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Hemerdon Mining Waste Facility

Environmental Permit Application
EPR/FB3639RK/A001

Dust Risk Assessment and Management Plan

Document Reference: Section 4B

May 2013

EXECUTIVE SUMMARY

Wolf Minerals (UK) Limited (Wolf) proposes to redevelop the existing Hemerdon wolframite and cassiterite mine at Hemerdon, 10km north east of Plymouth in Devon. The operations will comprise an open pit, processing plant and a combined tailings and mine waste management facility. The mine and processing plant will generate extractive waste, which falls under the scope of the Mining Waste Directive.

This report presents a dust risk assessment produced in support of the Environmental Permit application for the Mine Waste Facility (MWF).

The scope of this dust risk assessment is limited to consideration of the two waste streams which are:

- solid waste made up of the run of mine (ROM) waste and Dense Media Separation (DMS) rejects; and
- slurry waste which includes the gravity separation tails and froth flotation rejects.

The assessment considers potential risk as a result of airborne dust and dust deposition in terms of Air Quality Standards for the protection of health and benchmarks adopted for protection of amenity and ecological receptors.

Approach

For the purposes of environmental assessment, dust is generally categorised into two size classifications; 'suspended dust' with diameters less than 10µm (PM_{10}), and 'deposited dust' with diameters between 10µm and 75µm. The approach for assessing the potential impacts of each fraction has been undertaken separately with reference to published guidance and research.

- The assessment of suspended dust considers the potential for mine waste operations generate and release significant volumes of PM10 on the basis of published Defra guidance and sponsored research.
- The assessment of dust deposition has been undertaken using a semi-quantitative risk assessment approach, in which the probability of an impact occurring and the magnitude of the impact, if it were to occur, are considered.

Baseline Conditions and Sensitive Receptors

The land surrounding the proposed Hemerdon MWF is rural with isolated residential properties and farm buildings. Most of the 'currently' residential properties within approximately 500m of the Hemerdon Mine site boundary are subject to a Section 52 Agreement[1] and as such will be demolished or be used for site operations (offices /storage).

Areas of the surrounding moors and woods are protected habitats and include Special Areas of Conservation, Ancient Woodlands and County Wildlife Sites.

Baseline monitoring data shows:

[1] Pursuant to planning references: 9/42/49/0542/85/3, granted 1986 and 9/490405/91/3, granted 1991 and the subsequent Modification Order (Planning reference JS/SKC/A0577, issued 2010).

- measured dust deposition rates are relatively low and accord with typical levels reported for 'open country'; and
- PM_{10} concentrations are well below AQS objectives with an annual average of 21.3µg/m^3 measured at Sparkwell.

Source Term

Processes or activities associated with the MWF that may result in the generation and release of dusts include:

- haul traffic on unpaved roads;
- construction of embankment, i.e. rock unloading, compaction etc;
- wind raised dust from the embankment surface; and
- wind raised dust from the MWF surface (i.e. beached tailings).

Construction of embankment

The embankment will comprise ROM waste and DMS rejects. The ROM waste rock to be dumped is coarse but uncrushed rock. The DMS rejects (a finer granular material) are initially handled wet and will be enclosed within the coarser rock to minimise the potential for it to become a dust source once it has dried out

Wind raised dust from the embankment surface

Given the particle size distribution of the solid waste material used in the embankment construction, i.e. predominantly coarse sand and larger, there is low potential for dispersion of dusts by suspension (which affects particles of less than 0.1mm), with the most likely dispersion method being as a result of 'creep', i.e. larger particles (>0.5mm) rolling across the surface only a few meters.

Wind raised dust from the MWF surface (i.e. beached tailings)

The beached tailings will be maintained in a saturated state by progressive placement from spigots around the perimeter of the pond. Upon deposition the tailings are approximately 45% water with the long term moisture content estimated to be around 20%. The placement method provides for even placement and ensures the coarser material is beached at the perimeter of the tailings pond and the very fine material is deposited in the centre of the pond which will remain submerged in normal operating conditions. As a result, the potential dust source is largely limited to the coarser beached material.

Dust Composition

The ROM waste material is killas shale and granite (greisenised and kaolinised) and dusts associated with the ROM waste are unlikely to contain iron arsenic sulphide (arsenopyrite), and hydrated arsenic compounds in significant concentrations.

Due to the processing method, the DMS rejects may exhibit elevated concentrations of arsenic compounds and other metals in comparison to the ROM waste rock (as indicated by laboratory simulated test-work).

