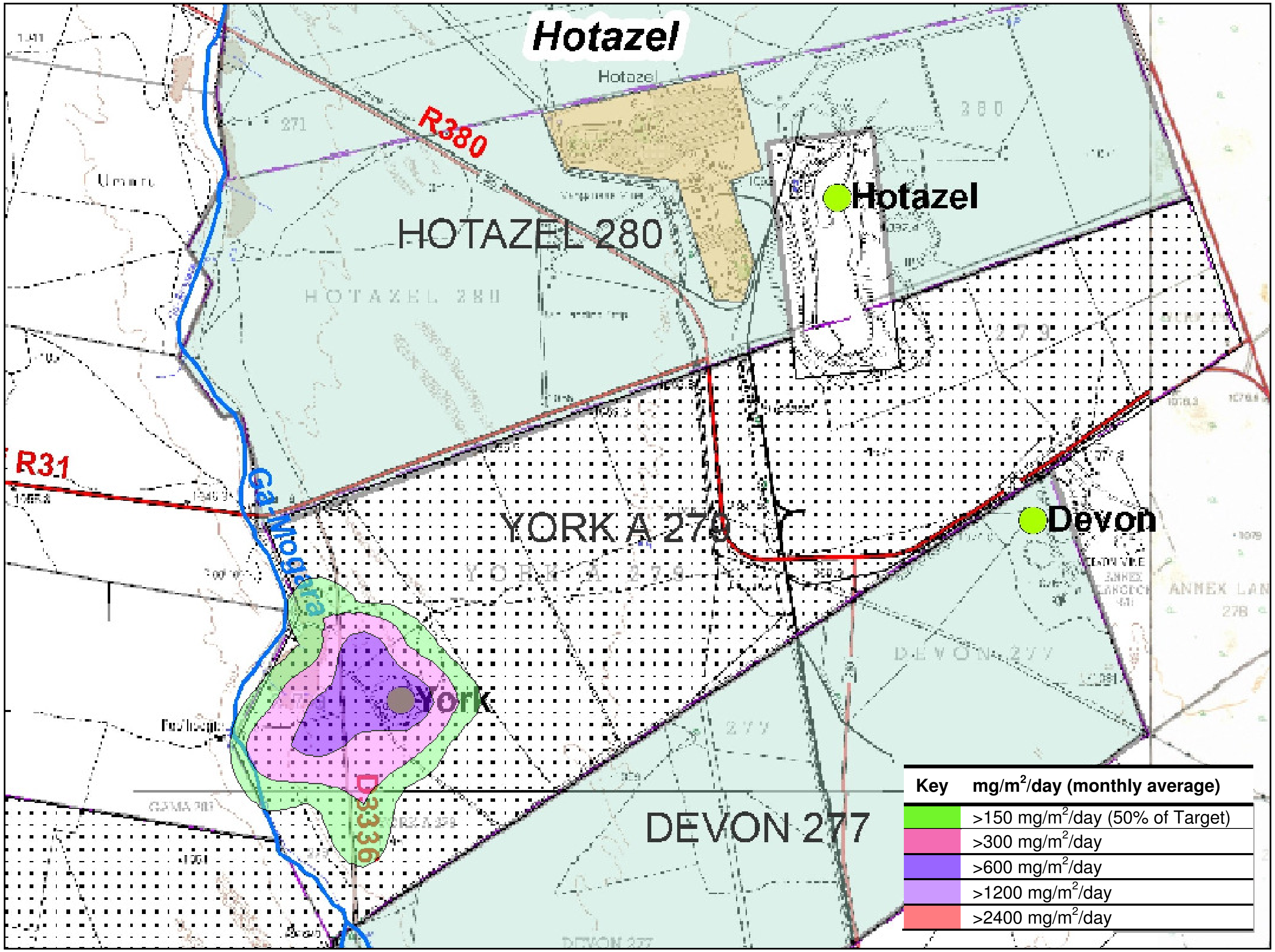


Figure A-20 Scenario 1a – Dust Deposition Impact (Unmitigated)

