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BHP Billiton Nickel West Pty Ltd

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NICKEL WEST
MOUNT KEITH SATELLITE OPERATIONS - PARTICULATE ASSESSMENT

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EXECUTIVE SUMMARY

BHP Billiton Nickel West (Nickel West) is proposing to develop the Mt Keith Satellite Operations (MKSO) project (the Project). The Project involves the development of open pit mining operations for the Six-Mile Well and Goliath nickel deposits at Yakabindie, located approximately 25 km south of Nickel West's Mount Keith (NMK) operations in the North Eastern Goldfields region of Western Australia.

Ramboll Environ Australia Pty Ltd (Ramboll Environ) was requested by Nickel West to undertake air dispersion modelling of dust emissions from the proposed MKSO Project to assess the potential ambient air quality concentrations and dust deposition that may occur due to the mining and transport operations. The assessment focused on fugitive emissions from major dust generating activities such as drilling and blasting, mining, material handling, stockpiling, reclaiming, vehicle movements on unpaved surfaces, transport of the ore for processing and wind erosion of unpaved surfaces and stockpiles.

Air dispersion modelling has been completed to predict short-term and long-term ambient ground level concentrations (GLCs) of Total Suspended Particulate (TSP), particulate matter less than 10 µm in equivalent aerodynamic diameter (PM_{10}) and particulate matter less than 2.5 µm in equivalent aerodynamic diameter ($PM_{2.5}$) across the modelled domain. The air dispersion model has also been used to predict particulate deposition rates within the Wanjarri Nature Reserve and Aboriginal heritage locations.

The US EPA Gaussian plume dispersion model AERMOD has been used to estimate the ambient concentrations and depositions associated with the dust emissions from the MKSO Project site. Surface meteorological data collected by BHP Billiton at the Yeelirrie monitoring station (located approximately 50 km west of the Project site) between April 2010 and March 2011 were used to compile a dataset for use in the model. The meteorological component of The Air Pollution Model (TAPM) was used to generate upper air data, solar radiation and cloud cover.

Dry depletion was selected to model particle settling. In the absence of site specific particle size distribution data for the TSP, PM_{10} and $PM_{2.5}$ fractions specific to Nickel West's operations, a composite distribution was derived from the USEPA's three emissions categories for batch drop, wind erosion and vehicle emissions. The mining pits were modelled as area sources, while the stockpiles and unsealed roads were modelled as volume sources. Where source parameters specific to the MKSO Project site were unavailable, generic information from other similar mine sites were used.

The particulate emission estimates for operations at the proposed Project site were based on the emission factors for fugitive emissions from mining operations, as recommended by the NPI (2012). Emission reductions were applied to the emission estimates for proposed dust mitigation measures, based on the NPI's (2011) recommended control factors. Hourly variable emissions for PM_{10} were created for each source and the TSP and $PM_{2.5}$ emissions were created by multiplying the PM_{10} emissions by 3.33 and 0.3 respectively, in line with the particle size distribution adopted for the study.

Each emission source was individually modelled in AERMOD using a fixed emission rate. The predicted concentrations for each source were then scaled against the corresponding hourly emission rate for TSP, PM_{10} and $PM_{2.5}$ to generate the predicted GLCs for each hour of the year at each model grid point. The scaled GLCs for each source were then combined to produce the overall predicted TSP, PM_{10} and $PM_{2.5}$ GLCs for the proposed MKSO Project.

The modelling indicated that without the use of watering dust controls on the transport corridor between MKSO and NMK, predicted concentrations are below the nominated standards at the defined receptors except at the NMK camp when the Project is considered in isolation. At the NMK camp, exceedances of the 24 hour average TSP, PM_{10} and $PM_{2.5}$ standards and annual $PM_{2.5}$ standard were predicted to occur. Analysis of the source contributions at the NMK camp indicate that the predicted exceedance of the TSP, PM_{10} and $PM_{2.5}$ standards are due to emissions from haulage of the MKSO ore along the transport

corridor. The modelling also indicated that when watering controls are applied to the transport corridor the concentrations at the NMK Camp were predicted to fall below the nominated standards. However it should be noted that it was outside the scope of this study to include emissions from NMK operations into the modelling. Predicted concentrations at the NMK camp for the scenario where the transport corridor was watered but at a rate less than 2 litres/m^2/hour were still elevated and cumulative emissions from the transport corridor and operations from NMK could possibly result in exceedances of the standards occurring at the NMK camp. Predicted concentrations at the NMK camp for the scenario where the transport corridor was watered at a rate greater than 2 litres/m^2/hour resulted in concentrations well below the nominated standard.

The modelling predicted the greatest depositional impacts within the Wanjarri Nature Reserve to occur at Wanjarri Nature Reserve 4 (WR4). Analysis of the wind directions indicates that the winds in the region are predominately from an easterly or south easterly direction and so the greatest depositional impacts would be expected to occur on the western side of the transport corridor as predicted by the modelling. A study completed by Doley and Rossato (2010) indicated that at deposition levels of approximately 0.3 g/m^2/d the estimated reductions in canopy photosynthesis of cotton plants would be less than 7% with a <1% decrease in productivity. Whilst it is difficult to determine definitive impacts on vegetation within the Wanjarri Nature Reserve without monitoring data, based on the work of Doley and Rossato (2010) the predicted impacts to vegetation within the Wanjarri Nature Reserve without use of controls on the transport corridor as a result of the Project is considered to be minimal.

The modelling predicted monthly dust deposition at a number of aboriginal heritage sites. There are no specific guidelines that assess the impact of dust deposition on heritage sites. In order to provide a reference as to the magnitude of the impacts the predicted deposition rates were compared against the New South Wales Department of Environment and Climate Change dust deposition criteria. The predicted deposition rates were in exceedance of the criteria at some receptor locations for all scenarios. However it should be noted that the criteria used were designed to take into account potential amenity impacts, such as dust depositing on fabrics and is not an indicator of the acceptability of the potential impacts to the heritage locations.

In considering these results it should be noted that the prediction of ambient dust concentrations from fugitive sources is difficult due to the complexity and uncertainty in estimating dust emissions as these are affected by numerous factors. Modelling results have a degree of inherent uncertainty but are useful in prioritising management measures to control and reduce dust emissions.

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1. INTRODUCTION

1.1 Background

BHP Billiton Nickel West (Nickel West) is proposing to develop the Mt Keith Satellite Operations (MKSO) project (the Project). The Project involves the development of open pit mining operations at the Six-Mile Well and Goliath nickel deposits located approximately 25 km south of Nickel West's Mount Keith (NMK) operations in the North Eastern Goldfields region of Western Australia (Figure 1).

The mine site is located adjacent to the Wanjarri Nature Reserve approximately 3 km from the Goldfields Highway. Waste rock will be disposed to a waste rock landform (WRL) located east of the two pits and road trains will transport the nickel ore from MKSO to the NMK operations along an unsealed road that passes through the Wanjarri Nature Reserve.

Ramboll Environ Australia Pty Ltd (Ramboll Environ) were requested by Nickel West to undertake air dispersion modelling of fugitive dust emissions from the proposed MKSO Project to assess the potential ambient air quality and deposition impacts associated with the mining and transport operations.

1.2 Purpose of this Report

The purpose of this air dispersion modelling study is to assess the potential impacts of dust emissions associated with the MKSO Project on ambient air quality and potential impact associated with deposition to sensitive receptor locations including vegetation within the Wanjarri Nature Reserve and Aboriginal heritage locations. The assessment focuses on dust emissions associated with mining operations, stockpiling, reclaiming, transport of ore to NMK, vehicle movements on unpaved surfaces and wind erosion of unpaved surfaces including the Run of Mine (ROM) and waste rock stockpiles.

Air dispersion modelling has been completed to predict short-term and long-term ambient ground level concentrations (GLCs) of total suspended particulate (TSP), particulate matter less than 10 µm in equivalent aerodynamic diameter (PM_{10}) and particulate matter less than 2.5 µm in equivalent aerodynamic diameter ($PM_{2.5}$), associated with a peak production scenario. The air dispersion model has also been utilised to predict particulate deposition rates of TSP in the surrounding environment and at select receptor locations.

2. SITE AND PROCESS DESCRIPTION

2.1 Site Location and Facility Layout

The proposed MKSO Project is located approximately 25 km south of Nickel West's Mount Keith operations in the North Eastern Goldfields region of Western Australia (Figure 1). The nearest sensitive receptors include the Wanjarri Nature Reserve (located directly adjacent to the WRL and part of the haulage road), the Wanjarri Shearing Shed Campsite (the 'Shearing Shed') (located approximately 7 km southwest of the WRL, within the Wanjarri Nature Reserve) and the Goldfields Highway (located approximately 3 km west of the proposed mine site). There are also a number of Aboriginal heritage sites located near the proposed mining operations and transport corridor. The locations of these receptors are shown on Figure 4.

A layout of the proposed mining operations is presented as Figure 2, highlighting the Six-Mile Well and Goliath mining pits, ROM pad, transport corridor from MKSO to NMK, WRL and primary onsite haul roads.

2.2 Production and Throughput

The life of mine is estimated to be approximately 35 years and based on information provided by Nickel West, material movements are expected to peak around Year 26, with approximately 12.4 Mt of ore and 135.7 Mt of overburden moved during that year.

2.3 Ore Moisture Content

Nickel West advised that the moisture content of the ore from the MKSO Project is expected to vary from 3.5% to 5%, depending on the type of ore. However, it is likely that the moisture content will increase with the use of water sprays to control fugitive dust emissions at each stage of the process.

2.4 Mining and Process Operations

The proposed MKSO Project will involve the development of the Six-Mile Well and Goliath open cut mining pits, targeting nickel sulphide ore. Traditional drill and blast methods will be used to break and loosen the material for extraction and hydraulic shovels will be used to load the blasted ore and waste rock material into 240t capacity haul trucks for transport to the ROM pad and WRL respectively. Mining operations are expected to be carried out 24 hours per day, 365 days per year.

2.5 Product Transport

Ore will be reclaimed from the ROM pad via front end loaders and loaded to road trains. The road trains will then travel along a purpose built haul road, approximately 23 km's in length to the NMK operations where the ore will be processed.

2.6 Dust Sources and Emission Controls

Dust emissions from the MKSO Project are expected to be primarily generated from the following sources:

- Drilling and blasting;
- Material handling (i.e., excavating and in-pit loading, stockpiling, reclaiming, transfers);
- Vehicle movement on unpaved surfaces (i.e. heavy vehicle movements along the haul roads and the transport of the ore to NMK); and
- Wind erosion of unpaved surfaces including the ROM pad and WRL.

Brief descriptions of the potential dust sources are provided in the following sections, along with details of dust control measures proposed by Nickel West. The efficiency of the dust control measures is also described and these are based on the National Pollutant Inventory (NPI)'s estimated control factors for mining activities (NPI, 2012).

2.6.1 Drilling and Blasting

The proposed MKSO Project will utilise drill and blast techniques to break and loosen ore and overburden. Nickel West advised that blasting would usually be carried out at 13:00 hours and for the purpose of this assessment it was assumed that blasting would occur daily in each pit at this time, 350 days of the year. An estimate of the number of holes drilled per blast was made based on information provided by Nickel West for the existing NMK operations, which indicated 134 holes are typically drilled for each blast.

For the purpose of this assessment it has been assumed that drilling activities occur continuously throughout the modelled year. It was also assumed that water sprays will be used during blasting to control dust emissions, as per the current dust management activities adopted at NMK (BHP Billiton, 2011). A control efficiency of 50% was adopted for this measure, in line with the suggested NPI (2012) emission reductions for water sprays.

2.6.2 Excavation and Haul Truck Loading

Hydraulic shovels will be used to excavate the blasted ore and waste rock at the proposed MKSO Project site and load the material into 240 t capacity haul trucks. Scheduling information provided by Nickel West indicates that material movement of up to approximately 148.1 Mt (comprising 12.4 Mt ore and 135.7 Mt waste rock) will occur during Year 26 of the Project and the emission estimates associated with excavation and truck loading activities were based on these throughputs. It was also assumed that excavation and truck loading would occur continuously throughout the modelled year.

Water sprays are expected to be used to minimise fugitive dust emissions generated during these activities, as per the current dust management activities adopted at NMK (BHP Billiton, 2011). A control efficiency of 50% was adopted for this measure, in line with the suggested NPI (2012) emission reduction for water sprays.

2.6.3 Stockpiling

Haul trucks will be used to transport the ore and waste rock to the ROM pad and WRL respectively. For modelling purposes it was assumed the 12.4 Mt of ore excavated during the modelled year will be stockpiled evenly across the ROM pad.

In the absence of specific scheduling information for the modelled year, it was assumed that waste rock from the Six-Mile Well pit would be stockpiled along the eastern boundary of the northern section of the WRL, and that waste rock from the Goliath pit would be stockpiled along the eastern boundary of the mid-section of the WRL (refer to Figure 2). These locations are considered representative of the worst case scenario as they lie immediately adjacent to the Wanjarri Nature Reserve. The size of the active areas was determined by calculating a ratio of tonnes per square metre, based on the total amount of waste rock going to the WRL.

For the purpose of this assessment it has been conservatively assumed that stockpiling activities at the ROM pad and WRL occurs continuously throughout the modelled year. Water sprays will be used on the ROM pad and WRL to minimise fugitive dust emissions and a control efficiency of 50% has been adopted for this measure, in line with the suggested NPI (2012) control factor for water sprays.

2.6.4 Reclaiming

Front end loaders will be used to reclaim ore from the ROM pad and load it onto the road trains for transport to NMK. Water sprays will be used at the ROM pad to minimise dust emissions during reclaiming operations and a control efficiency of 50% has been adopted for this measure, in line with the recommended NPI (2012) control factor for use of water sprays.

2.6.5 Haul Vehicle Movements

Vehicles travelling on unwatered, unpaved roads can generate dust. Under normal site conditions, trucks generally have the greatest potential for dust generation, although this is highly dependent on road conditions. Fugitive dust emissions generated from haul trucks travelling from the pits to the ROM pad and WRL were included in the modelling assessment. An average round trip distance of 5.8km for ore to ROM and 3.5 km for waste rock to WRL(s) was used to calculate fugitive dust emissions generated by the haul trucks. Based on the total amount of material moved over the modelled year (148.1 Mt) and a haul truck capacity of 240 tonnes, it is estimated that over 610,000 trips will be made during peak operations.

The on-site haul roads will be constructed of caprock, a material associated with lower silt loadings than roads constructed with sand or gravel (USEPA, 2006). The roads will be regularly watered and a soil binding agent will be added to further reduce the potential for wheel generated emissions associated with vehicle traffic. A control factor of 75% was adopted for regular watering, in line with the NPI (2012) recommended emission reduction for applications of greater than 2 litres/m^2/hour. An additional control factor of 80% was applied to account for the use of a soil binding agent, in line with the associated control efficiencies experienced at existing NMK mine site where soil binding agents have been utilised. The combined efficiency of these measures is 95% (as controls are multiplicative).

Nickel West advised light vehicles are not expected to be used on unsealed roads within the mine site and as such, these have not been included in the modelling assessment.

2.6.6 Transport of Ore

The ore will be transported from the MKSO operations to NMK for processing via road trains in a purpose built haul road. The haul road will be approximately 23 km in length and passalongside the Wanjarri Nature Reserve. Nickel West provided information indicating that the road trains will have a capacity of 217 tonnes. Based on the ore to be transported to NMK (12.4 Mt), it is estimated that approximately 57,000 trips will be required during peak operations.

Emissions estimates were derived for three scenarios as follows:

- **Scenario 1** - No controls on the transport corridor;
- **Scenario 2** – Water spraying of the transport corridor at a rate less than 2 litres/m^2/hour assuming a control of particulate emissions of 50%; and
- **Scenario 3** - Water spraying of the transport corridor at a rate greater than 2 litres/m^2/hour assuming a control of particulate emissions of 75%.

The emissions estimates incorporated the speed and weights of the vehicles both loaded (45 km/h and 281 tonnes) and unloaded (65 km/h and 64 tonnes).

2.7 Criteria Pollutants

Emissions of the criteria pollutants oxides of nitrogen (NO_x) and sulphur dioxide (SO_2) are expected to be generated as a result of fuel combustion and explosives use at the MKSO Project site. However, NO_x and SO_2 emissions have not been included in the air dispersion modelling as it is anticipated that the air quality impacts associated with these compounds will be small at sensitive receptors due to the remote location of the MKSO Project site.

3. ASSESSMENT CRITERIA

3.1 Ambient Particulate Standards

Dust is generally defined as particles that can remain suspended in the air by turbulence for a period of time and can consist of a range of matter including crustal material, pollens, sea salts and smoke from combustion products. Dust or particulate matter is commonly defined by the size of the particles, measured as:

- TSP, which refers to all particulate matter with an equivalent aerodynamic particle size below 50 µm diameter. The term equivalent aerodynamic particle is used to reference a spherical shaped particle and a density of 1 g/cm^3;
- PM_{10}, particulate matter below 10 µm in equivalent aerodynamic diameter; and
- $PM_{2.5}$, particulate matter below 2.5 µm in equivalent aerodynamic diameter.

TSP, which contains both the PM_{10} and $PM_{2.5}$ fractions, is normally associated with nuisance impacts such as dust fallout and soiling of washing. PM_{10} and $PM_{2.5}$ are associated with the potential for health impacts as finer particle fractions can enter deeper into the lungs.
The National Environment Protection Council (NEPC) has produced national ambient air quality standards for the protection of human health relevant to particulates.

These include the National Environment Protection (Ambient Air Quality) Measure (NEPM) (NEPC, 2015), which sets national air quality standards for criteria pollutants including particulate (as PM_{10} and $PM_{2.5}$). The NEPM standards for PM_{10} and $PM_{2.5}$ have been applied in this assessment.

In addition to the NEPC NEPMs, the Western Australian Environmental Protection Authority (EPA) has established an Environmental Protection Policy (EPP) which provides ambient air quality standards for TSP and SO_2 (EPA, 1999) for Kwinana. These standards were established in order to maintain acceptable air quality within and around the Kwinana Industrial Area. The Kwinana EPP defines three regions which are covered by the policy; the industrial zone (Area A), the buffer zone surrounding heavy industry (Area B) and the rural and residential zone beyond the buffer zone (Area C). In the absence of national ambient air quality standards for TSP, the EPA's standard for TSP within residential areas (Area C) has been applied at sensitive receptors including the MKO camp, the 'Shearing Shed' and the Goldfields Highway.

The NEPC and Kwinana EPP ambient air quality standards for particulates relevant to this study are provided in Table 1.