Dust Impact Assessment

PM_{10}

The baseline monitoring indicates that PM_{10} concentrations in the area of the MWF are well below the Air Quality Standard at 21.3µg/m^3 (annual average). On the basis of LAQM.TG(09) and given the available 'headspace' of c19µg/m^3 PM_{10} it is highly unlikely that levels of dust would exceed the Air Quality Standard, even on the conservative assumption that the installation contributed a 5µg/m^3 increase at receptor locations.

Nuisance Dust

Due to the distance, the high frequency of rainfall and the low frequency of winds affecting the receptors, the risks are judged to be insignificant at human receptor locations.

Effects of Dust on Ecological Receptors

The potential for dust impacts on sensitive ecological systems can be associated with the chemical effects of the dust and physical effects of the deposited material on plants.

From the analysis it is evident that due to their location to the north and west the Ancient Re-Planted Woodlands are likely to be affected by winds from the direction of the MWF relatively infrequently when precipitation is taken into account. Given the prevailing winds, Small Hanger Waste and Crownhill Down will be subject to winds from the direction of the site most frequently.

pH: As the waste is not considered highly alkaline or acidic, and given the stand-off distance between the beached tailings areas and the ecological receptors limiting the potential for deposition, the risk of significant effects as a result of acid or alkaline dusts is considered low.

Metals: Critical load ranges have been used, in conjunction with the tailings metal content analysis, to establish a total dust deposition rate threshold below which the risk is negligible, i.e. below the level at which there are no known effects according to present knowledge. The findings indicate that in general very high deposition rates are required to exceed the critical loads provided by the literature. The risk of dust depositing at levels likely to exceed the deposition thresholds is considered to be low

Dust Control and Mitigation Measures

The dust assessment presented in this report has been used in order to develop an appropriate Dust Management Plan (DMP) in combination with best practice guidance as follows:

- Report to The Mineral Industry Research Organisation (MIRO), Good practice guide: control and measurement of nuisance dust and PM10 from the extractive industries AEAT/ENV/R3140 Issue 1 (February 2011);
- Institute of Air Quality Management (UK) Dust and Air Emissions Mitigation Measures (2012).
- Reference Document on Best Available Techniques (BREF Note) for Management of Tailings and Waste-Rock in Mining Activities (January 2009).

The BREF note has been used to ensure that the proposed dust control and management methods represent BAT.

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1.0 INTRODUCTION

Wolf Minerals (UK) Ltd (Wolf) has retained SLR Consulting Ltd (SLR) to prepare a Dust Risk Assessment and Management Plan in support of an Environmental Permit (EP) application. The application is for a Mining Waste Facility (MWF) at the Hemerdon Mine, Devon. The mine is comprised of an open pit, processing facility, MWF and associated infrastructure; this application relates solely to the MWF.

The Hemerdon site is located within an area characterised by historic and current quarrying and mining operations. The city centre of Plymouth is located approximately 10km to the south west, with the suburban town of Plympton approximately 3km to the south west, as shown on Figure 1-1 below. There are a number of scattered farms and residential properties within 2km of the proposed site boundary in all directions, with the small villages of Yondertown, Sparkwell and Hemerdon to the southeast and south, respectively.