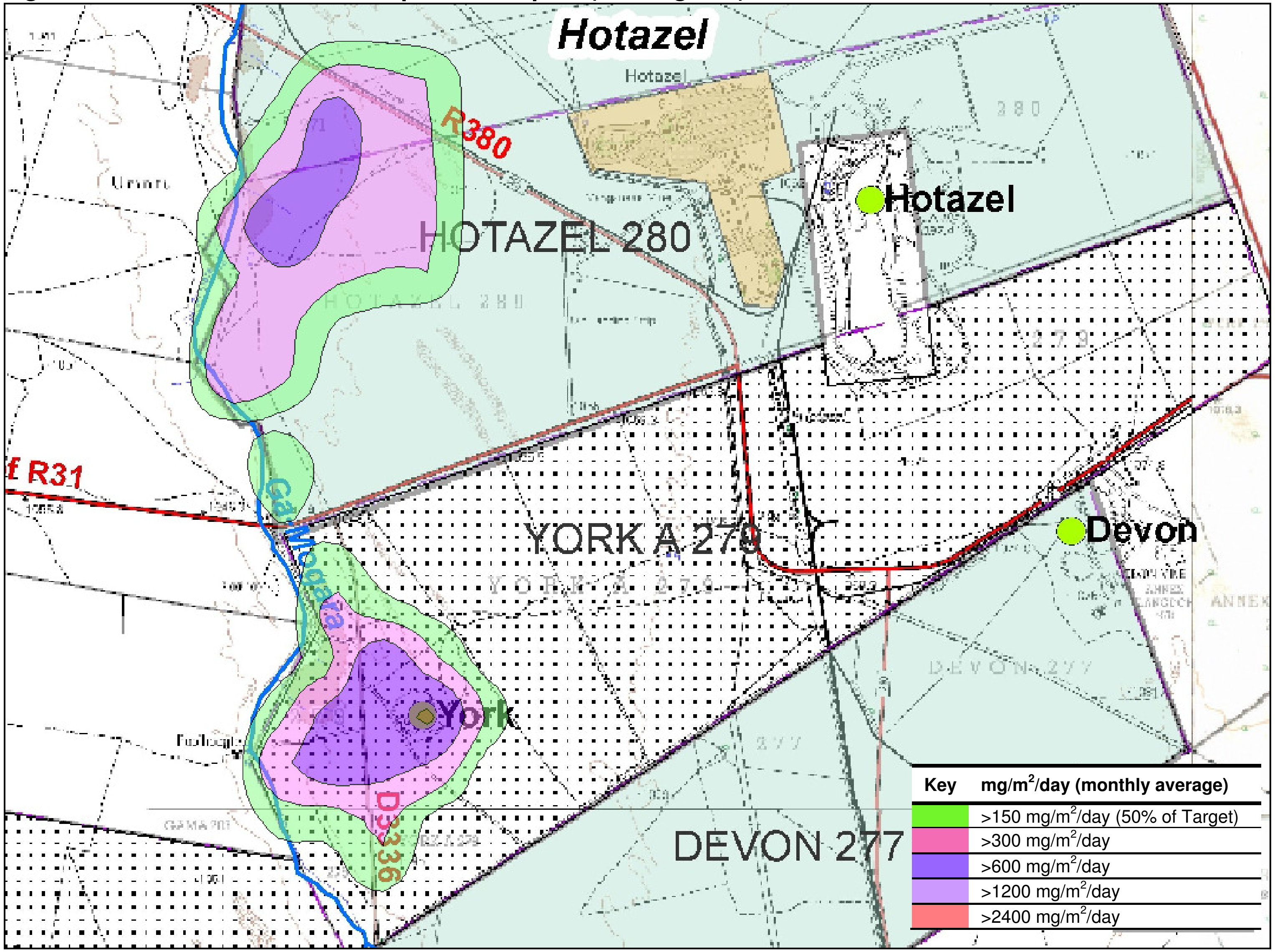


Figure A-21 Scenario 1b – Dust Deposition Impact (Unmitigated)