Table 1: Particulate Ambient Air Quality Standards

Pollutant	Averaging Period	Standard (µg/m³)	Reference
TSP	1 day	Area C - 90[3]	EPA (1999)
Particles as PM_{10}	1 day	50	NEPC (1998)
	1 year	25	NEPC (2015)
Particles as $PM_{2.5}$	1 day	25	NEPC (2015)
	1 year	8	

Notes
1. Kwinana EPP Area C (Residential and Rural Zone beyond the buffer zone) standard.

3.2 Particulate Deposition

3.2.1 Vegetation

Nickel West requested that Ramboll Environ focus on potential impacts of dust deposition on vegetation within the Wanjarri Nature Reserve. There are no specific guidelines available for impacts on vegetation from dust deposition, however a number of studies on impacts to vegetation from particulate deposition have been completed in Australia and globally.

Most studies of the effects of mineral dusts on vegetation have focussed on dusts that have chemical effects (e.g. cement dust) or where dust loads exceed 7 g/m². Relatively inert mineral dusts, such as those generated in the mining process or from unsealed haul roads principally influence light and temperature relations of leaves.

A study by Doley and Rossato (2010) used published data to assess the impacts of particulate deposition on photosynthesis in cotton leaves and canopies. The study indicated that many plants species have similar ranges of values for the photosynthetic parameters used in assessing the impacts on cotton and it is possible to use the cotton estimates as a general estimate for the purpose of modelling the impacts particulate deposition and thereby the environmental risks associated with dust generating activities.

It should be noted that as the area around the mine is an arid environment and background concentrations of dust deposition are likely to be elevated, it is likely that natural vegetation in the region would likely have a degree of tolerance to these conditions. The Doley and Rossato (2010) study also noted that in more complex plant associations, species that grow in heavily shaded understories are much more likely to be susceptible to dust deposition than plants exposed to direct sunlight. The vegetation of the region does not typically contain dense undergrowth and this is therefore not considered as a factor for the air dispersion modelling study.

3.2.2 Amenity

There are no specific guidelines that assess the impact of dust deposition on heritage sites in Australia. In the absence of specific guidelines, the predicted dust deposition has been compared against the New South Wales Department of Environment and Climate Change (NSW DECC) dust deposition criteria (presented in Table 2). It should be noted however that these criteria were not designed to assess potential impacts at heritage locations but were designed to take into account potential amenity impacts, such as dust depositing on fabrics and buildings. The use of these guidelines serve as a reference as to the magnitude of the impacts from MKO operations and should not be used as an indication of acceptability of the predicted impacts on the heritage locations.

The NSW guidelines are based on studies undertaken on coal dust deposition in the Hunter Valley in NSW by the National Energy Research and Demonstration Council (NERDC, 1988). While the dust deposition guideline is expressed as g/m^2/month, the NSW DECC has indicated that the monthly average deposition (to be compared against the guideline value) is to be determined from data spanning no less than one year, so as to account for seasonal variations.

Table 2: Amenity Dust Deposition Criteria

Pollutant	Averaging Period	Criteria (g/m^2/month)
Deposited Dust[1]	Annual (increase)[2]	2
	Annual (total)[3]	4

Notes
1. Dust is assessed as insoluble solids as defined by AS 3580.10.1-1991 (AM-19).
2. Maximum increase in deposited dust level.
3. Maximum total deposited dust level.

The NSW Environmental Defender's Office (EDO) advises that the criteria for the maximum increase in deposited dust of 2 g/m2/month is applicable when baseline data on deposited dust exists, while the total deposited dust criteria of 4 g/m2/month criteria is applied when no baseline data exists.

4. MODELLING METHODOLOGY

4.1 Air Dispersion Model

Air quality impacts from the proposed MKSO Project have been modelled using the USEPA AERMOD plume dispersion model (V14134). AERMOD is regularly used for assessing impacts from mining and industrial sites within Australia.

4.2 Meteorological Data

The AERMOD model requires time series meteorological data, including hourly averaged values of:

- wind speed and direction;
- ambient air temperature;
- atmospheric stability; and
- atmospheric mixing height.

BHP Billiton operated a meteorological monitoring station at Yeelirrie, located approximately 50 km west of the Project site. BHP Billiton provided Ramboll Environ with surface monitoring data collected at the site between February 2010 and July 2011. Wind speed, wind direction and ambient temperature data collected over the 12-month period from April 2010 to March 2011 were selected from the dataset to compile the required meteorological data file, as this represented the most complete 12-month period of monitoring records.

The seasonal wind roses derived from the meteorological data file indicates that the most commonly occurring winds are from the east-southeast (Figure 3). The wind roses indicate that stronger winds are most common during the summer months. Wind direction is most variable during the winter months, although the prevailing east-southeasterlies continue to dominate.

In the absence of upper air observations, vertical temperature profiles were predicted for the 12-month period from April 2010 to March 2011 using the meteorological component of The Air Pollution Model (TAPM). These data were used in conjunction with the surface temperature data to determine mixing height. Solar radiation and cloud cover data were also sourced from TAPM for use in model.

4.3 Model Setup and Parameterisation

For this study, AERMOD was set up with the following parameters and input data:

- A model domain of 22 km by 22 km, centred on 262,000 mE and 6,970,000 mN (GDA 94) and 1,000 m grid spacing. A number of discrete receptor locations were also modelled at identified sensitive locations;
- Terrain data from the US National Aeronautics and Space Administration's (NASA) Shuttle Radar Topography Mission (SRTM) were obtained for the region. These data were interpolated to provide terrain elevations for each of the model grid points; and
- Dry depletion included to model particle settling.

The mining pits have been modelled as area sources, while the ROM pad, WRL and unsealed roads have been modelled as volume sources. For volume sources, the initial estimates for plume width and height were assumed to be equal to ¼ of the actual dimensions for each source and plume release height was assumed to be ½ of the actual height.

As well as the gridded receptor locations, a number of discrete receptor locations were selected to assess impacts at sensitive receptor locations in the region. Ambient air concentrations and deposition rates were predicted for the Shearing Shed Campsite, the NMK Camp, seven locations along the Goldfields Highway, seven locations along the boundary of the Wanjarri Nature Reserve and five Aboriginal heritage sites. An additional receptor location was selected to assess deposition impacts on the western side of the transport corridor at a short distance. The receptor location was within 50 m of the centre of the transport corridor, approximately 2 km south of the MKO camp. Figure 4 presents the locations of the sensitive receptors.

4.4 Particle Size Distribution

The USEPA's particle size distributions for batch drop, wind erosion and vehicle emissions (USEPA, 2004a and b; USEPA, 2006) are presented in Table 3. The distribution data for batch drop and wind erosion are similar, while the particle size distribution for vehicle emissions contains a lower percentage of $PM_{2.5}$ particulate. The distribution data for batch drop also indicates that dustiness is proportional to the silt content of the ore.

In the absence of site specific particle size distribution data for the TSP, PM_{10} and $PM_{2.5}$ fractions specific to Nickel West's operations, a composite distribution was derived from the USEPA's three emissions categories (Table 3). It is noted that adoption of a composite distribution represents a simplification as different particulate emission sources will have different particle size distributions (e.g. wind erosion versus vehicular dust) and there may also be differences between particle size distributions between different ore types and process stages.

Table 3: Particle Size Distributions

Particle Size Range (µm)	Representative Particle Size (µm)	Percentage of Particulate (%) in Various Size Ranges					
		USEPA Batch Drop	USEPA Wind Erosion	USEPA Unpaved Road	This Study		
					TSP	PM_{10}	$PM_{2.5}$
<2.5	1.3	11	14.8	3.3	9	30	100
2.5 - 5.0	3.8	9	22.2	18.7	8	27	-
5.0 - 7.5	6.3	15			7	23	-
7.5 – 10	8.7				6	20	-
10 – 15	12.5	13	7	52	14	-	-
15 – 23	19	26	30		15	-	-
23 – 30	26				15	-	-
30 – 40	35	26	26	26	15	-	-
40 – 50	45				11	-	-

Notes

1. Particle sizes are equivalent aerodynamic size and not the physical size. The equivalent aerodynamic size relates to the aerodynamic properties of the particle as is used in dust sampling. For example PM_{10} samplers measure the dust below 10 µm equivalent aerodynamic size and not the physical size.
2. Wind erosion and vehicle emission size distributions are given for below 30 µm only, but have been adjusted here to less than 50 µm based on assuming 74% of the particulate is less than 30 µm as per the batch drop distribution.

The USEPA particle size diameters are given in equivalent aerodynamic particle diameters which assume a particle density of 1 g/cm^3.

4.5 Fugitive Particulate Emission Estimates

To predict dust concentrations in a realistic manner, hourly dust emissions are required from all major sources. Factors which are important for dust generation include:

- the type of material being handled including particulate size;
- moisture content;
- operational activities;
- quantity of ore being moved and the number of movements;
- size of stockpiles and level of activity;
- level of vehicle traffic, weight and speed of vehicles;
- rainfall;
- evaporation;
- ambient wind speed; and
- management controls.

The throughput rates, emission factors, control factors and resultant particulate emission estimates for operations at the MKSO Project site are presented in Table 4. The emission factors are primarily based on the default values recommended by the NPI (2012) for 'high' moisture ores (i.e. those with a moisture content of 4% or more). The control efficiencies adopted for each dust control measure are also based on factors recommended by the NPI (2012).

Nickel West advised that the moisture content of the ore at the MKSO site will range from 3.5% to 5% (refer to Section 2.3). However, it is likely that with the use of water sprays to control dust emissions at each stage of the process, the moisture content will remain 'high'. It is noted that the classification of ores into 'high' and 'low' moisture groups does not reflect the variation that can occur in dust emissions.

The calculation of emission estimates associated with mining activities has been conservatively based on the maximum anticipated mining rates. Scheduling information provided by Nickel West indicates that the greatest mass of material will be handled in year 26 of the Project. The emission estimates for excavating, truck loading, stockpiling, reclaiming and waste rock dumping were subsequently based on the annual throughputs for this period.

The WRL will be developed in stages over the life of the Project, with activity initially focusing on the northern and southern sections and the middle of the waste dump filled in as mining progresses. This assessment has conservatively assumed that waste rock dumping during the modelled year will occur along the eastern boundary of the WRL, as this area is located most closely to sensitive receptors within the adjacent Wanjarri Nature Reserve.

It should be noted that dust emission estimates for fugitive dust sources contain a degree of uncertainty due to the complexity of characterising emission rates and control efficiencies.

Table 4: Emission Factors, Control Factors and Particulate Emission Estimates for Fugitive Dust Emissions

Activity	Emission Factor		Emission Factor Variable		Dust Control		PM_{10} Emission Rate	Comments
	PM_{10}	Unit	Rate	Unit	Measure	Efficiency	g/s	
Drilling								
Six-Mile Well	0.31	kg/hole	76,003	No. Holes per year	Water Sprays	50%	0.4	Based on NMK blast data was used to calculate the PM_{10} emission rate for drilling. Drilling operations were assumed to occur continuously throughout the modelled year.
Goliath Pit	0.31	kg/hole	17,797	No. Holes per year	Water Sprays	50%	0.1	
Blasting								
Six-Mile Well	157	kg/blast	350	No. Blasts per year	NA	NA	42	A ratio of 0.036m^2 per tonne of material blasted (as advised by Nickel West) was used to calculate the average surface area of each blast in each pit, in order to determine the PM_{10} emission rate for blasting. Blasting was assumed to occur daily in each pit, between the hours of 13:00 and 14:00.
Goliath Pit	18	kg/blast	350	No. Blasts per year	NA	NA	5	
Excavating								
Six-Mile Well	0.002	kg/t	120,000,000	tpa	Water Sprays	50%	3.8	The maximum throughput rates (Year 26) were used in the calculation of the PM_{10} emission rate for excavating. Excavating was conservatively assumed to occur continuously throughout the modelled year.
Goliath Pit	0.002	kg/t	28,100,000	tpa	Water Sprays	50%	0.9	
Truck Loading								
Six-Mile Well	0.001	kg/t	120,000,000	tpa	Water Sprays	50%	1.3	The emission factor for truck loading was based on the USEPA (2004a) equation for batch loading and assumes a mean wind speed of 2.6 m/s and moisture content of 2%. Tuck loading was conservatively assumed to occur continuously throughout the modelled year.
Goliath Pit	0.001	kg/t	28,100,000	tpa	Water Sprays	50%	0.3	

Table 4: Emission Factors, Control Factors and Particulate Emission Estimates for Fugitive Dust Emissions

Activity	Emission Factor		Emission Factor Variable		Dust Control		PM_{10} Emission Rate	Comments
	PM_{10}	Unit	Rate	Unit	Measure	Efficiency	g/s	
Stockpiling								
ROM Pad	0.002	kg/t	12,400,000	tpa	Water Sprays	50%	0.4	The maximum throughput rates (Year 26) were used in the calculation of the PM_{10} emission rate for stockpiling. Stockpiling was assumed to occur continuously throughout the modelled year.
Waste Rock Landform	0.002	kg/t	135,700,000	tpa	Water Sprays	50%	4.3	
Reclaiming								
ROM Pad	0.002	kg/t	3,653	t/hr	Water Sprays	50%	0.5	
Wheel Generated Dust Emissions								
Haul Trucks	1.2	kg/VKT	260	VKT/hr	Water Sprays with Chemical Dust Inhibitor (>2 $L/m^2/hr$);	95%	3.0	Emissions equation based on average weight of haul trucks = 264 tonnes and assuming 4% silt content. Total VKT based on average round trip distance of 3.5 km for waste to dumps and 5.8km for ore to ROM and payload of 240 tonnes. Wind erosion from haul roads was not included in the modelling as likely to be an insignificant source in comparison to wheel generated dust and other unsealed surfaces.
Road Transport Corridor – Loaded to NMK	0.8	kg/VKT	151	VKT/hr	No Control and Water Sprays (<2 $L/m^2/hr$ and >2 $L/m^2/hr$)	0% / 50% / 75%	29.1 / 14.6 / 7.3	The emission factor for wheel generated dust was based on the recommended NPI (2012) equation for wheel dust from unpaved roads, assuming an average vehicle weight of 280 tonnes loaded and 64 tonnes unloaded and a silt content of 4%. Total VKT was based on an average round trip distance of 23.1 km. Haul trucks were conservatively assumed to operate continuously throughout the modelled year. Concentrations were predicted for three scenarios with no controls assumed on the transport corridor and watering of the roads to control particulate emissions at rates <2 $L/m^2/hr$ and >2 $L/m^2/hr$.
Road Transport Corridor – Empty to MKSO	0.66	kg/VKT	151	VKT/hr	No Control and Water Sprays (<2 $L/m^2/hr$ and >2 $L/m^2/hr$)	0% and 50%	24.0 / 12.0 / 6.0	

Hourly variable PM_{10} emissions were defined for each source based on the emission factors and dust control measures presented in Table 4. The effects of wind and rainfall on emission estimates were also taken into consideration, as per the methodologies described in the following sections (Sections 4.5.1, 4.5.2 and 4.5.3). Hourly variable emission files for TSP and $PM_{2.5}$ were created for each source by multiplying the PM_{10} emissions estimates by 3.33 and 0.3 respectively, in accordance with the assumed particle size distribution in Table 3 (i.e., PM_{10} is 30% of TSP and $PM_{2.5}$ is 30% of PM_{10}).

Where specific hours of the day were required to be nominated for the model during which emissions may be released, Ramboll Environ has assumed that operations will occur at regular intervals across the whole day. For sequential activities (i.e. reclaiming from the ROM pad) the modelled hours have been staggered to reflect the potential sequence of activities at the site. These measures ensure that the number of activities occurring at any one hour of the day is distributed relatively evenly across a 24-hour period and that the assessment has considered the impact of emissions released over the modelled year.

Each emission source was individually modelled in AERMOD using a fixed emission rate and the particle size distribution data detailed in Table 3. A particle size density of 1 g/cm^3 was used in line with the assumption upon which the USEPA particle size distributions are based. The resultant outputs for each source were scaled against the corresponding hourly variable emissions for TSP, PM_{10} and $PM_{2.5}$ to generate predicted GLCs for each hour of the year, at each model grid point and sensitive receptor. The predicted GLCs for each source were then combined to produce the overall TSP, PM_{10} and $PM_{2.5}$ GLCs predicted for the modelled scenario.

4.5.1 Wind Speed Dependence for Material Handling

For all material handling processes exposed to the wind, increasing wind speed acts to increase dust emissions through winnowing of the particles from the falling ore. The USEPA batch drop equations (USEPA, 2004a) specify that the dust emission increases with the wind speed to the power of 1.3, as follows:

$$E_{Actual} = E_{2.2} (WS/2.2)^{1.3}$$

Where:

- WS is the wind speed at the drop height;
- $E_{2.2}$ is the dust emission given for a wind speed of 2.2 m/s; and
- E_{Actual} is the final emission rate.

The average source height was assumed to be 5 m above the surface, with the 10 m wind speeds used to estimate the 5 m wind speeds using the 1/7 power law given by:

$$WS_5 = WS_{10}\ (5/10)^{(1/7)}$$

Where:

WS_{10} is the wind speed at 10 m.

WS_5 is the calculated wind speed at 5 m.

4.5.2 Wind Erosion

Dust emissions generated by wind erosion are generally negligible below a wind speed threshold, but increase rapidly when wind speeds exceed that threshold. Dust emissions from wind erosion are also dependent on the erodibility of the material which in turn is dependent on a range of factors including the size distribution of the material, whether a crust has developed, and moisture content. In general, material with a large (>50%) fraction of non-erodible particles (generally particles greater than 1 mm to 2 mm) will not erode as the smaller erodible fraction is protected by the larger particles. Fine ores are generally much more erodible by wind erosion, particularly if they have a large fraction of particles in the range from 0.1 mm to 0.25 mm which can be dislodged by wind and then rolled and skipped along the surface (saltation). These larger particles can then dislodge the smaller (<50 µm) dust fraction which can remain suspended in the air.

The NPI Emission Estimation Technique (EET) Manual for Mining (NPI, 2012) specifies a wind erosion factor of 0.2 kg/ha/hr for all sources with the exception of coal stockpiles. However, this factor is considered approximate as it does not take into account variations in the climate of an area or the soil or ore type. Previous studies investigating the impact of dust emissions from mining and export facilities (e.g. ENVIRON, 2004) have used the Shao (2000) equation to parameterise PM_{10} emissions for live stockyards and surrounding roads. The same method was also adopted to estimate the wind erosion factor for this assessment, as follows:

$$E_{wind} = 5.2E\text{-}07 * WS^3 * (1- (WS_T/WS_{10})^2))$$

Where:

WS_T is the threshold for wind erosion in m/s, taken to be 7.5 m/s (SKM, 2003); and

E_{wind} is the PM_{10} emissions (g/m^2/s).