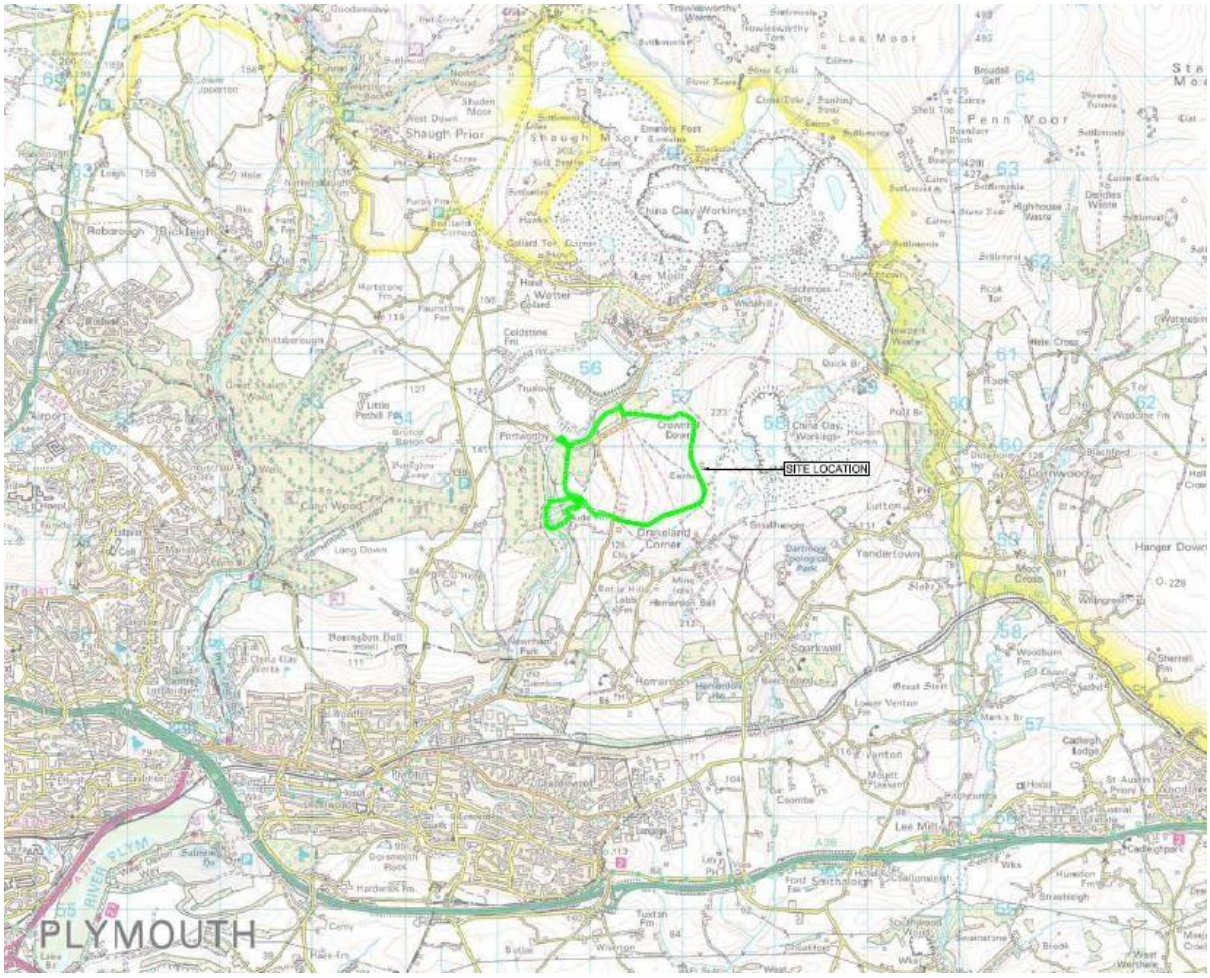

Figure 1-1
MWF and Site Location.

The MWF lies on Crownhill Down, covering an area of approximately 175 hectares extending to the lower slopes of the Tory Brook valley. Waste from the open pit will be used to progressively construct the MWF embankments with tailings (generated from the processing plant) continuously deposited and contained within the MWF. The final stage of the MWF's development is shown in Figure 1-2 below.

Figure 1-2
MWF Graphic

The site benefits from conditional Planning Permission, granted by Devon County Council (the Mineral Planning Authority) in 1986. A Modification Order was approved (January 2011) updating the planning conditions in line with legislative changes since 1986.

The wastes generated at the site are defined as extractive waste, which fall under the scope of the Mining Waste Directive (MWD), and an Environmental Permit (EP) is therefore required.

1.1 Scope of Assessment

The scope of this dust risk assessment is limited to consideration of the two waste streams which are:

- solid waste made up of the run of mine (ROM) waste and Dense Media Separation (DMS) rejects; and
- slurry waste which includes the gravity separation tails and froth flotation rejects.

The assessment considers potential risk as a result of airborne dust and dust deposition in terms of Air Quality Standards for the protection of health and benchmarks adopted for protection of amenity and ecological receptors.

1.2 Report Structure

The remainder of the report is structured as follows:

- Section 2 details the relevant guidance and environmental quality standards/benchmarks;

- Section 3 presents the dust risk assessment methodology;
- Section 4 describes the baseline environment with regard to sensitive receptors and prevailing meteorological conditions;
- Section 5 describes the dust source term;
- Section 6 presents an assessment of potential risks; and
- Section 7 sets out the dust mitigation measures.

2.0 GUIDANCE AND ENVIRONMENTAL BENCHMARKS

2.1 Environmental Permitting Regulations and Guidance

The Environmental Permitting (England and Wales) Regulations 2010 (SI 2010 No, 675) came into force on the 10th March 2010 (and have been followed by subsequent amendments). The EP Regulations transpose the Mining Waste Directive (Directive 2006/21/EC and amending Directive 2004/35/EC) which seek to prevent or reduce as far as possible any adverse effects on the environment as well as any resultant risk to human health from the management of waste from the quarrying and mineral extraction industries.