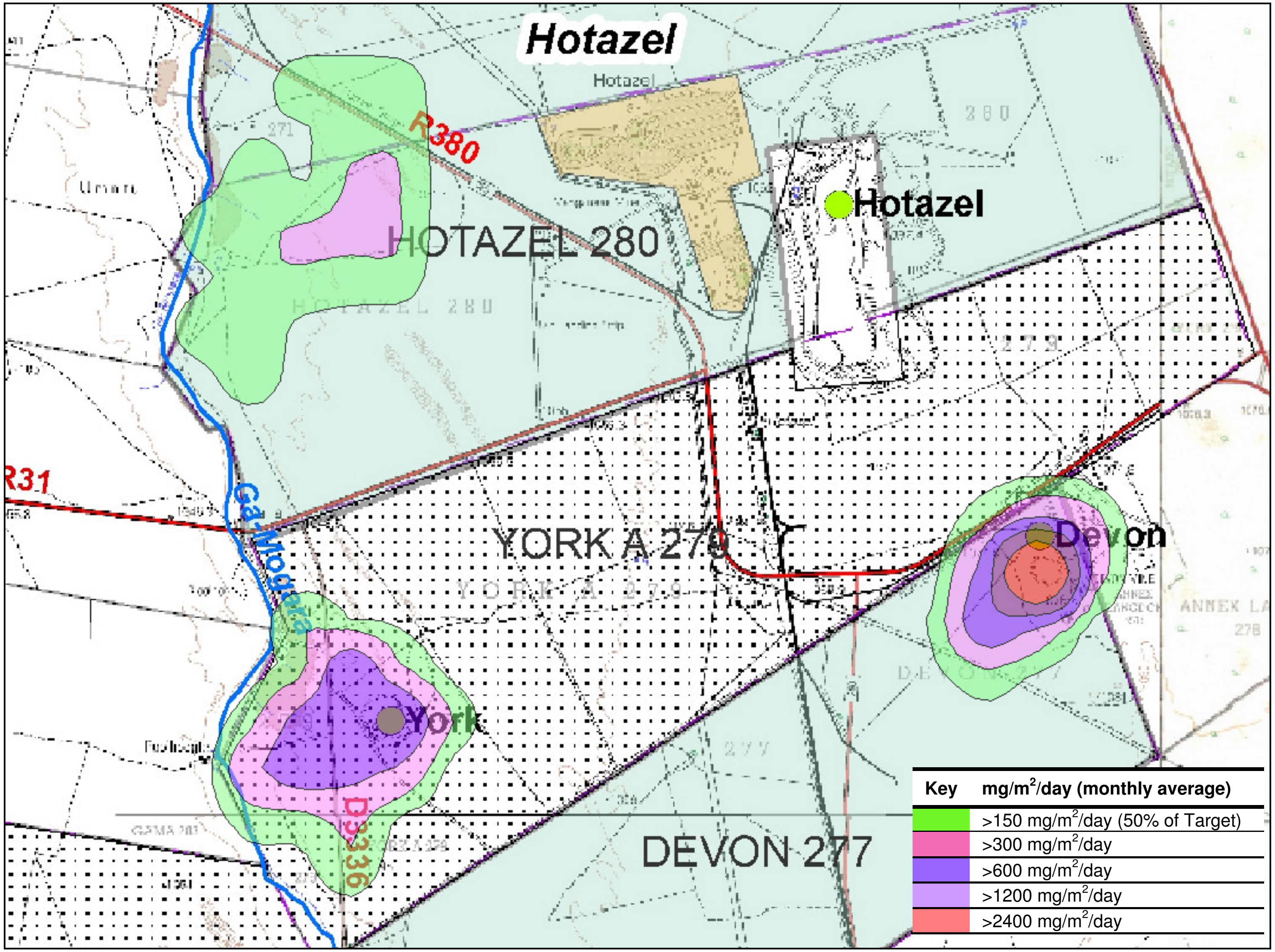


Figure A-22 Scenario 0 – Dust Deposition Impact (Mitigated)