Dust emissions generated by wind erosion were considered in this assessment for all exposed surface areas, including Six-Mile Well and Goliath Pits, the ROM Pad, and WRL roads. However, wind erosion is expected to have a negligible impact on predicted ground level concentrations as a result of the relatively low wind speeds measured at Yeelirrie (refer to Section 4.2). Only 0.2% of the wind speed data recorded at Yeelirrie were greater than the wind erosion threshold of 7.5 m/s.

4.5.3 Rainfall Dependence

To account for the effects of rainfall in reducing dust emissions, a simple scheme was adopted. With regards to wind erosion, rainfall was assumed to not only suppress dust emissions at the time rain was occurring, but to also result in a suppression of the dust emissions that gradually decreases over time as the areas dry out. Without stockpile activity, material can form a strong crust and be resistant to wind erosion for extended periods.

Dust emissions were taken to linearly return to a rainfall unaffected state within 400 hours of the rainfall evaporating if the rainfall event was greater than 25 mm. During the period when it was raining or if the rainfall had not evaporated, emissions were set to zero. The evaporation rate at the surface was assumed to be 1.25 times the amount from a Class A pan with a limit to the amount of water on/near the surface of 75 mm. In the absence of reliable evaporation data for the Yeelirrie monitoring site, Class A pan evaporation rates were obtained from long-term monthly averages at the Bureau of Meteorology's Kalgoorlie monitoring station, located approximately 380 km north-northwest of the MKSO Project site (the closest operating station to have monthly evaporation data available).

These time scales have been adopted from previous dust assessments (ENVIRON, 2004) and were originally based on observations of the time taken for high dust levels to return following a large rainfall event in the Pilbara region. It is noted that the return to dusty conditions is not just a function of the evaporation of the water, but is determined more importantly from the activity level within the stockpile area, as surfaces are disturbed and fresh surfaces are created as a result of reclaiming, stacking and vehicle movement.

5. MODELLING RESULTS

5.1 Predicted Ambient Particulate Concentrations

A summary of the maximum TSP, PM_{10} and $PM_{2.5}$ concentrations predicted for peak operations at the proposed MKSO project site for the three modelled scenarios are presented in Table 5. Maximum 24 hour and annual average concentrations were predicted at the seven Goldfields Highway locations, NMK Camp and Shearing Shed Campsite are also presented in the table. Predicted concentration contours are presented in Figures 5 to 19.

Table 5 shows that without watering controls employed on the transport corridor between MKSO and NMK, predicted concentrations are below the nominated standards at all discrete receptors except at the NMK camp where exceedances of the 24 hour average TSP, PM_{10} and $PM_{2.5}$ standards and annual $PM_{2.5}$ standard are predicted. Analysis of the source contributions at the NMK camp indicate that the exceedance of the PM_{10} and $PM_{2.5}$ standards are due to emissions from haulage of the product along the transport corridor. Table 5 also indicates that when watering controls are applied to the transport corridor, the predicted concentrations at the NMK Camp are below the nominated standards as all of the discrete receptors.

However, the existing NMK operations were not included in the modelling and emissions from the NMK operations could impact on the NMK camp. Predicted concentrations at the NMK camp for the scenario where the transport corridor was watered at a rate less than 2 litres/m^2/hour were still elevated and cumulative emissions from the transport corridor and operations from NMK could possibly result in exceedances at the NMK camp. Predicted concentrations at the NMK camp where the transport corridor was watered at a rate greater than 2 litres/m^2/hour resulted in concentrations well below the nominated standard.

Table 5: Summary of Predicted TSP, PM_{10} and $PM_{2.5}$ GLCs ()

Location	Predicted GLC (µg/m^3)				
	TSP	PM_{10}		$PM_{2.5}$	
	Maximum 24-hour Average	Maximum 24-hour Average	Annual Average	Maximum 24-hour Average	Annual Average
Standard	**90**	**50**	**25**	**25**	**8**
Scenario 1 - No Controls on MKSO – NMK Transport Road					
NMK Camp	110	75	24	25	8
Shearing Shed	47	28	2	9	1
Goldfields Highway 1	74	41	8	14	3
Goldfields Highway 2	53	34	4	11	1
Goldfields Highway 3	47	33	2	12	1
Goldfields Highway 4	62	43	9	15	3
Goldfields Highway 5	35	26	7	9	2
Goldfields Highway 6	41	28	8	9	3
Goldfields Highway 7	48	34	11	12	4
Scenario 2 - Watering on MKSO < 2 litres/m^2/hour – NMK Transport Road					
NMK Camp	55	38	12	13	4

Table 5: Summary of Predicted TSP, PM_{10} and $PM_{2.5}$ GLCs ()					
Location	Predicted GLC (µg/m³)				
	TSP	PM_{10}		$PM_{2.5}$	
	Maximum 24-hour Average	Maximum 24-hour Average	Annual Average	Maximum 24-hour Average	Annual Average
Standard	**90**	**50**	**25**	**25**	**8**
Shearing Shed	39	23	1	7	0.5
Goldfields Highway 1	74	27	5	9	2
Goldfields Highway 2	35	22	3	7	1
Goldfields Highway 3	33	20	2	7	1
Goldfields Highway 4	52	37	5	12	2
Goldfields Highway 5	25	19	4	7	1
Goldfields Highway 6	24	15	4	5	1
Goldfields Highway 7	27	19	6	7	2
Scenario 3 - Watering on MKSO > 2 litres/m²/hour– NMK Transport Road					
NMK Camp	27	19	6	6	2
Shearing Shed	35	21	1	7	0.4
Goldfields Highway 1	74	26	4	8	1
Goldfields Highway 2	32	19	3	6	1
Goldfields Highway 3	32	20	1	6	1
Goldfields Highway 4	47	33	4	11	1
Goldfields Highway 5	20	15	2	5	1
Goldfields Highway 6	17	11	2	4	1
Goldfields Highway 7	18	13	3	4	1

5.2 Predicted Particulate Deposition Rates

A summary of the predicted average daily and monthly deposition rates for Scenarios 1 to 3 is presented in Table 6. Figures 20, 21 and 22 present the predicted average daily deposition rates across the modelling domain for Scenarios 1 to 3.

Table 6: Summary of Predicted Daily Average Deposition at Sensitive Receptor Locations	
Location	**Predicted Daily Deposition ($g/m^2/d$)**
Scenario 1 - No Controls on MKSO – NMK Transport Road	
Wanjarri Nature Reserve 1	0.020
Wanjarri Nature Reserve 2	0.029
Wanjarri Nature Reserve 3	0.035
Wanjarri Nature Reserve 4	0.252
Wanjarri Nature Reserve 5	0.198
Wanjarri Nature Reserve 6	0.239
Wanjarri Nature Reserve 7	0.009
Transport Corridor West	0.288
Scenario 2 - Watering on MKSO < 2 litres/m²/hour – NMK Transport Road	
Wanjarri Nature Reserve 1	0.012
Wanjarri Nature Reserve 2	0.026
Wanjarri Nature Reserve 3	0.034
Wanjarri Nature Reserve 4	0.128
Wanjarri Nature Reserve 5	0.099
Wanjarri Nature Reserve 6	0.120
Wanjarri Nature Reserve 7	0.005
Transport Corridor West	0.144
Scenario 3 - Watering on MKSO > 2 litres/m²/hour – NMK Transport Road	
Wanjarri Nature Reserve 1	0.008
Wanjarri Nature Reserve 2	0.024
Wanjarri Nature Reserve 3	0.033
Wanjarri Nature Reserve 4	0.066
Wanjarri Nature Reserve 5	0.050
Wanjarri Nature Reserve 6	0.060
Wanjarri Nature Reserve 7	0.003
Transport Corridor West	0.072

The modelling predicted the greatest impacts at the selected receptor locations within the Wanjarri Reserve to occur at Wanjarri Nature Reserve 4 (WR4). Figures 20, 21 and 22 indicate that the greatest impacts occur to the west of the transport corridor. Impacts at the Transport Corridor West receptor, which is located within 50m of the centre of the transport corridor were predicted to be greater than in the reserve. Analysis of the wind directions indicates that the winds are predominately from an easterly or south easterly direction and so the greatest depositional impacts are expected to occur on the western side of the road corridor outside of the Wanjarri Nature Reserve.

Based on the depositional impacts outlined in Doley and Rossato (2010) (i.e. 0.3 g/m^2/day) the predicted impacts to vegetation within the Wanjarri Nature Reserve from activity along the transport corridor with no controls applied is likely to be low. The study completed by Doley and Rossato (2010) indicated that at deposition levels of approximately 0.3 g/m^2/d the estimated reductions in canopy photosynthesis of cotton plants would be less than 7% with a <1% decrease in productivity.

Whilst it is difficult to determine definitive impacts on vegetation within the Wanjarri Nature Reserve without monitoring data, the predicted impacts to vegetation within the Wanjarri Nature Reserve without use of controls on the transport corridor as a result of the Project is considered to be low.

A summary of the predicted average daily and monthly deposition rates for Scenarios 1 to 3 is presented in Table 6. Figures 23, 24 and 25 present the predicted average monthly deposition rates across the modelling domain for Scenarios 1 to 3.

Table 6 indicates that the predicted levels of dust deposition for Scenario 1 at all nominated locations are above the NSW DECC dust deposition criteria (4 g/m2/month) for amenity. For Scenario 2, the levels of were also above the NSW DECC dust deposition criteria except at Location 2. For Scenario 3, the NSW DECC dust deposition criteria were exceeded at Locations 1 and 5.

Table 7: Summary of Predicted Monthly Average Deposition at Sensitive Receptor Locations

Location	Predicted Monthly Deposition (g/m^2/month)
Scenario 1 - No Controls on MKSO – NMK Transport Road	
Aboriginal Heritage Location 1	15.2
Aboriginal Heritage Location 2	4.2
Aboriginal Heritage Location 3	14.4
Aboriginal Heritage Location 4	11.0
Aboriginal Heritage Location 5	17.3
Scenario 2 - Watering on MKSO < 2 litres/m^2/hour – NMK Transport Road	
Aboriginal Heritage Location 1	8.3
Aboriginal Heritage Location 2	2.2
Aboriginal Heritage Location 3	7.3
Aboriginal Heritage Location 4	6.1
Aboriginal Heritage Location 5	8.9
Scenario 3 - Watering on MKSO > 2 litres/m^2/hour – NMK Transport Road	
Aboriginal Heritage Location 1	4.9
Aboriginal Heritage Location 2	1.2

Aboriginal Heritage Location 3	3.6
Aboriginal Heritage Location 4	3.7
Aboriginal Heritage Location 5	4.7

6. CONCLUSIONS

Air dispersion modelling has been completed to assess the potential ambient air quality and depositional impacts of atmospheric dust emissions associated with Nickel West's proposed MKSO Project.

Air dispersion modelling has been completed to predict short-term (24-hour) concentrations of TSP, PM_{10} and $PM_{2.5}$ and long-term (annual) ambient concentrations of PM_{10} and $PM_{2.5}$, across the modelled domain and at selected receptor locations. The air dispersion model has also been utilised to predict particulate deposition rates in order to determine the potential impact of particulate deposition on the surrounding environment. The assessment primarily focuses on fugitive dust emissions associated with mining operations, stockpiling, reclaiming, vehicle movements on unpaved surfaces both within MKSO operations and on a transport corridor between MKSO and NMK operations as well as wind erosion of unpaved surfaces including the ROM and WRL.

The modelling indicated that without watering controls employed on the transport corridor between MKSO and NMK, predicted concentrations are below nominated standards at the nominated receptors except at the NMK camp where exceedances of the 24 hour average TSP, PM_{10} and $PM_{2.5}$ standards and annual $PM_{2.5}$ standard are predicted to occur. Analysis of the source contributions at the NMK camp indicate that the exceedance of the TSP, PM_{10} and $PM_{2.5}$ standards are due to emissions from haulage of the ore along the transport corridor. The modelling also indicated that when watering controls are applied to the transport corridor the predicted concentrations at the NMK Camp fall below the nominated standards.

The modelling predicted the greatest daily depositional impacts within the Wanjarri Nature Reserve to occur at Wanjarri Nature Reserve 4 (WR4). Comparison of the predicted deposition rates with a guideline of 0.3 g/m^2/day for vegetation impacts indicates that the predicted deposition rates are not considered to be significant.

The modelling predicted monthly dust deposition at a number of Aboriginal heritage sites for all scenarios. The modelling indicated that the predicted levels of dust deposition for Scenario 1 at all nominated locations are above the NSW DECC dust deposition criteria (4 g/m2/month) for amenity. For Scenario 2, the levels of were also above the NSW DECC dust deposition criteria except at Location 2. For Scenario 3, the NSW DECC dust deposition criteria were exceeded at only Locations 1 and 5. It should be noted that the criteria used was not designed to assess potential impacts at heritage locations but were designed to take into account potential amenity impacts, such as dust depositing on fabrics and buildings. The use of these guidelines serve as a reference as to the magnitude of the deposition resulting from MKO operations and should not be used as an indication of potential acceptability of these deposition levels.

In considering these results it should also be noted that the prediction of ambient dust concentrations from fugitive sources by air dispersion modelling is difficult primarily due to the complexity and uncertainty in estimating dust emissions due to numerous factors that can affect the emissions. Modelling results have a degree of inherent uncertainty but are useful in prioritising management measures to control and reduce dust emissions.

7. REFERENCES

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8. LIMITATIONS

Ramboll Environ Australia prepared this report in accordance with the scope of work as outlined in our proposal to BHP Billiton Nickel West dated 19 July 2016 and in accordance with our understanding and interpretation of current regulatory standards.

The conclusions presented in this report represent Ramboll Environ's professional judgement based on information made available during the course of this assignment and are true and correct to the best of Ramboll Environ's knowledge as at the date of the assessment.

Ramboll Environ did not independently verify all of the written or oral information provided to Ramboll Environ during the course of this investigation. While Ramboll Environ has no reason to doubt the accuracy of the information provided to it, the report is complete and accurate only to the extent that the information provided to Ramboll Environ was itself complete and accurate. This report does not purport to give legal advice. This advice can only be given by qualified legal advisors.

8.1 User Reliance

This report has been prepared exclusively for and may not be relied upon by any other person or entity without Ramboll Environ's express written permission.

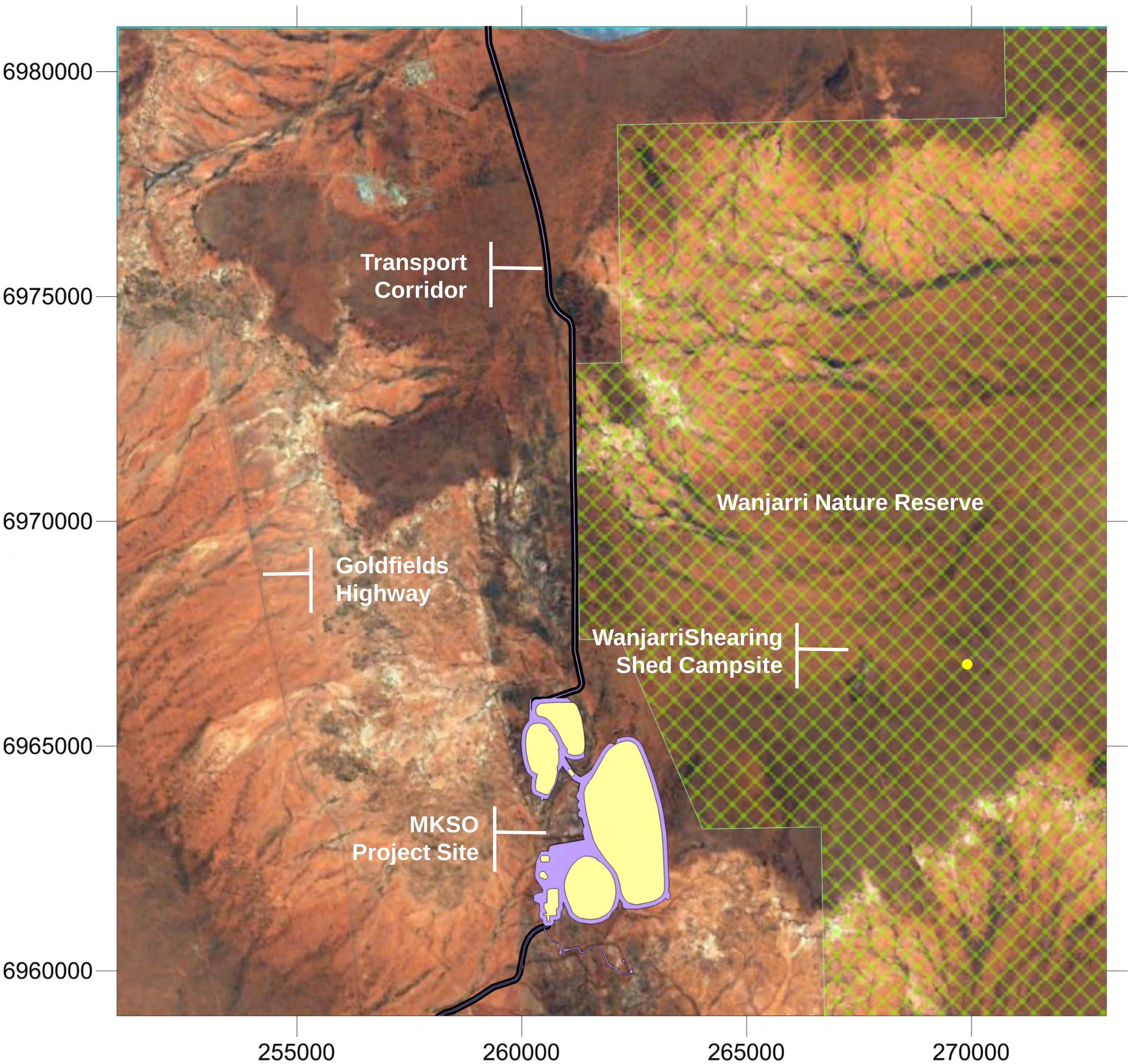

Figure 1 **Regional Location**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