A series of guidance documents have been produced by the European Commission and Environment Agency that have been consulted in undertaking this dust assessment, these are set out in the sections below.

2.1.1 European BAT Reference Document (BREF)

The Mining Waste Directive requires that measures taken to prevent or reduce as far as possible any adverse effects on the environment are based amongst other things on best available techniques (BAT). The current European BAT Reference Document (BREF) is the '*Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities'* (2009).

2.1.2 Horizontal Guidance Notes

Horizontal Guidance Notes produced by the Environment Agency provide overarching guidance across sectors. *Horizontal Guidance Note H1 - Environmental risk assessment for permits*[2] is intended to assist operators to assess risks to the environment and human health when applying for a permit under the EP Regulations.

2.1.3 Additional guidance for mining waste operations

Additional guidance for mining waste operations[3] (EPR 6.14) describes the standards and measures expected of businesses in order to control the risk of pollution. This guidance highlights the importance of risk assessments in justifying appropriate mitigation and control measures.

2.1.4 Dust Monitoring Guidance

The Environment Agency's technical guidance document on dust monitoring around waste facilities known as M17[4] includes information on sources, abatement and exposure impacts that are of relevance to this dust assessment in addition to monitoring techniques.

[2] Environment Agency, Horizontal Guidance Note H1 - Environmental risk assessment for permits v2.1 (April 2010).

[3] Environment Agency, EPR 6.14 How to comply with your environmental permit. Additional guidance for: mining waste operations (February 2011)

[4] Environment Agency, Monitoring of particulate matter in ambient air around waste facilities. Technical Guidance Document (Monitoring) M17 (March 2004)

2.2 Further Guidance and Research

In undertaking the dust risk assessment reference has been made to guidance documents and research relevant to the minerals sector from the government and other industry bodies in addition to the Environment Agency guidance listed above.

2.2.1 Mineral Industry Research Organisation (MIRO)

The Mineral Industry Research Organisation (MIRO) published a series of documents as part of the MIRO Protodust project. The first document, the 'Good Practice Guide[5]' provides methods for reducing dust from mineral extraction and measuring dust levels in the areas around minerals sites. The second document[6] is an overview providing background information on the management, control and monitoring of dust arising from the extractive industries.

2.2.2 Technical Guidance to the National Planning Policy Framework

Whilst the National Planning Policy Framework is specific to the landuse planning process and not of direct relevance in the context of Environmental Permitting, the Technical Guidance to the NPPF[7] has been referred to for its guidance on the key stages in a dust assessment study.

2.2.3 Local Air Quality Management Technical Guidance

The core guidance documents for use by local authorities for Local Air Quality Management (LAQM), or considering the impacts of a development with the potential to impact on air quality are LAQM.TG(09)[8] and LAQM.PG(09)[9].

An Environment Agency position statement[10] clarified the role of the Environment Agency in relation to Local Air Quality management, stating:

> *'In discharging its pollution control functions, the Agency has a statutory responsibility under the Environment Act 1995 to have regard to the Government's Air Quality Strategy, including the achievement of the air quality standards and objectives'*
>
> *'The Agency has an important role to play in this process …… through the provision of information and the regulation of emissions to air from processes it regulates'.*

On this basis the guidance within LAQM.TG(09) has been referred to with regard to suspended particulate (PM_{10}).

[5] The Mineral Industry Research Organisation (2011) Good practice guide: control and measurement of nuisance dust and PM_{10} from the extractive industries. AEAT/ENV/R3140 Issue 1, (February 2011)

[6] The Mineral Industry Research Organisation (2011) Management, mitigation and monitoring of nuisance dust and PM_{10} emissions arising from the extractive industries: an overview. AEAT/ENV/R3141 Issue 1, (February 2011)

[7] Department for Communities and Local Government, 2012. Technical Guidance to the National Planning Policy Framework, (March 2012)

[8] DEFRA, Local Air Quality Management Technical Guidance LAQM.TG(09), (February 2009).

[9] DEFRA, Local Air Quality Management Policy Guidance, LAQM.PG(09) (February 2009).

[10] Position statement (July 2003) setting out the Environment Agency's policy position on air quality.