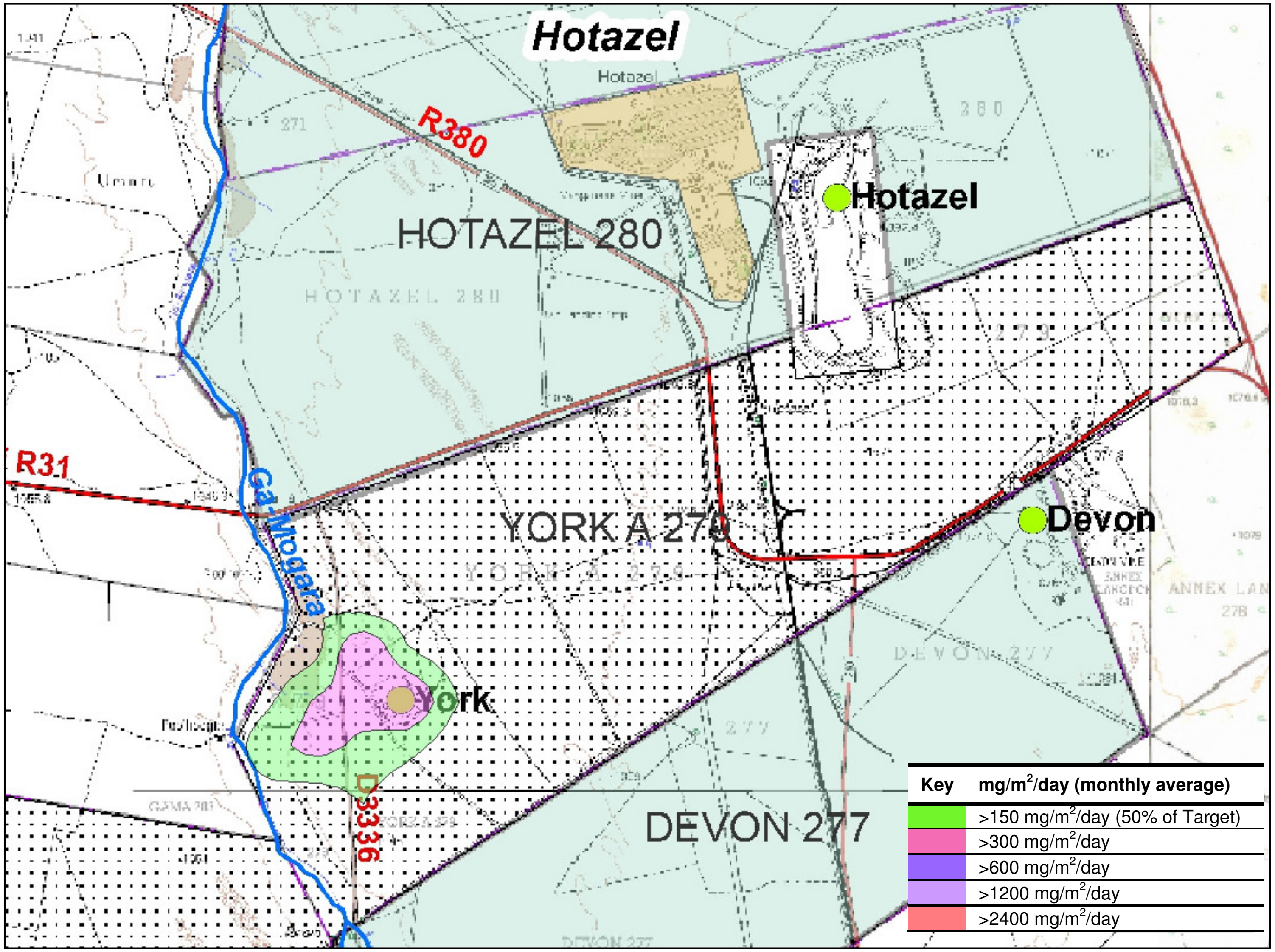


Figure A-23 Scenario 1a – Dust Deposition Impact (Mitigated)