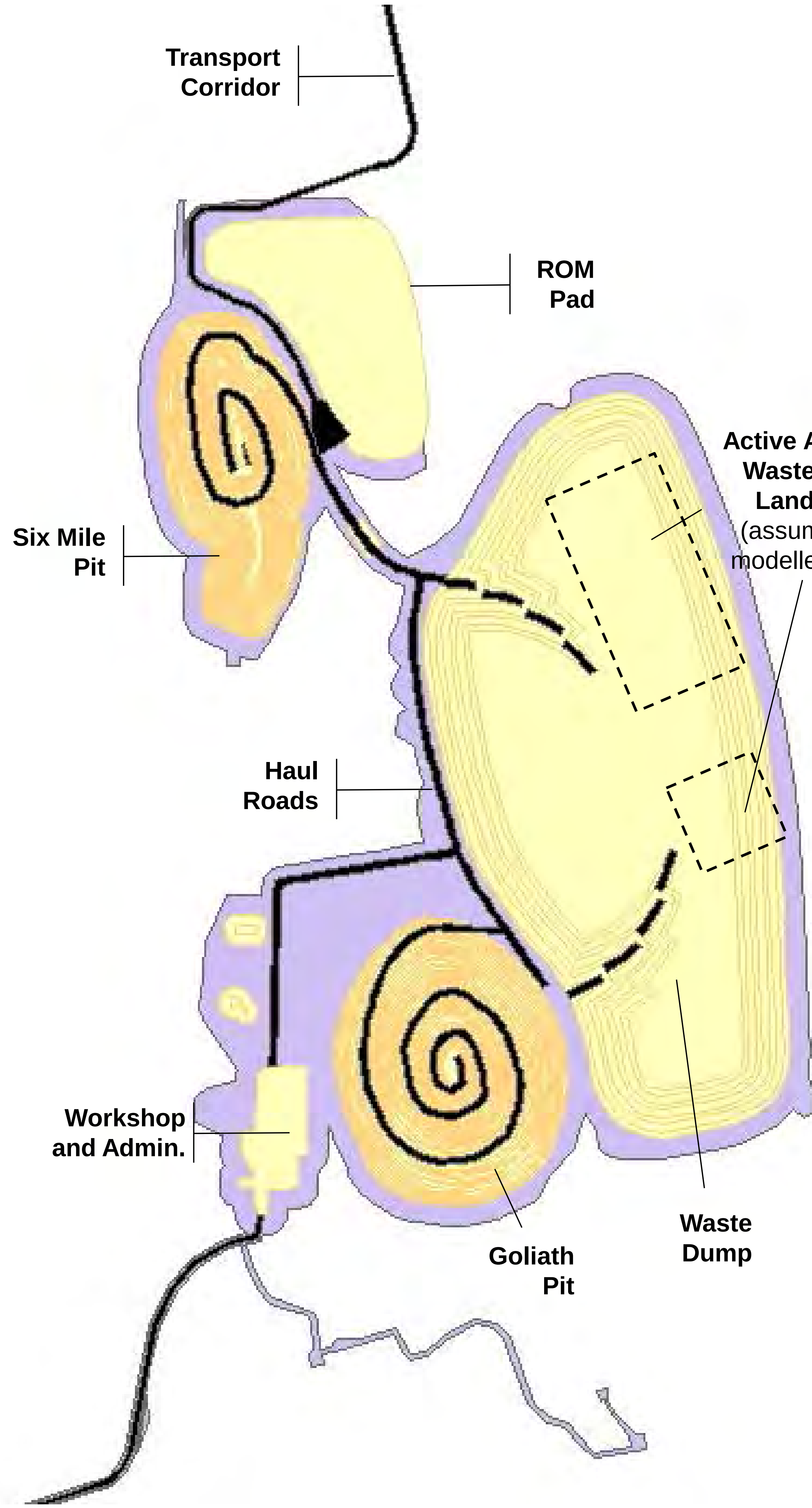

Figure 2 **Site Layout**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

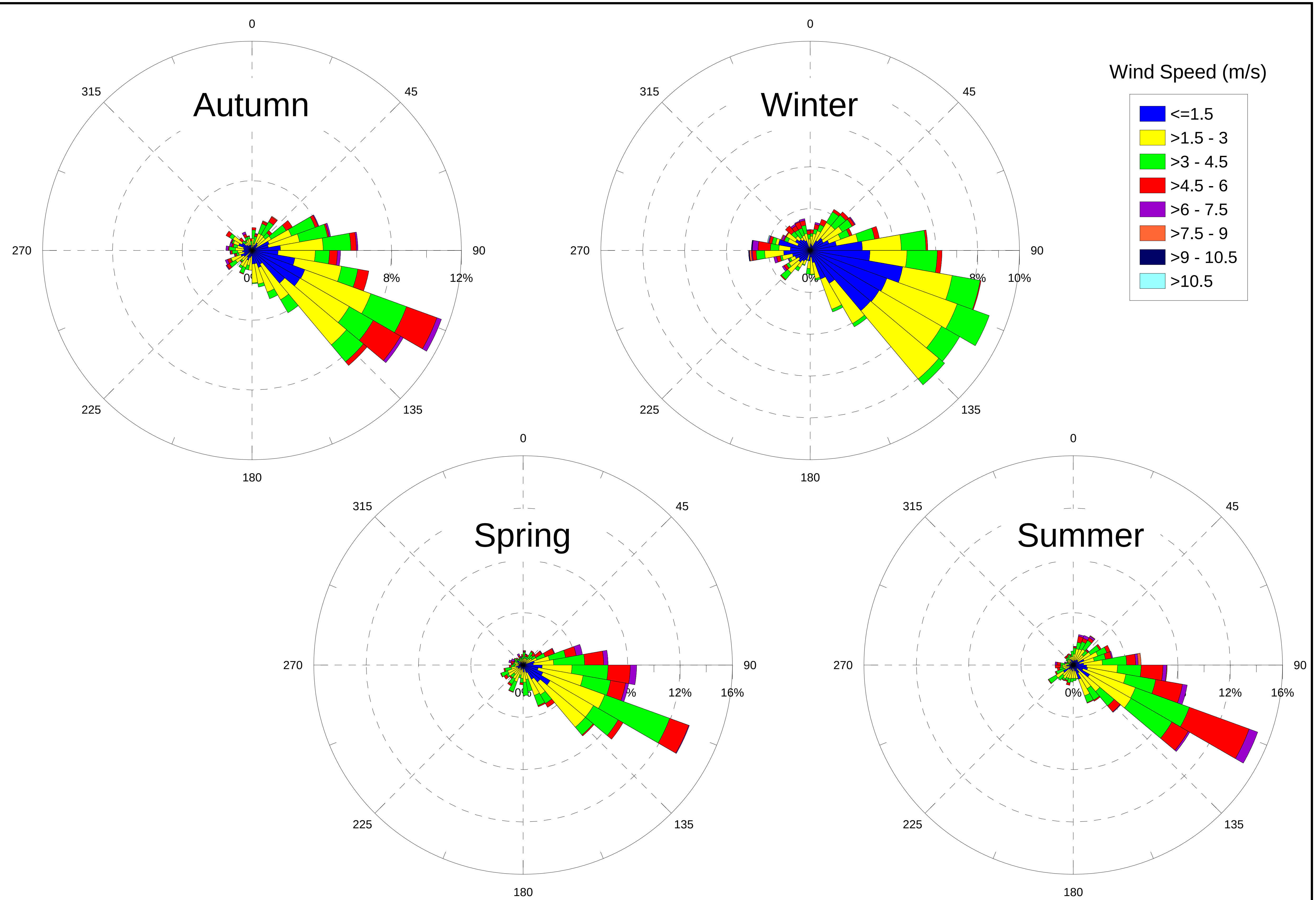

Figure 3

Yeelirrie Seasonal Wind Roses - March 2010 to April 2011

Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
Project: MKSO Dust Modelling Assessment	Drawn: MP	Date: Mar 2017

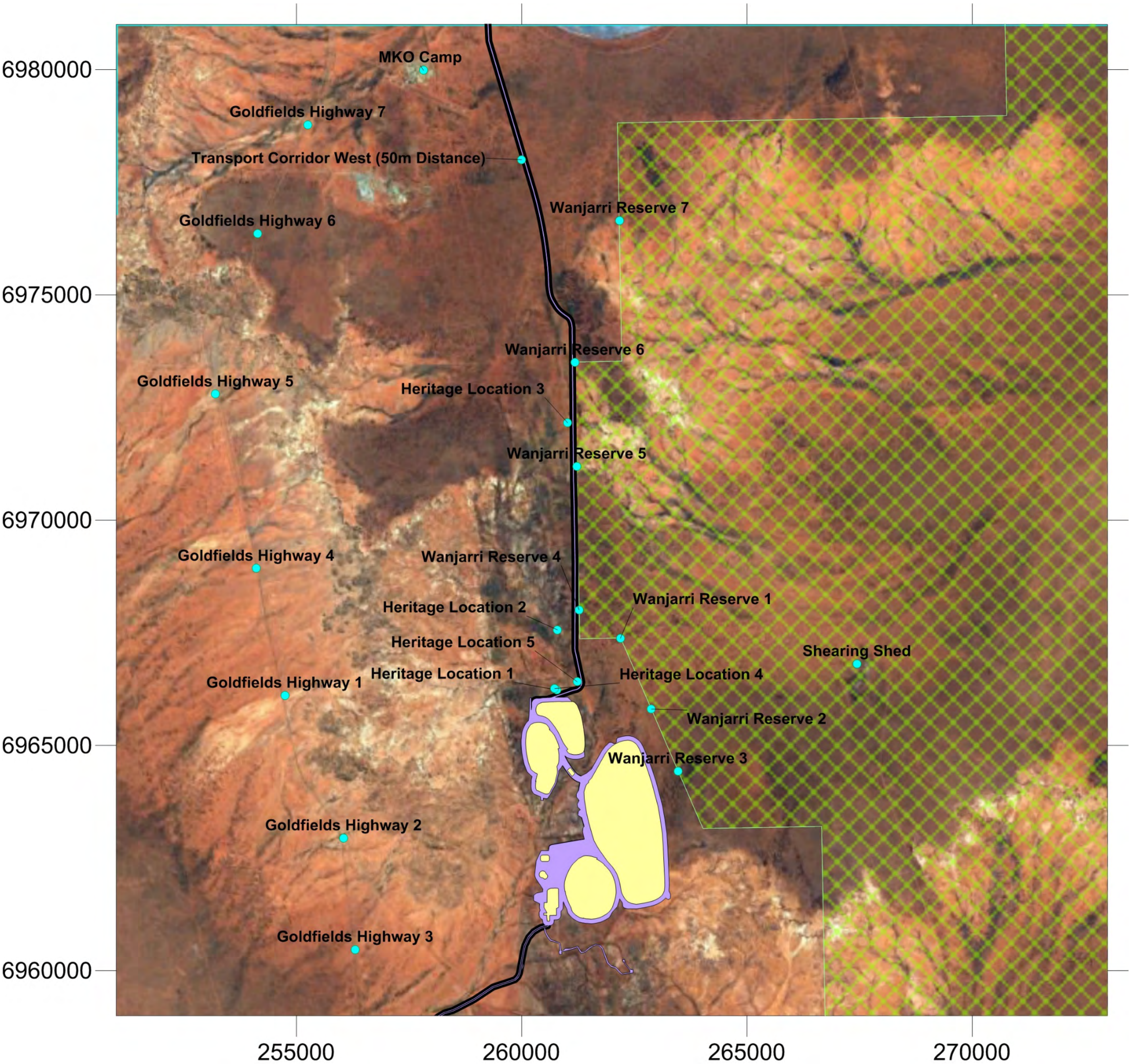

Figure 4 **Discrete Receptor Locations**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

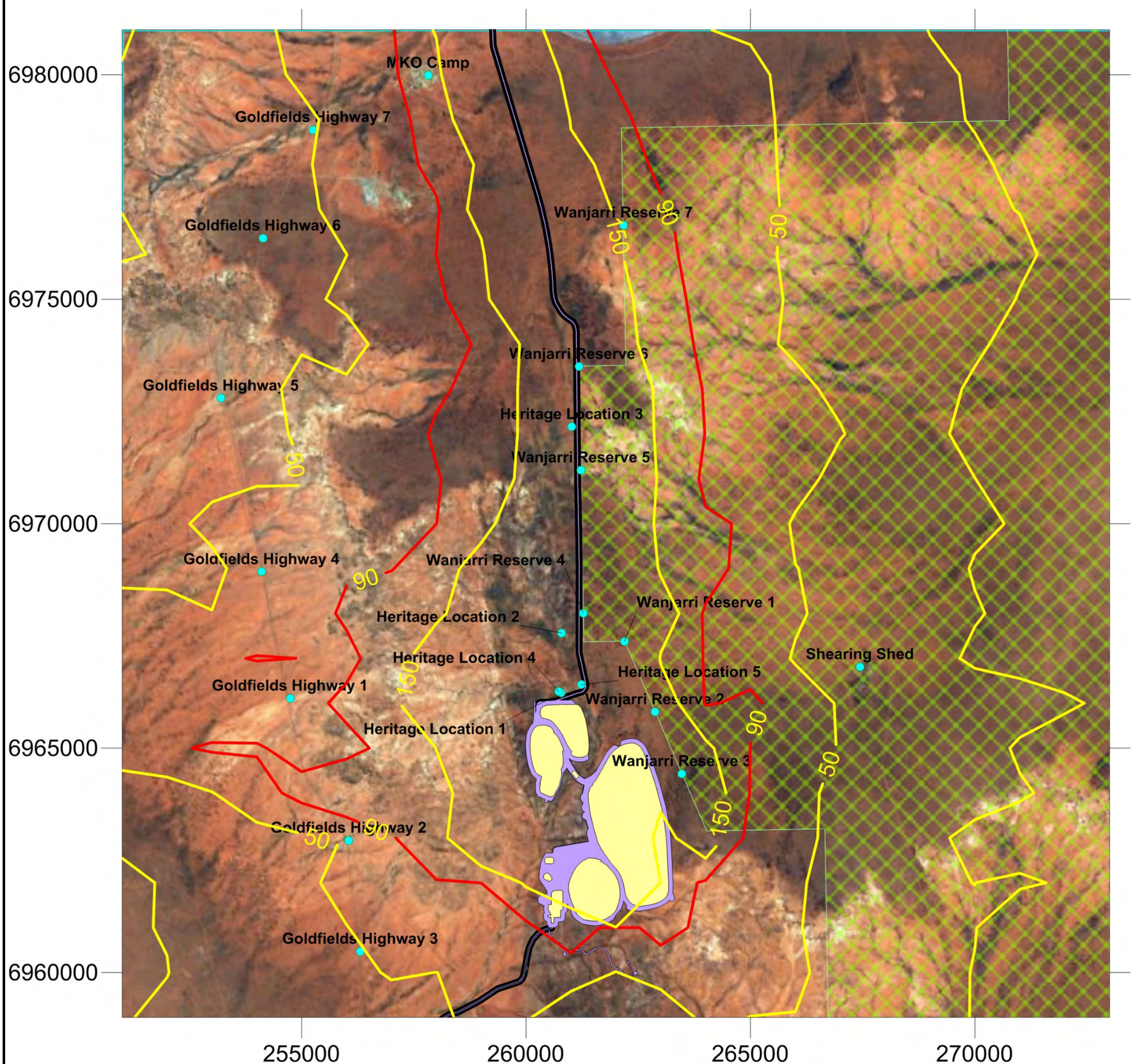

Figure 5 **Scenario 1 – TSP 24hr Av Predicted Conc. (µg/m³)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

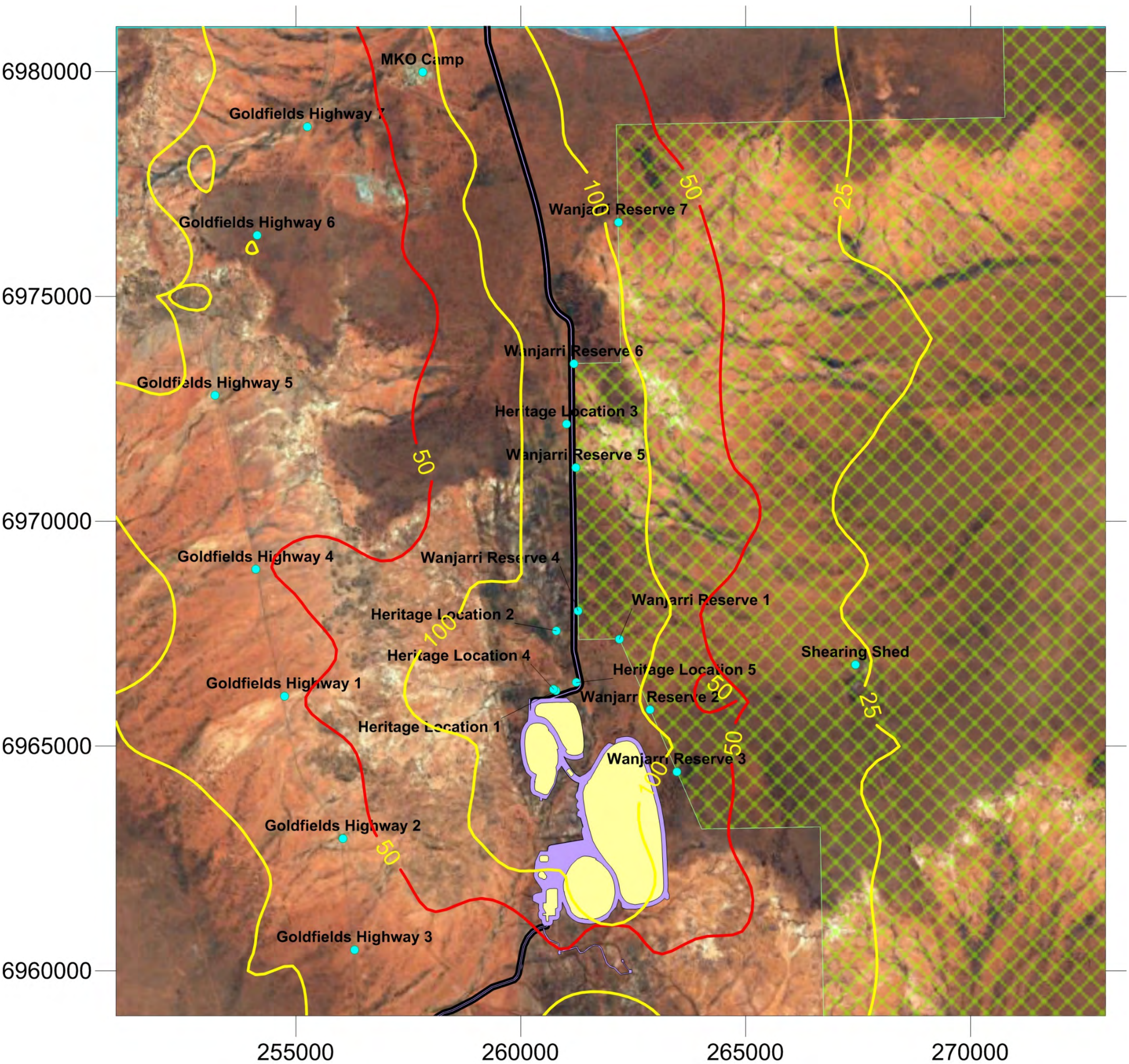

Figure 6 **Scenario 1 – PM_{10} 24hr Av Predicted Conc. (µg/m³)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