2.2.4 The Environmental Effects of Dust from Surface Mineral Workings

A Department of the Environment (DoE) sponsored study published in 1995[11] considered the environmental effects of dust from surface mineral workings. The DoE report provides extensive information about dust generation, emission, dispersion, impacts, and best management practice for the control of dust. This review considered that dust impacts from surface mineral operations were restricted to potential nuisance rather than public health impacts.

2.3 Environmental Quality Standards

2.3.1 Air Quality Standards and Objectives

The 'Air Quality Strategy for England, Scotland, Wales and Northern Ireland' (AQS) 2007, contains air quality objectives based on the protection of both human health and vegetation (ecosystems). The AQS sets out a framework for reducing hazards to health from air pollution and ensuring that international commitments are met. These objectives were set taking into account the Air Quality Standards defined in the Air Quality Standards Regulations 2007 (now superseded by the Air Quality Standards Regulations 2010).

In relation to dust the AQS includes objectives for particulate matter less than 10 microns in diameter (PM_{10}), presented in Table 2-1.

Table 2-1
UKAQS Air Quality Objectives and Standards

Pollutant	Concentration	Measured as
Particulate matter (PM_{10}) (gravimetric)	40 µg/m^3	Annual mean
	50 µg/m^3	24-hour mean (no more than 35 exceedences per year)

2.3.2 Standards for Protection of Amenity

Larger airborne particles are resident in the atmosphere for short periods of time after release as they are heavy enough to fall out of suspension in the air relatively quickly. Therefore, they do not cause long-term or wide spread changes to local air quality but their deposition on property and cars can cause soiling and dis-colouration and may therefore result in complaints through amenity loss.

There are no statutory limit values for dust deposition above which 'nuisance' is deemed to exist – 'nuisance' is a subjective concept and its perception is highly dependent upon the existing conditions and the change which has occurred. The Environment Agency's dust monitoring guidance M17[12] proposes limit values for protection against dust annoyance for different monitoring methods that are acknowledged as coming into use through 'custom and practice' rather than a robust study. A limit of 200mg/m^2/day is proposed for use with dust gauges and various complaint thresholds (e.g. 'possible complaint', 'probable complaint') for use with surface soiling measurement techniques.

[11] Department of Environment, The Environmental Effects of Dust from Surface Mineral Workings – Technical Report, Arup Environmental (1995)

[12] Environment Agency, Monitoring of particulate matter in ambient air around waste facilities. Technical Guidance Document (Monitoring) M17 (March 2004)

2.3.3 Standards for Protection of Ecological Receptors

The 'critical load' is the concept used to assess the risk of impacts on sensitive ecosystems from aerial deposition, it is defined as '*a quantitative estimate of exposure to deposition of one or more pollutants, below which significant harmful effects on sensitive elements of the environment do not occur, according to present knowledge'*.

Empirical critical loads for eutrophication (nitrogen deposition) and acidification (due to sulphur and nitrogen oxide deposition) have been developed for a range of protected habitats. These are presented on the UK Air Pollution Information System (APIS) website (www.apis.ac.uk/). However, to date, no 'critical load' estimates for dust, or metal constituents of dust have been developed within a legislative context. On this basis the assessment of potential impacts is undertaken with reference to available published research (further discussion is provided in Section 6.0).

3.0 METHODOLOGY

For the purposes of environmental assessment, dust is generally categorised into two size classifications; 'suspended dust' with diameters less than 10µm (PM_{10}), and 'deposited dust' with diameters between 10µm and 75µm. The impacts associated with deposited dust are related to potential nuisance effects whilst for PM_{10} air quality standards exist. The approach for assessing the potential impacts of each fraction has been undertaken separately.

3.1 Suspended Dusts

The assessment of suspended dust considers the activities on site in relation to mine waste management with the potential to release or generate significant volumes of PM_{10}, the existing levels of PM_{10} in the local area, and the proximity of communities and other sensitive receptors. The potential for the operations to increase ambient particulate concentrations above the relevant AQS objectives is then assessed.

Baseline PM_{10} concentrations in the study area have been derived from the site specific monitoring undertaken by Wolf Minerals and estimated concentrations provided on a 1km by 1km grid by DEFRA.

An approach is detailed within the Local Air Quality Management technical guidance LAQM.TG(09)[13] (Box 5.10) for the assessment of dust emissions from fugitive and uncontrolled sources. The initial phase of the assessment establishes whether there is relevant exposure "near" to the source(s) of emissions. Relevant exposure is identified as "near" as follows:

- 50m from off-site access roads where background PM_{10} concentrations are >25 µg/m^3;
- 1000m for a background PM_{10} level >28 µg/m^3;
- 400m for a background >26 µg/m^3; and
- 200m for any background concentration.