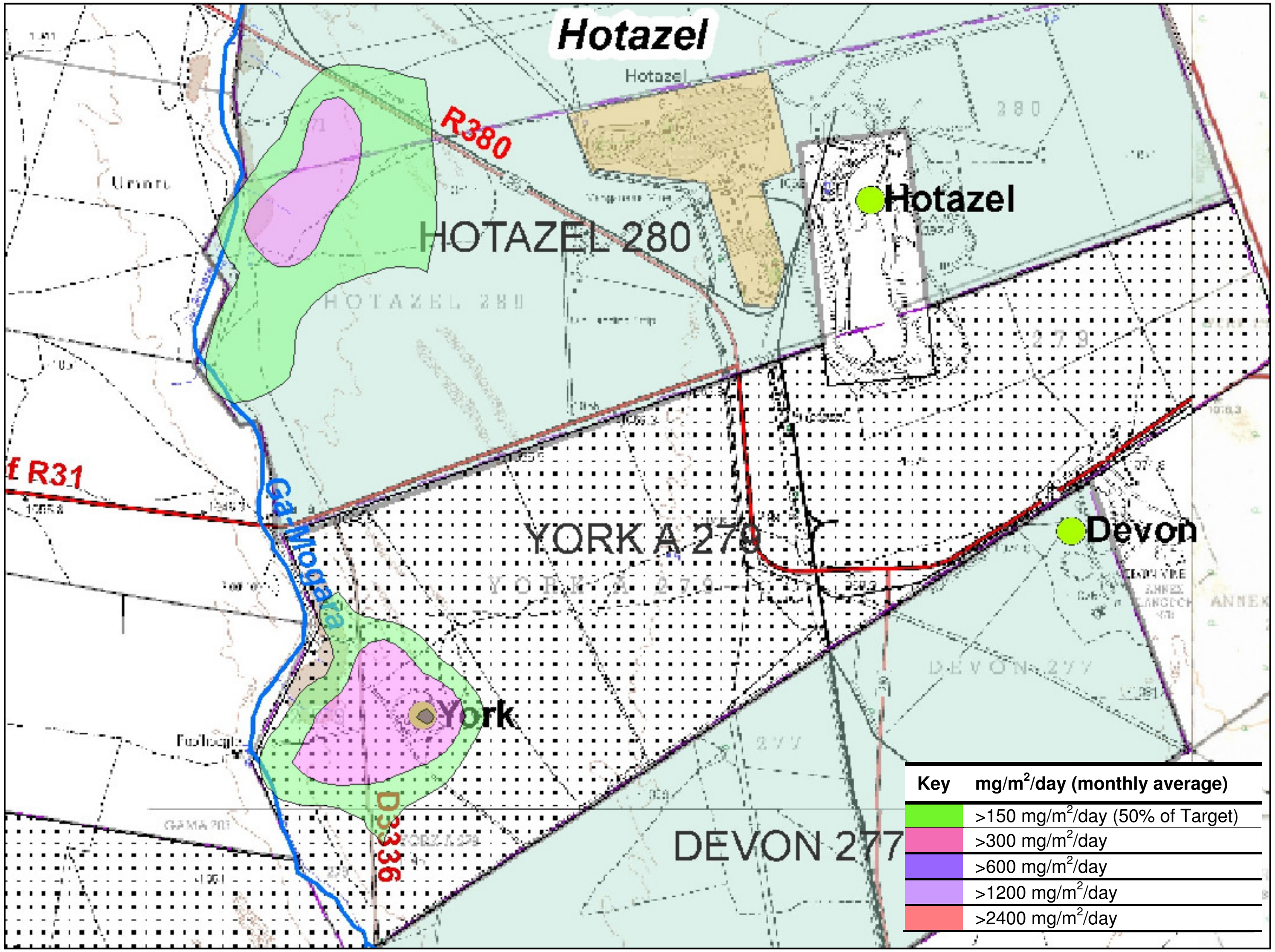
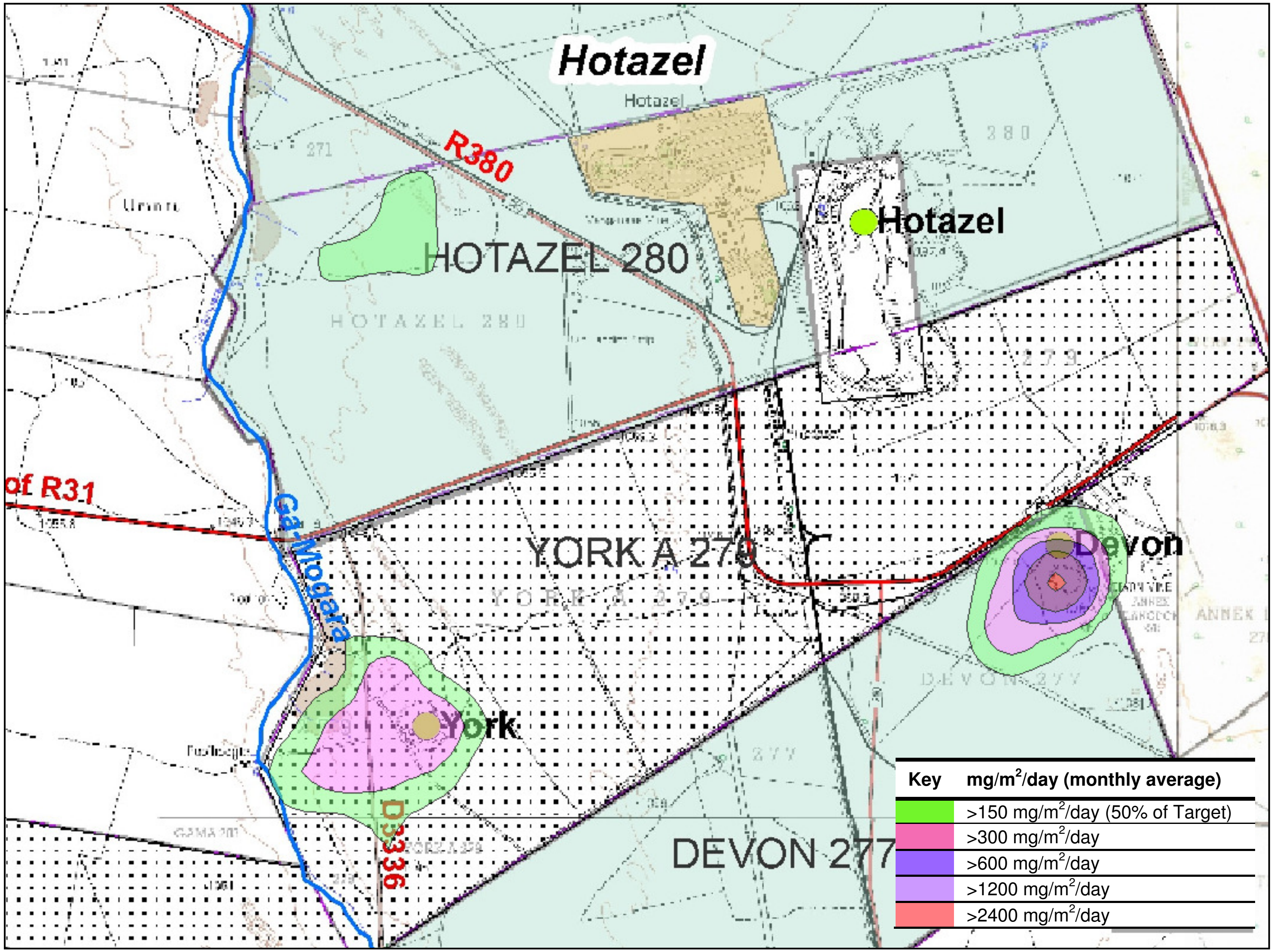


Figure A-24 Scenario 1b – Dust Deposition Impact (Mitigated)



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