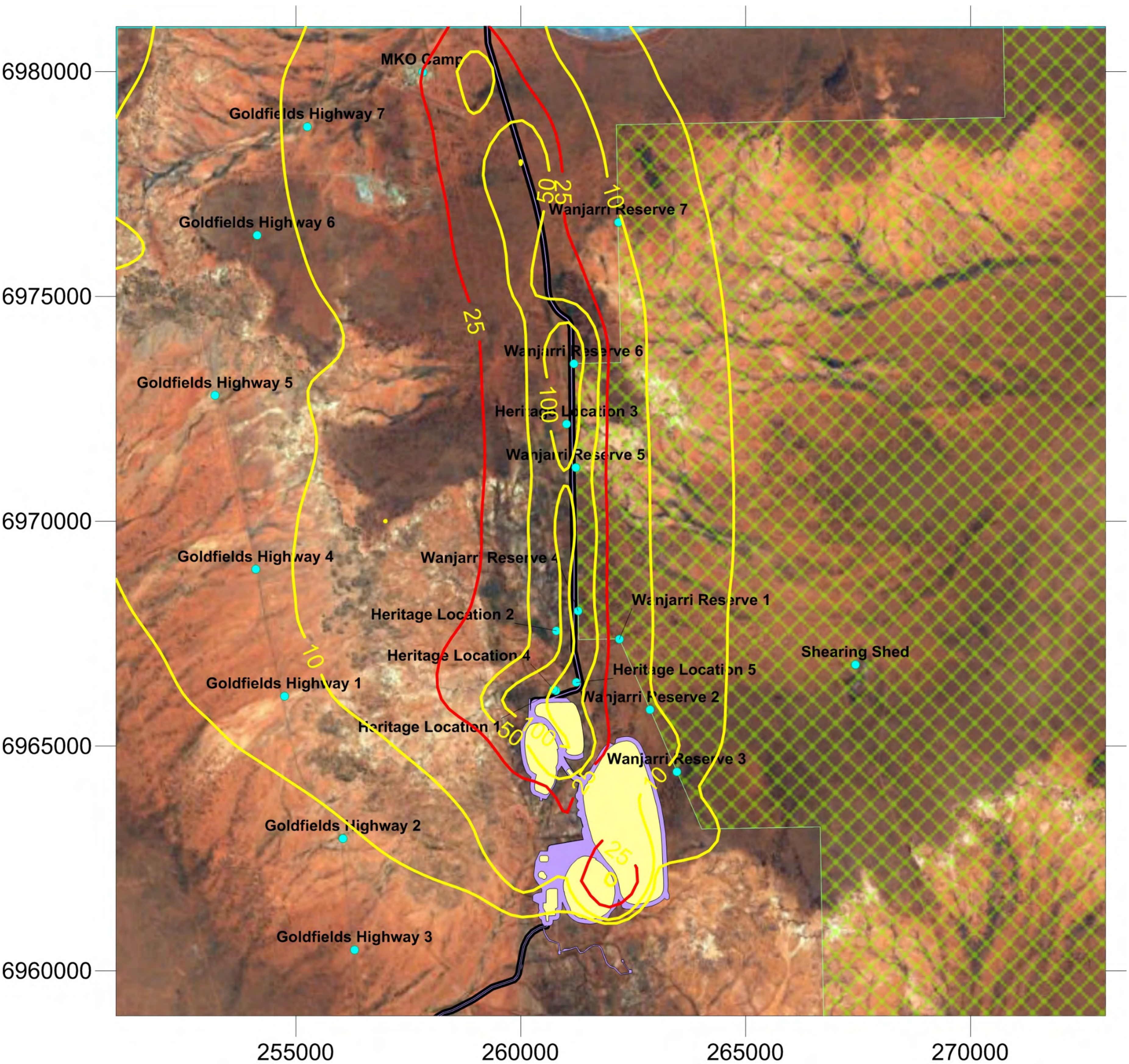

Figure 7 **Scenario 1 – PM_{10} Annual Av Predicted Conc. ($\mu g/m^3$)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

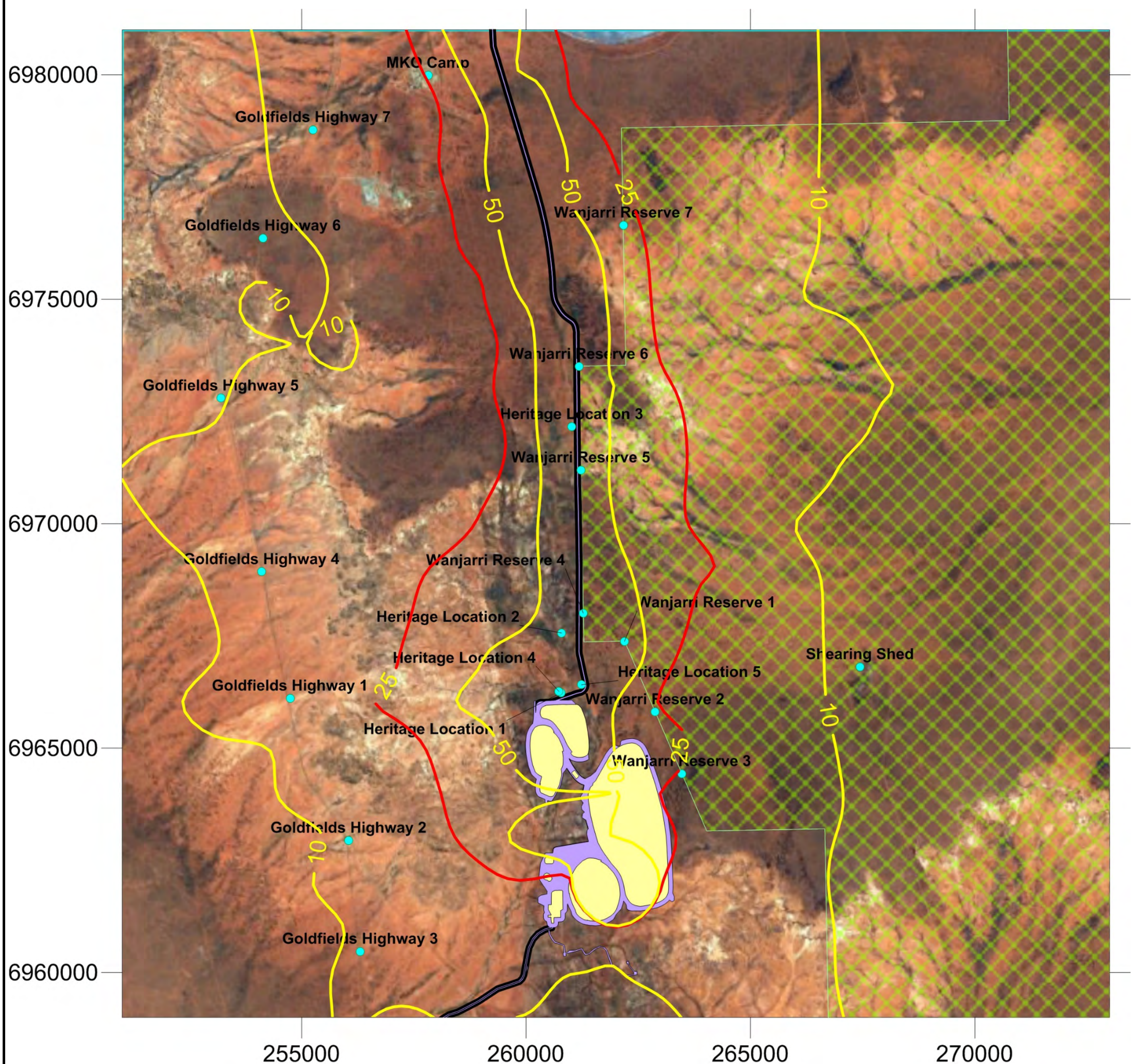

Figure 8 **Scenario 1 – PM2.5 24hr Av Predicted Conc. (µg/m³)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

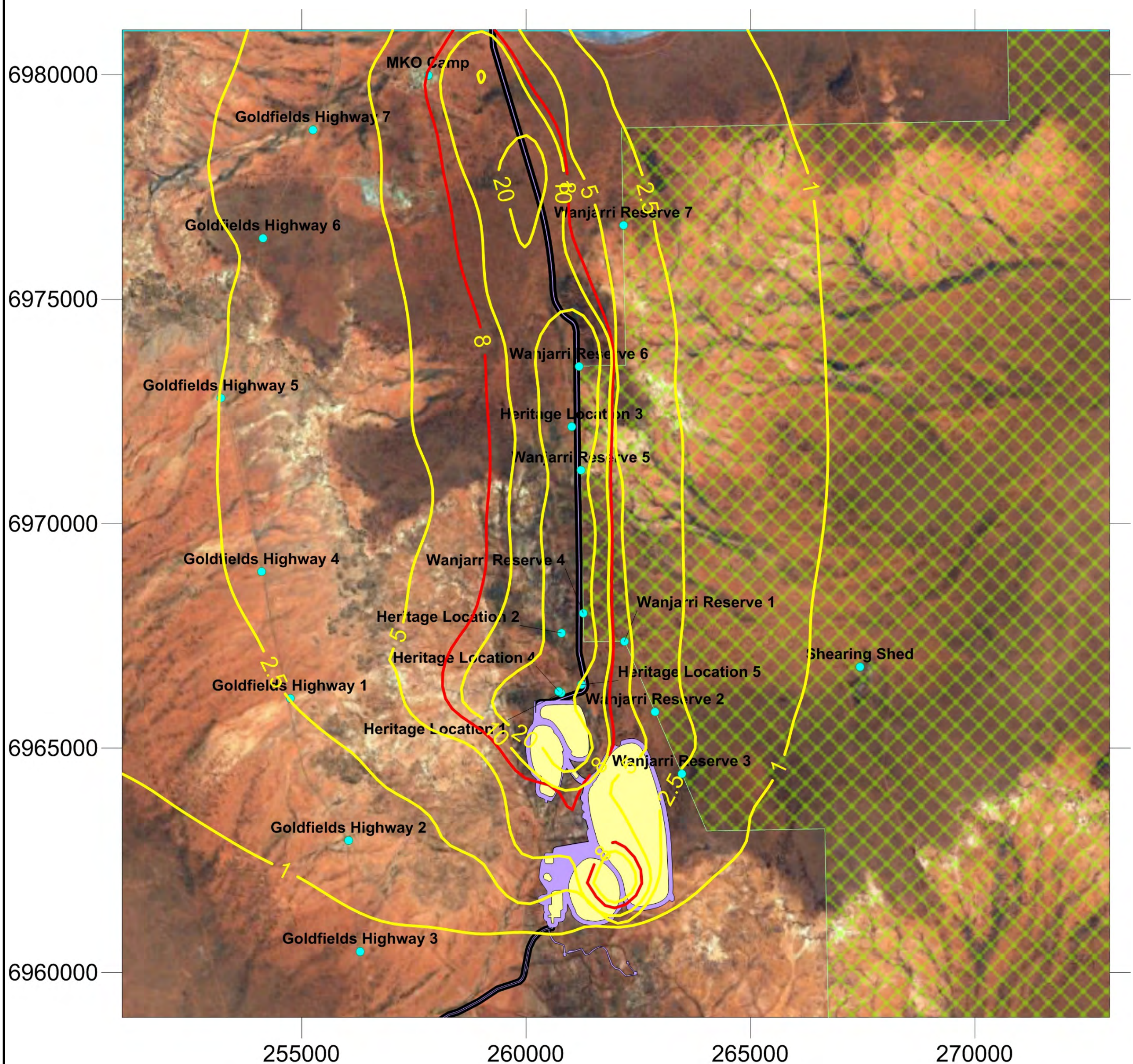

Figure 9

Scenario 1 – $PM_{2.5}$ Annual Av Predicted Conc. (µg/m³)

Client: BHP Billiton Nickel West Pty Ltd		RAMBOLL ENVIRON	
Project: MKSO Dust Modelling Assessment		Source: BHP Billiton	Date: Mar 2017

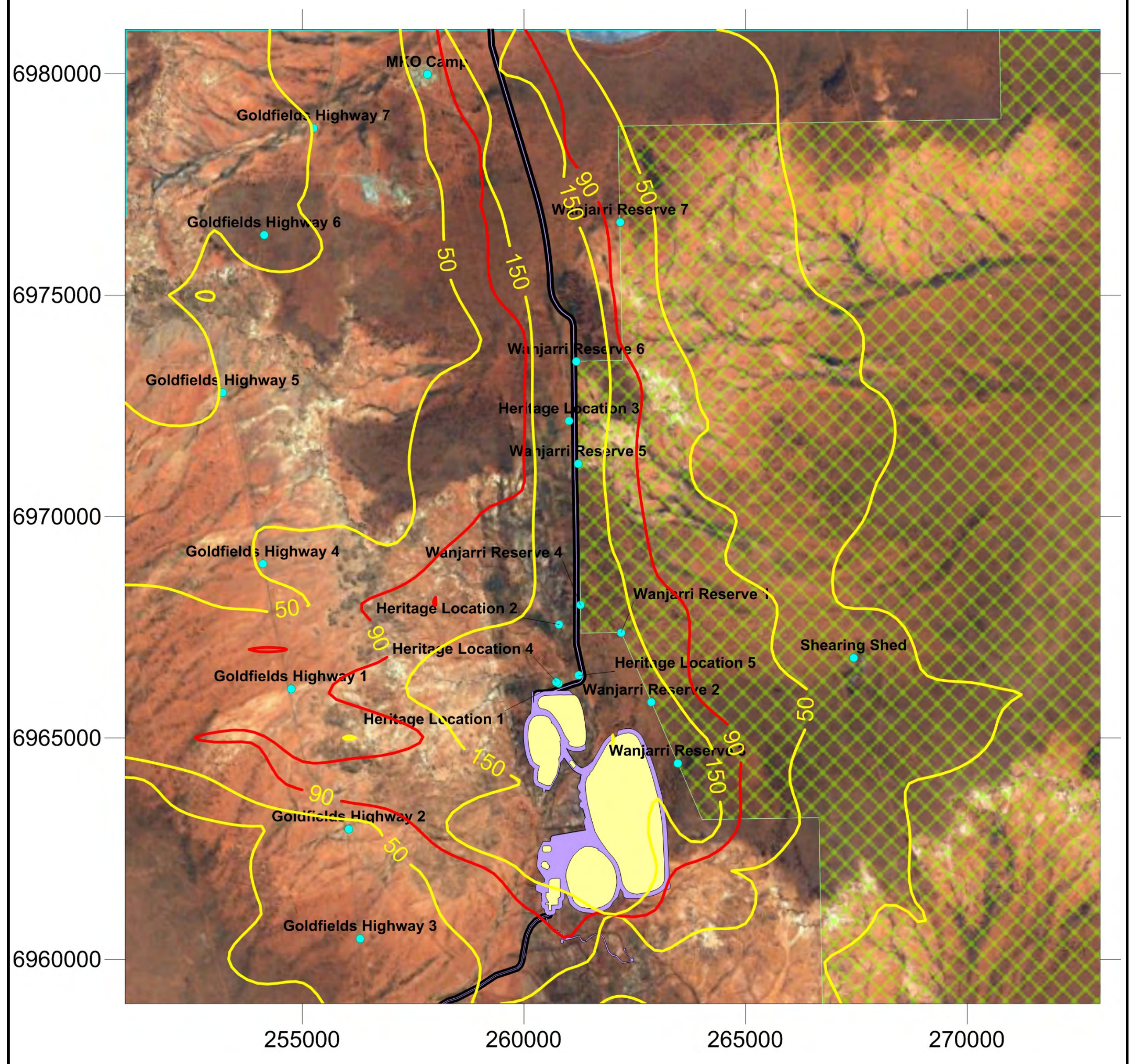

Figure 10 **Scenario 2 – TSP 24hr Av Predicted Conc. (µg/m³)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

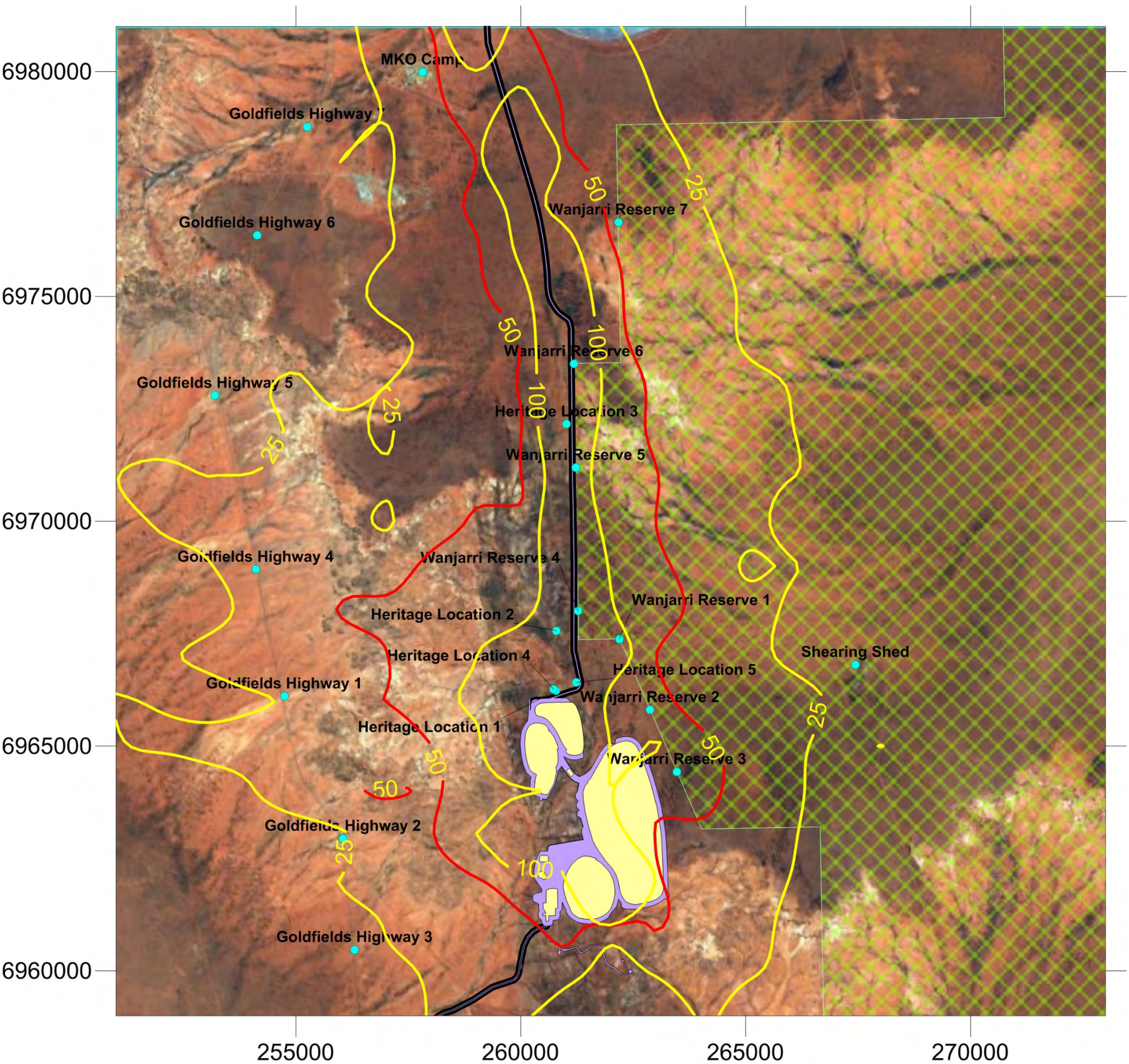

Figure 11 **Scenario 2 – PM_{10} 24hr Av Predicted Conc. (µg/m^3)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

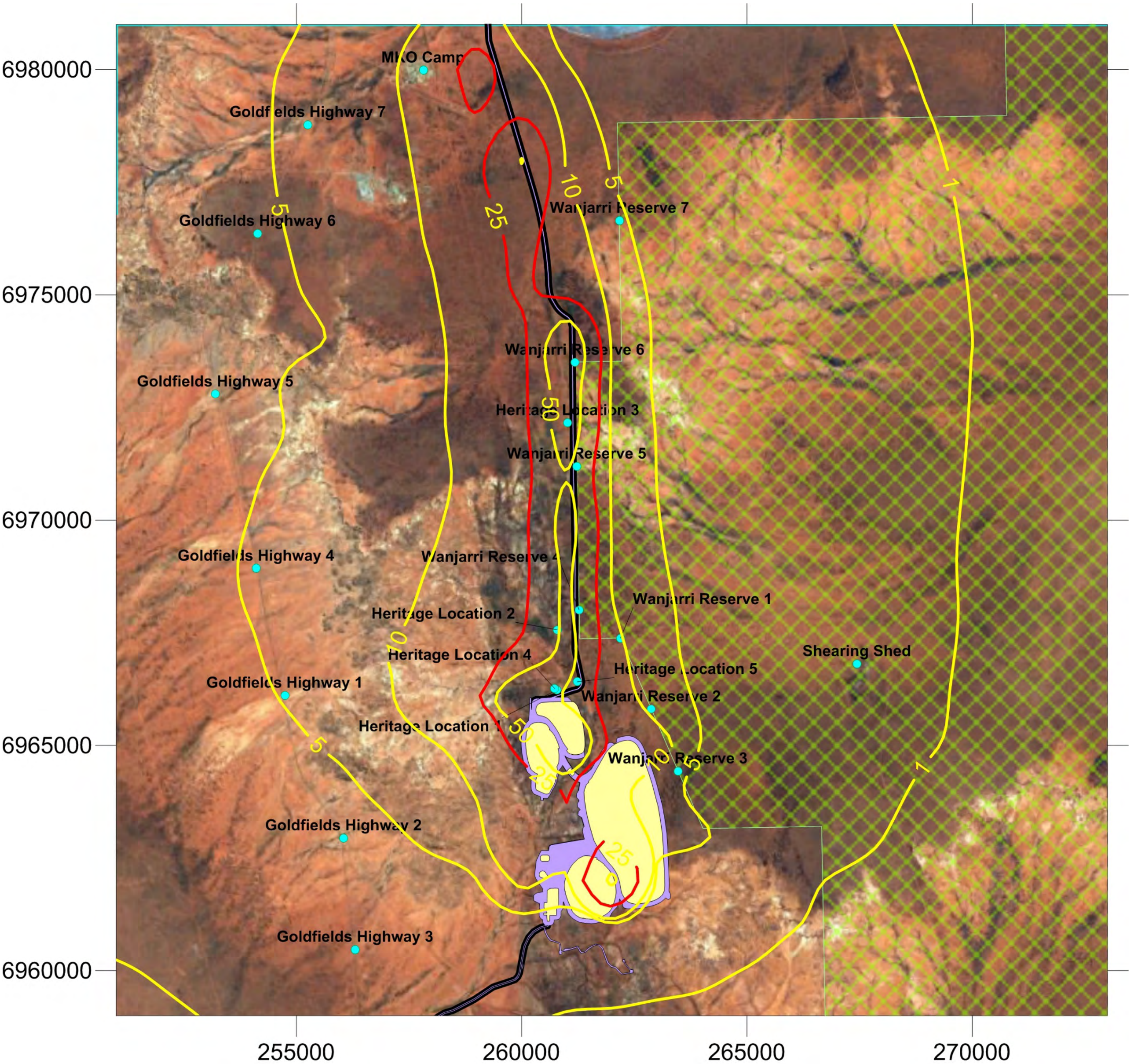

Figure 12 **Scenario 2 – PM10 Annual Av Predicted Conc. (µg/m³)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

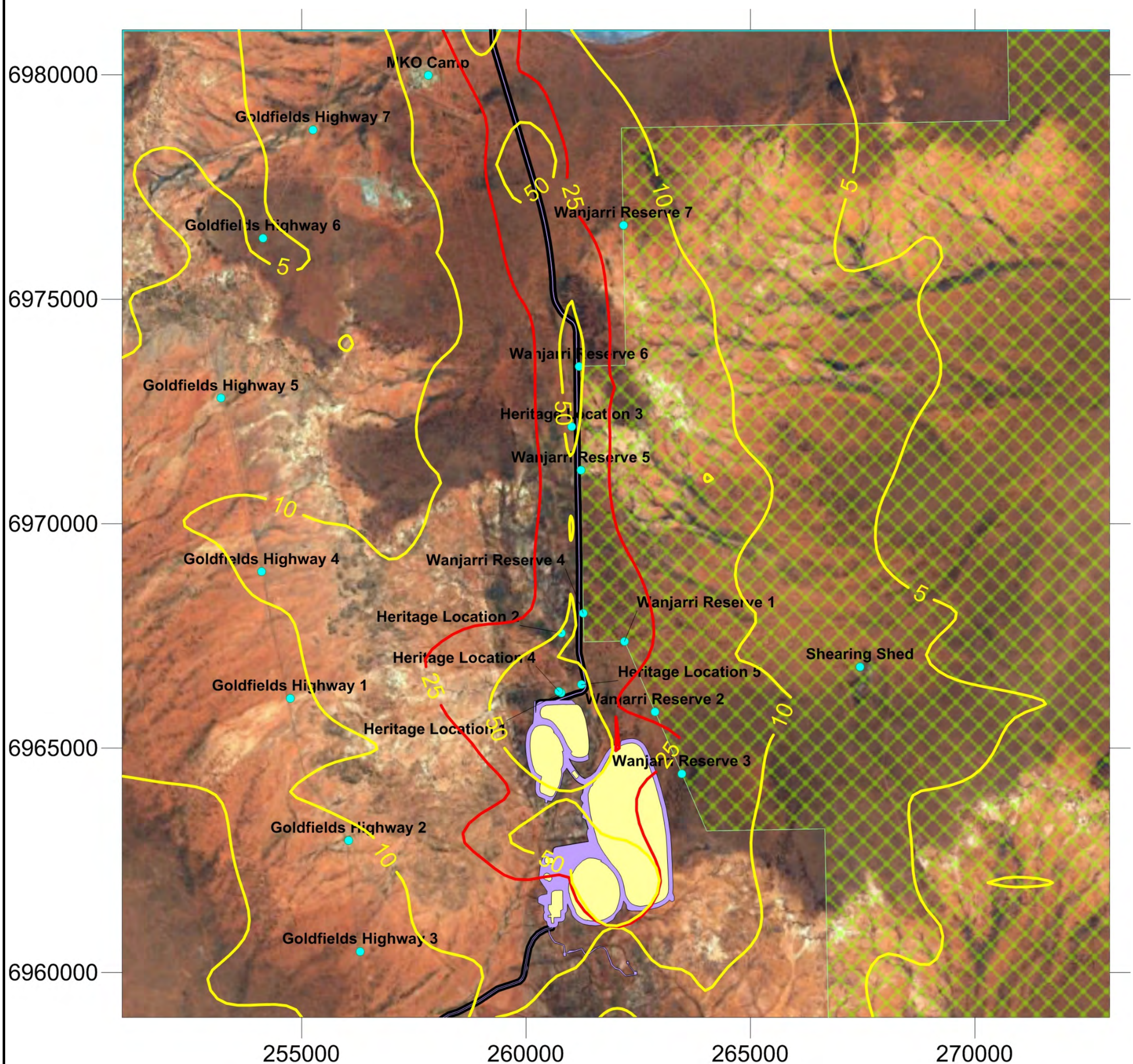

Figure 13 **Scenario 2 – $PM_{2.5}$ 24hr Av Predicted Conc. (µg/m^3)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

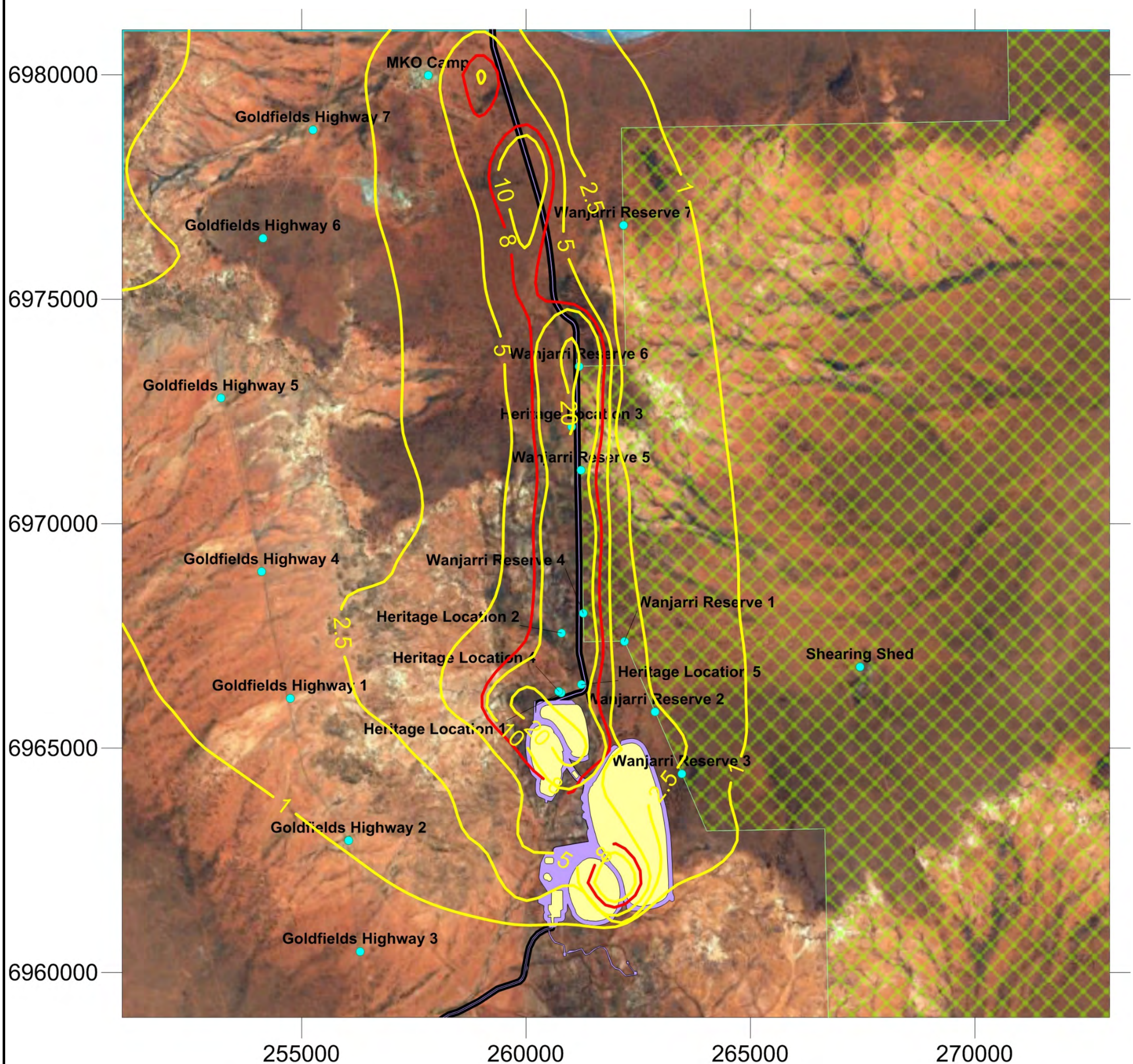

Figure 14 **Scenario 2 – PM2.5 Annual Av Predicted Conc. (µg/m³)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBØLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

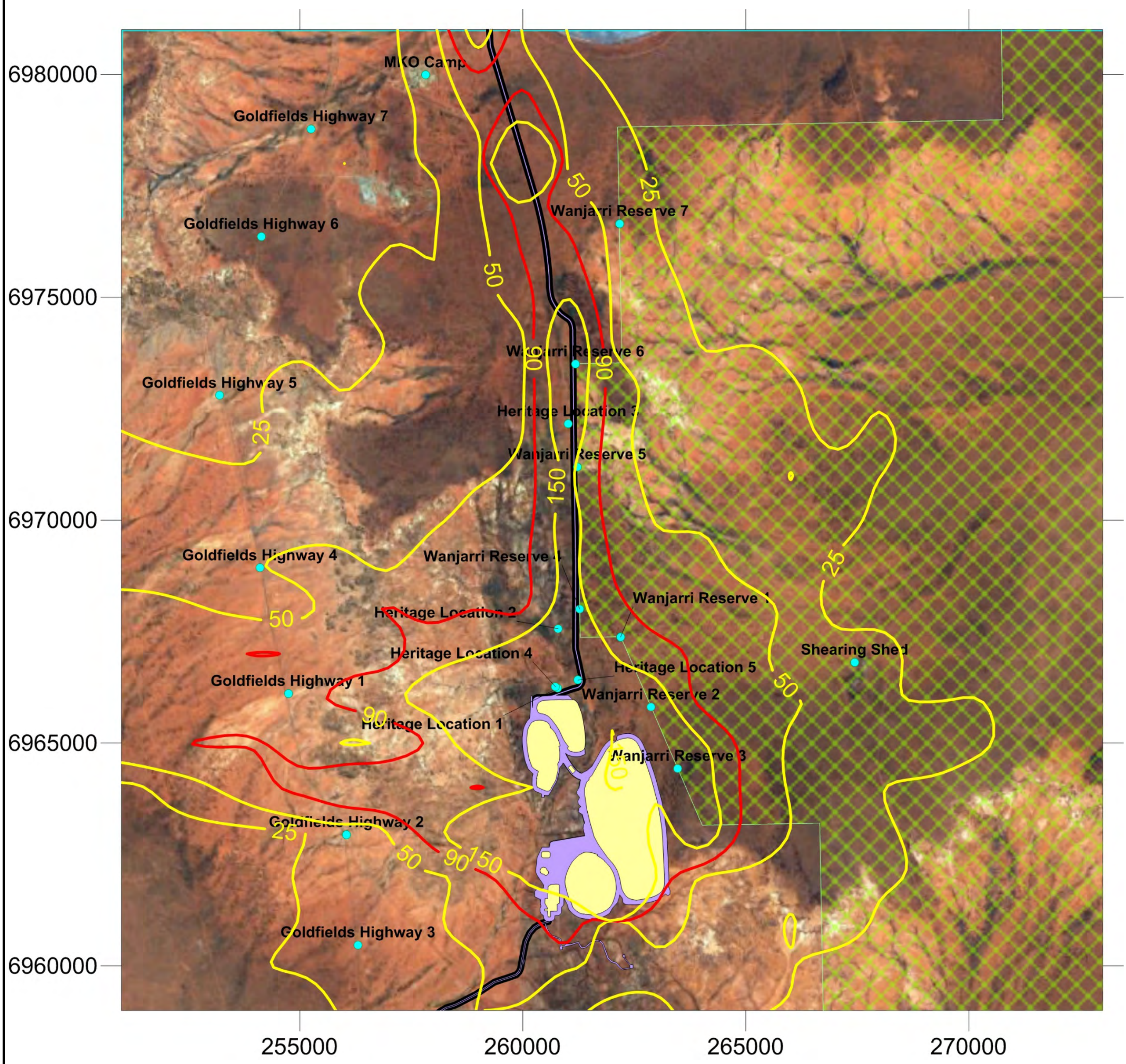

Figure 15 **Scenario 3 – TSP 24hr Av Predicted Conc. (µg/m³)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

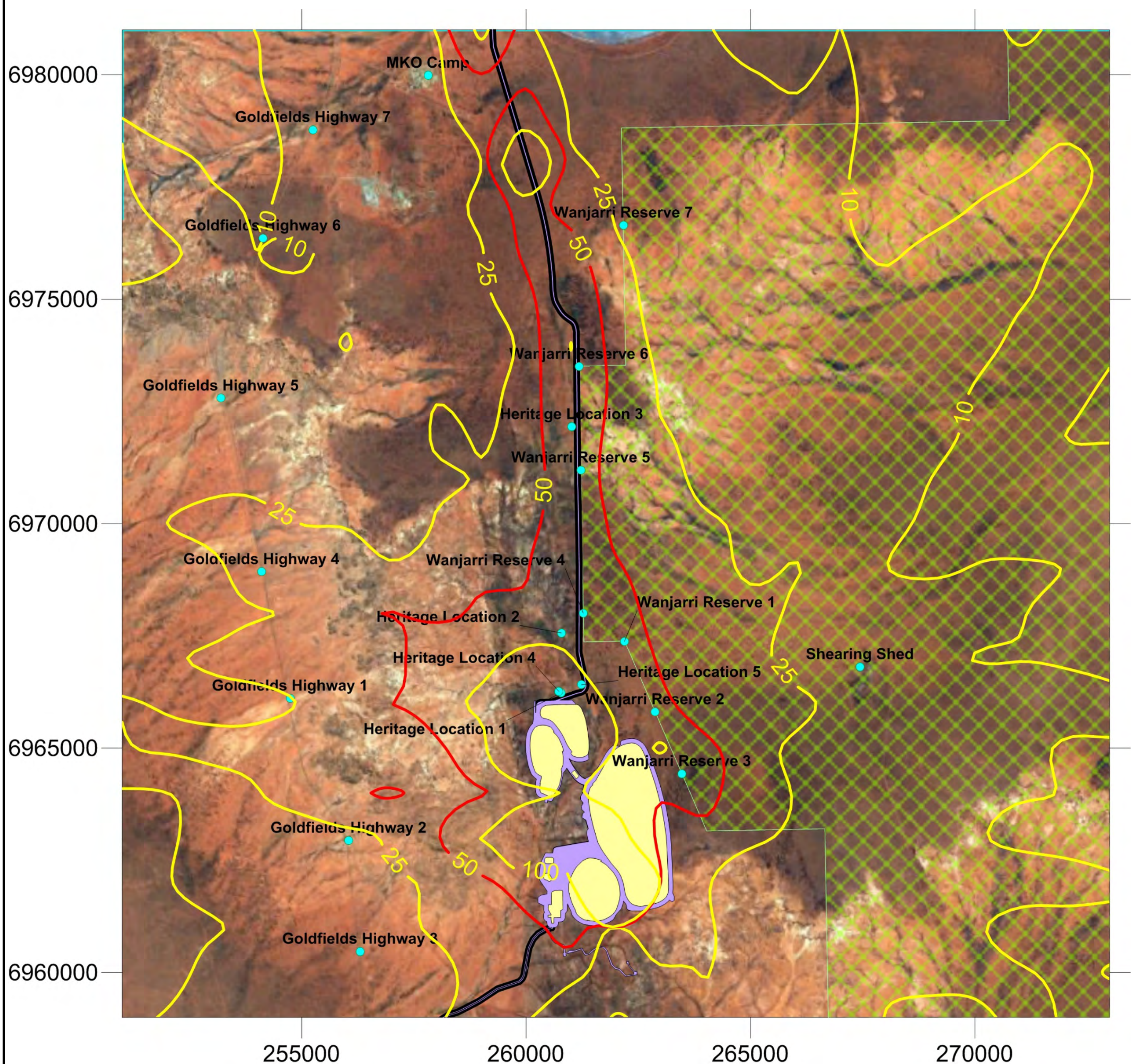

Figure 16 **Scenario 3 – PM10 24hr Av Predicted Conc. (µg/m³)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

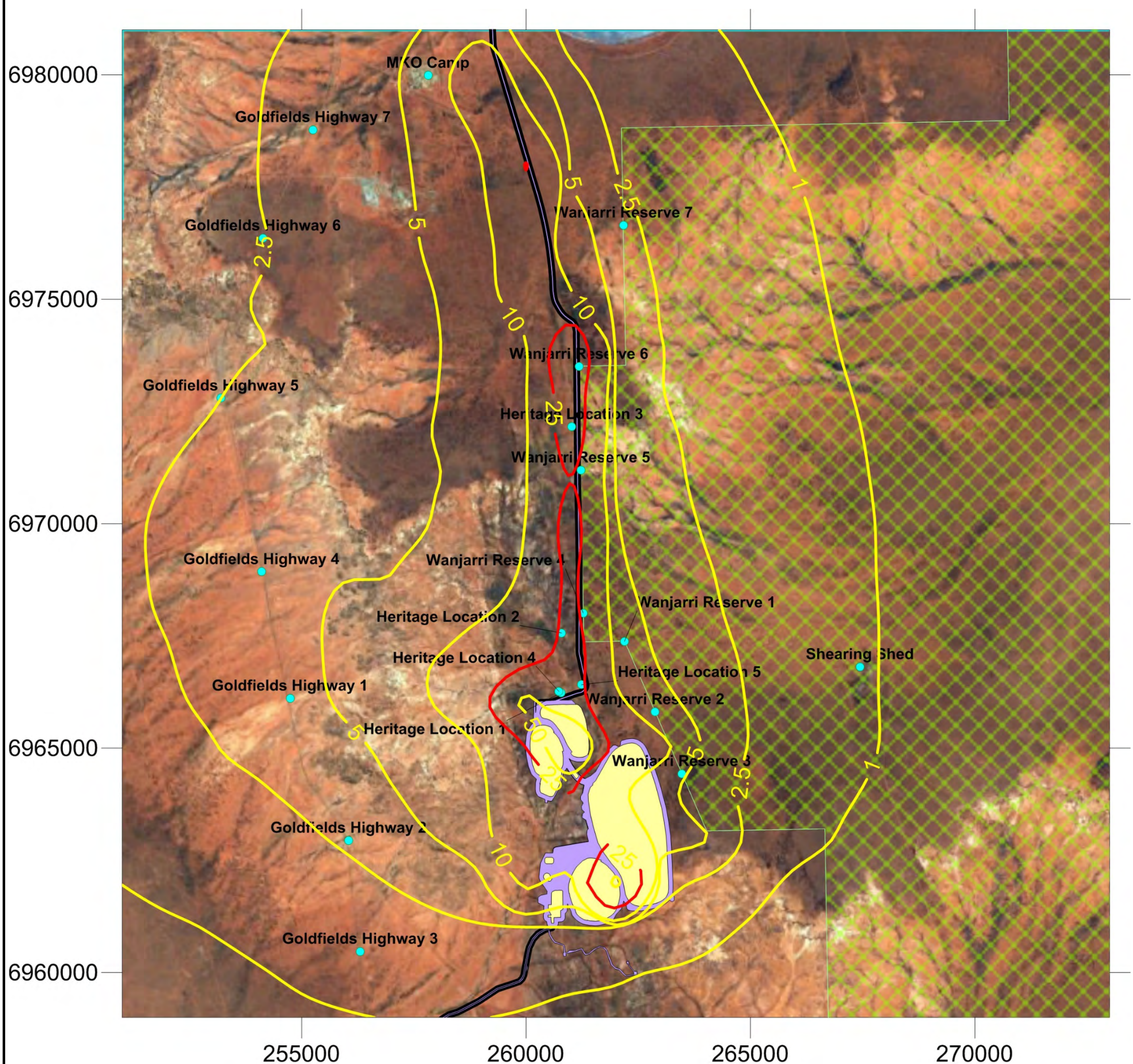

Figure 17 **Scenario 3 – PM_{10} Annual Av Predicted Conc. (µg/m³)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

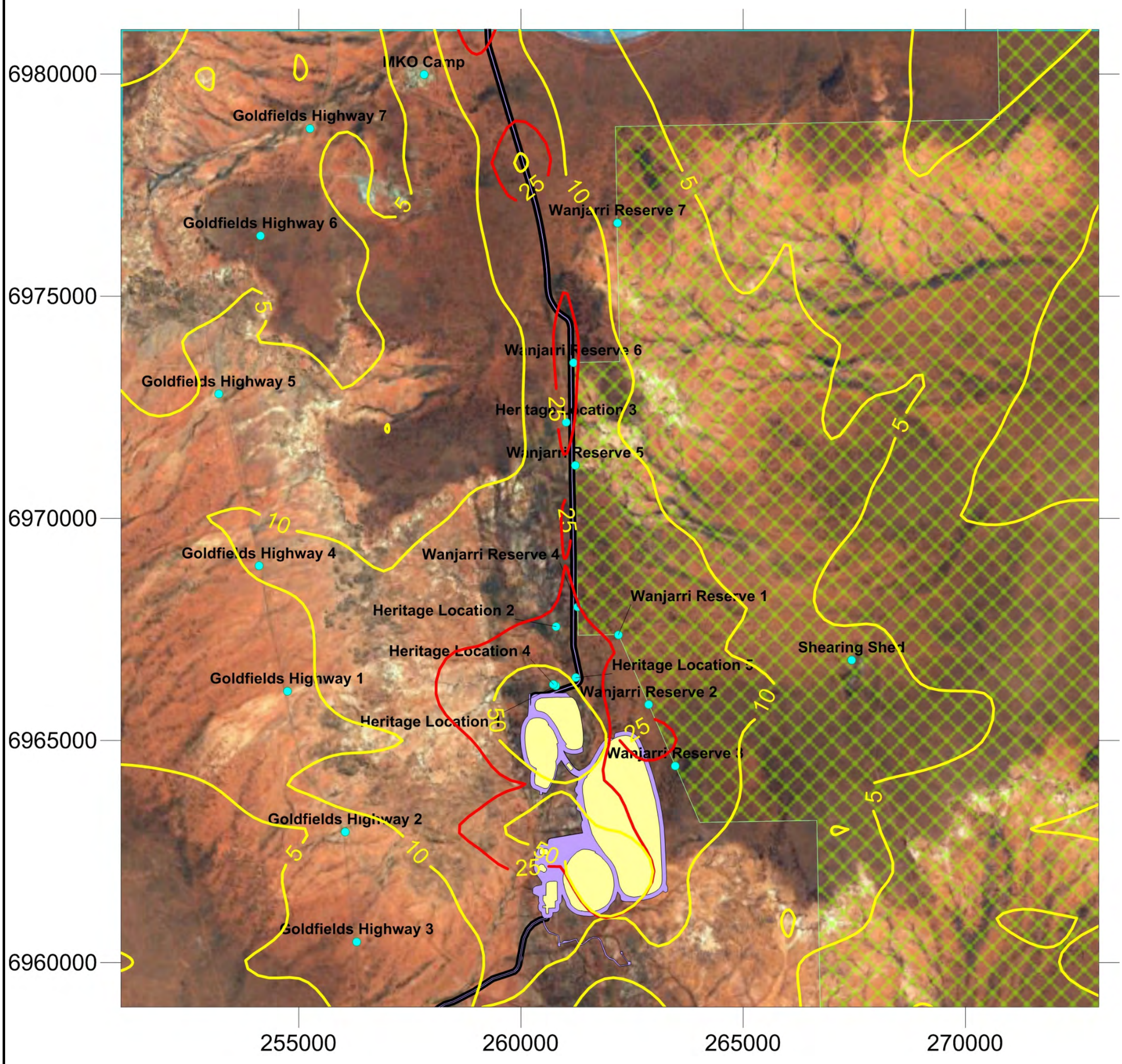

Figure 18 **Scenario 3 – PM2.5 24hr Av Predicted Conc. (µg/m³)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

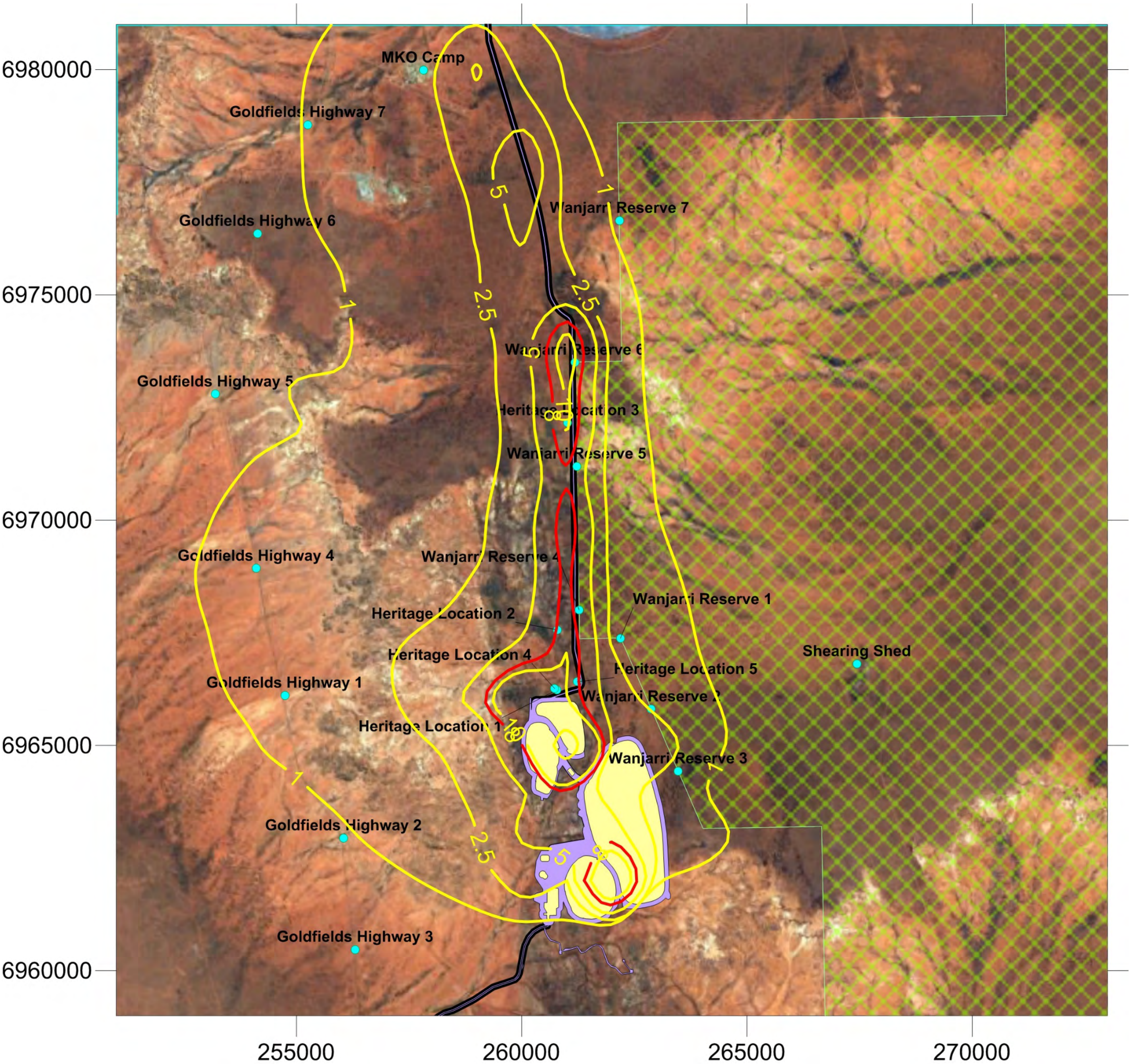

Figure 19 **Scenario 3 – $PM_{2.5}$ Annual Av Predicted Conc. (µg/m³)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

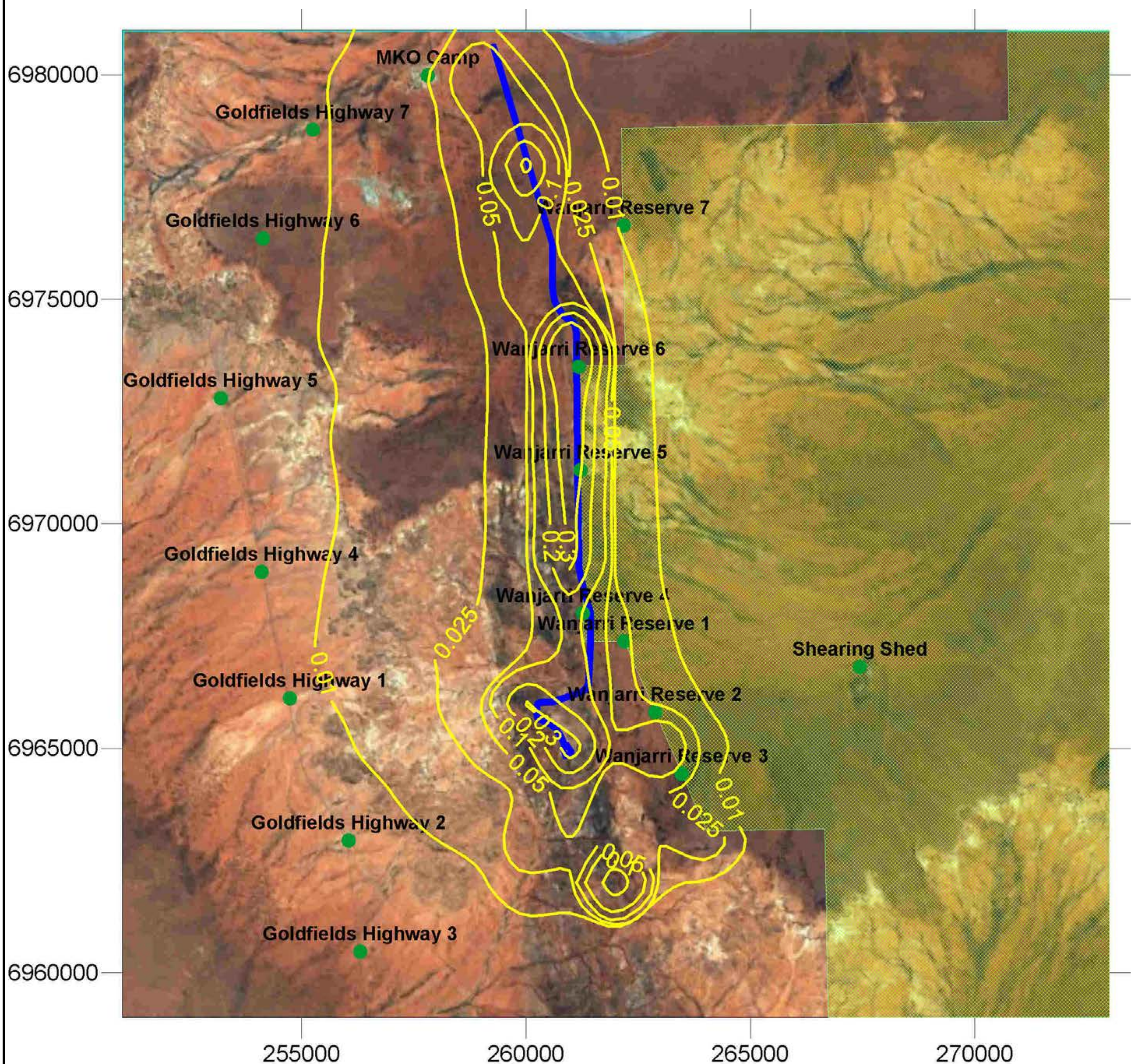

Figure 20 **Scenario 1 – TSP Predicted Deposition (g/m²/day)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

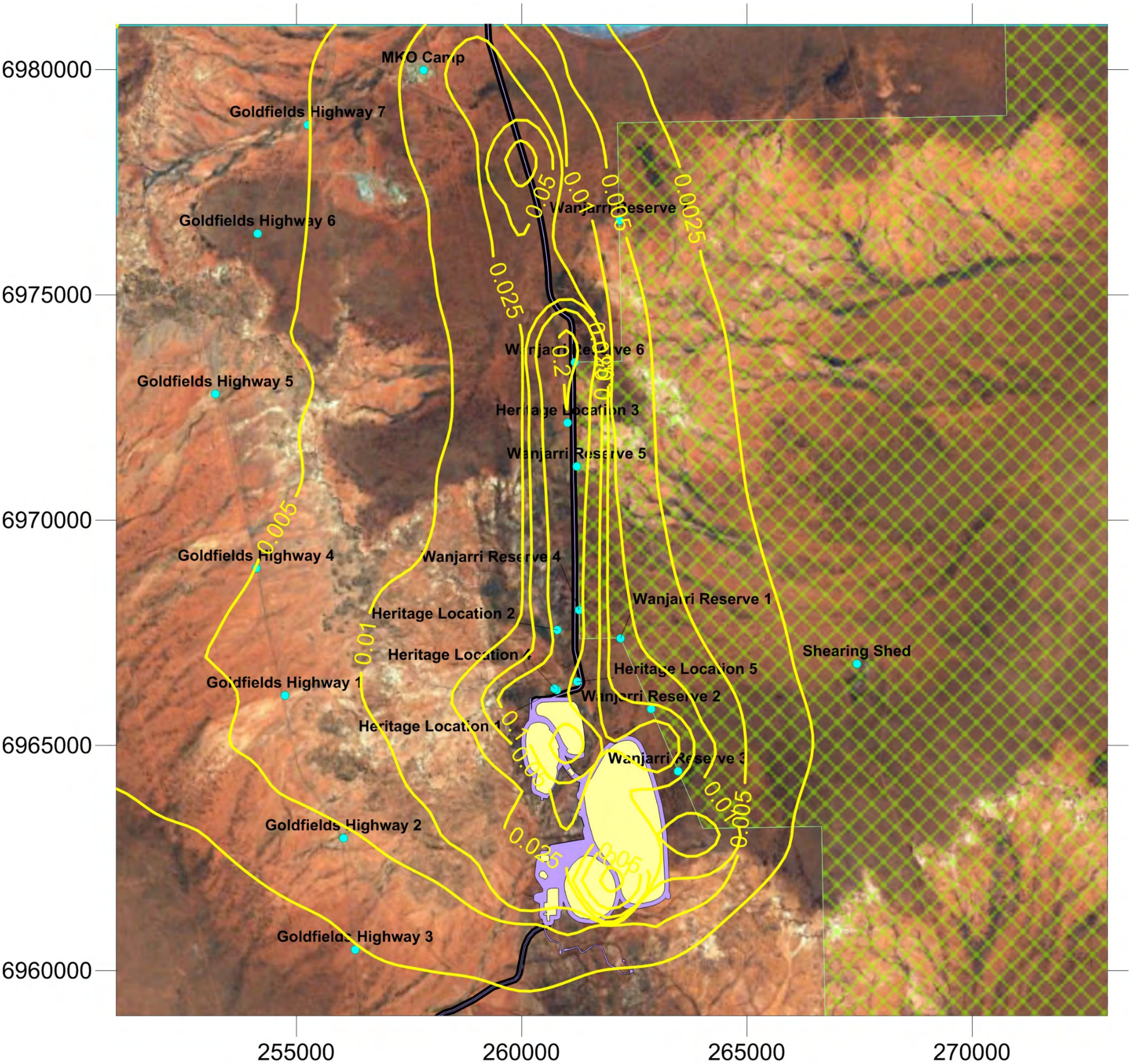

Figure 21 **Scenario 2 – TSP Predicted Deposition (g/m²/day)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

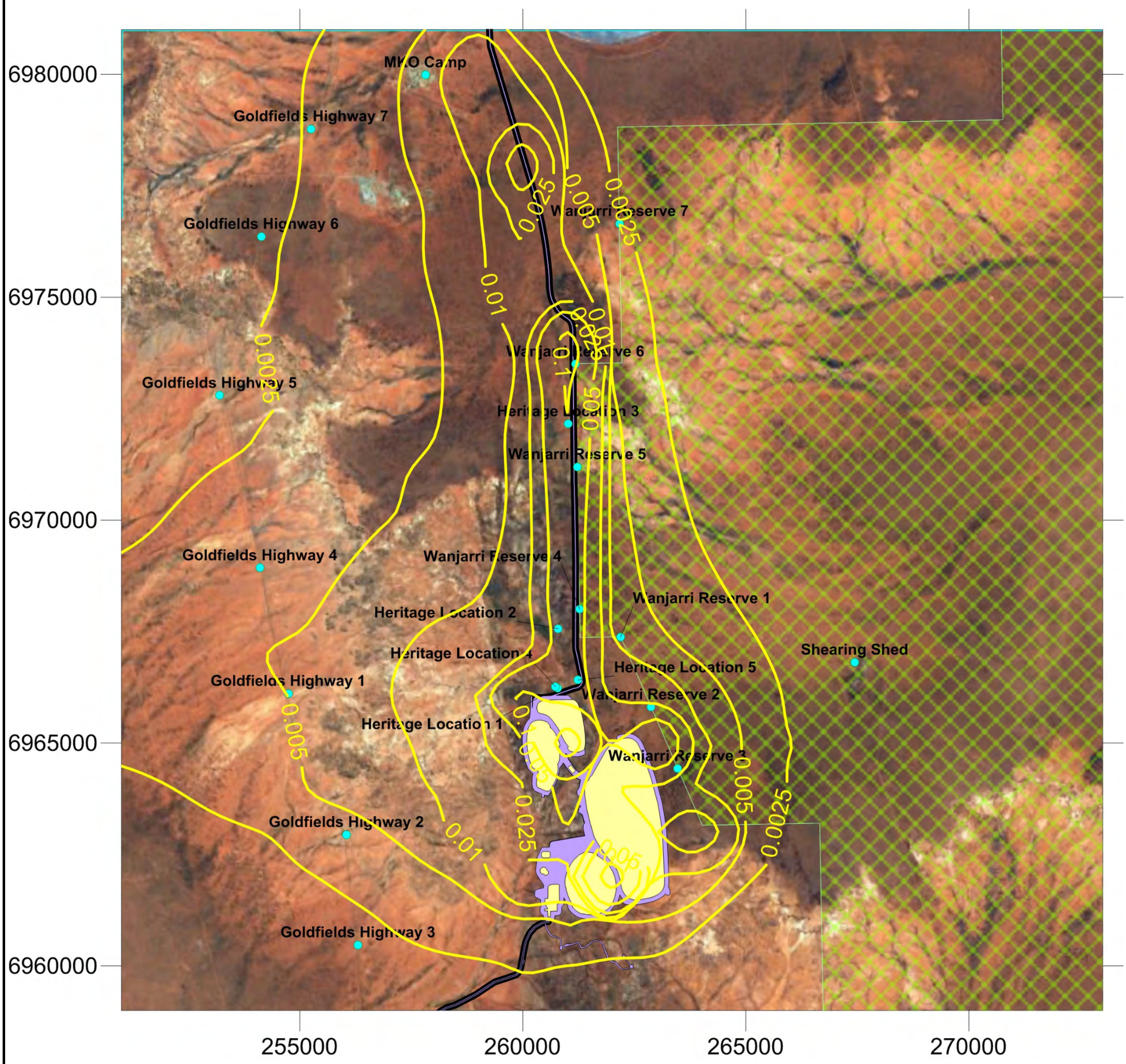

Figure 22 **Scenario 3 – TSP Predicted Deposition (g/m²/day)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

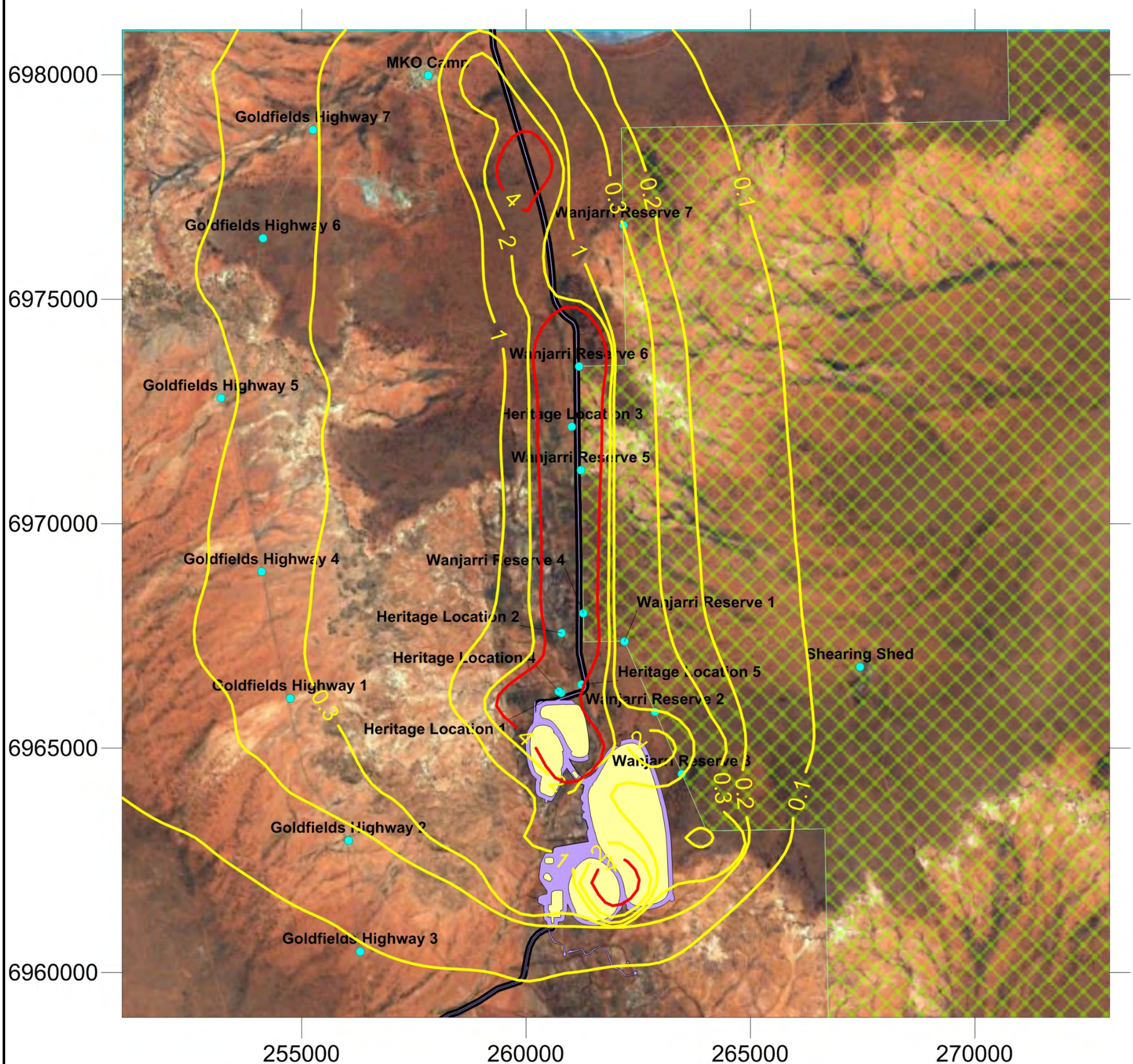

Figure 23 **Scenario 1 – TSP Predicted Deposition (g/m²/month)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

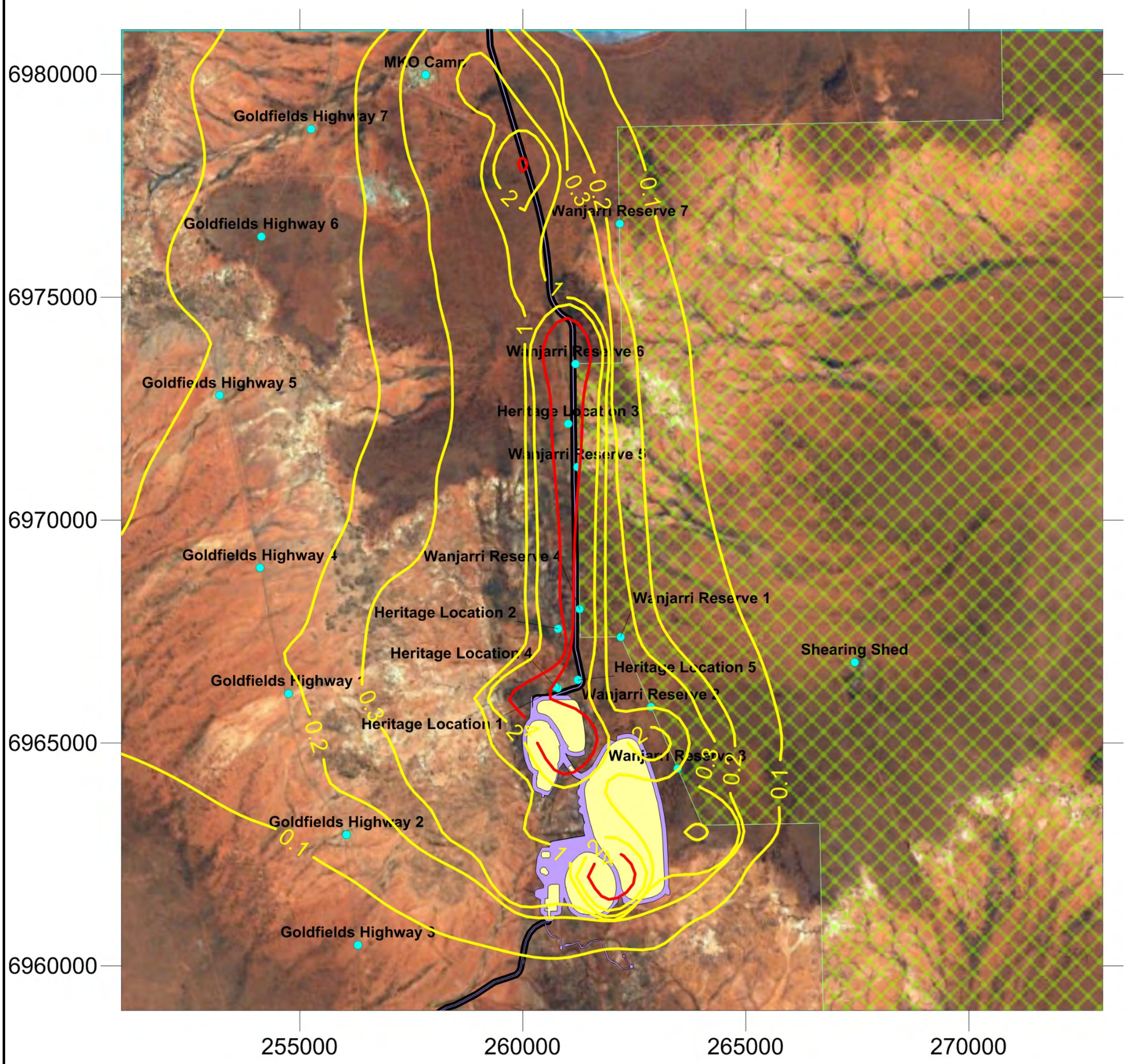

Figure 24 **Scenario 2 – TSP Predicted Deposition (g/m²/month)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017

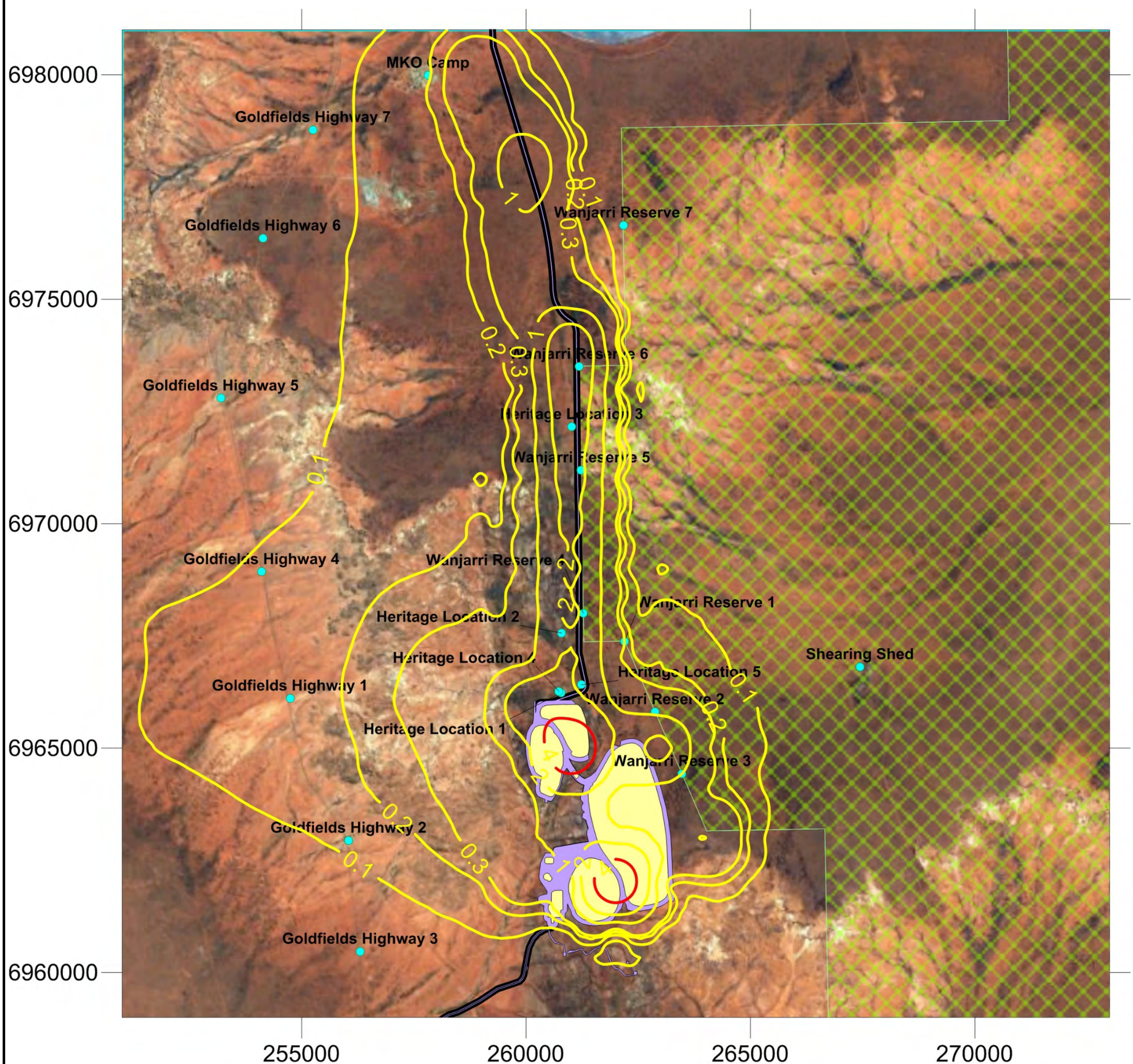

Figure 25 **Scenario 3 – TSP Predicted Deposition (g/m²/month)**	Client: BHP Billiton Nickel West Pty Ltd	RAMBOLL ENVIRON	
	Project: MKSO Dust Modelling Assessment	Source: BHP Billiton	Date: Mar 2017