With regard to the likely contribution of quarries to local PM_{10} levels, research undertaken by the University of Newcastle upon Tyne and endorsed by COMEAP (known as The Newcastle Research[14]) concluded that the average daily PM_{10} level was 2µg/m³ higher at opencast sites than at the control sites.

To ensure a robust assessment of worst case emissions of PM_{10} from the site operations, a higher value of 5µg/m^3 has been used to represent the development contribution to annual ambient PM_{10} concentrations. This value is then added to the existing background level to determine whether the AQS is likely to be exceeded during the proposed operations

3.2 Deposited Dust (Nuisance)

The methodology applied in the assessment is a semi-quantitative risk assessment approach, in which the probability of an impact occurring and the magnitude of the impact, if it were to occur, are considered.

The distance from the source to the sensitive receptor is crucial. Research indicates that particles of >30µm which make up the greatest proportion of dust emitted from minerals sites

[13] DEFRA 2009. Local Air Quality Management. Technical Guidance LAQM.TG(09)

[14] Newcastle Research on Health Effects from Particulates. Do particulates from opencast coal mining impair children respiratory health? 1999 University of Newcaslte upon Tyne

will deposit within 100m, and particles of <30µm but >10µm may travel 250 to 500m[15]. To allow for this effect of distance, buffer zones are often defined by mineral and waste planning authorities around potentially dusty activities to ensure that sufficient protection is provided. The 1995 DoE Guidance[16] recommended a stand-off distance of 100-200m from significant dust sources (excluding short-term sources), although it is recognised that these distances can be reduced if effective mitigation measures are identified and implemented.

On the basis of this research, receptors located within 500m of the site are identified and a selection made to represent isolated dwellings or settlements as appropriate. This initial screening may be regarded as a 'tier 1 assessment' and if there are no residences within this distance no further assessment is required.

If there are receptors located within 500m of the site, a Tier 2 (semi-quantitative) assessment is required. This approach provides a mechanism for identifying the areas where mitigation measures are required and for identifying mitigation measures appropriate to the risk presented by the development.

The magnitude of the potential risk at each receptor is classified depending on the frequency of exposure and the distance from the site to the receptor.

The screening assessment tool assesses the significance of the distance from site and the frequency of exposure of each receptor by assigning a ranked number. Receptors with a higher potential for dust impacts would therefore result in a higher value whilst receptors with lower potential would expect to carry a lower value. The value corresponding to an evaluation of risk is a product of the significance of the distance and frequency of exposure, each assigned a value representing its significance. The multiplication of the two values assigned gives a total, which is then corresponded to a qualitative term of risk magnitude.

3.2.1 Frequency of Exposure Criterion

The potential for any site to emit dust is greatly influenced by weather. Increased wind speed increases the potential for the generation of airborne dust due to the suspension and entrainment of particles in airflow. A worst case situation would be strong, warm, drying winds which increase the rate at which dust is lifted from an untreated surface and emitted into the air. Wind can also have the effect of spreading dust over a large area. Conversely, rainfall decreases dust emissions, due to both surface wetting and increasing the rate at which airborne dust is removed from air. Research[17] suggests that rainfall of greater than 0.25mm per day is considered sufficient to effectively suppress wind blown dust emissions.

The frequency of exposure to dust emissions represents the percentage of time that wind speeds capable of carrying airborne dust (greater than 3.1m/s) are blowing from the site to the direction of the receptor. The frequency of exposure at this point would provide an overestimate or risk given that during days of rainfall no dust emissions would occur despite wind speed values.

For the screening assessment, a value of 1mm would be used for the criteria to classify days as 'dry' or 'wet'; four times the recommended value, using annual average rainfall data. The

[15] Arup, The Environmental Effects of Dust at Surface Mineral Workings. (Report to the DETR 1995)

[16] Based upon research document - DETR, The Environmental Effects of Dust from Surface Mineral Workings (Dec 1995)

[17] US-EPA, AP-42, Section 13.2.2 states '*annual average emissions are inversely proportional to the number of days with measurable (more than 0.254 mm [0.01 inch]) precipitation*'

average number of days when rainfall exceeds 1mm is calculated over the year to provide an average.

The resulting frequency of moderate to high wind speeds with the potential of carrying airborne dust towards receptors is then classified into the criteria in Table 3-1 with the respective rank value assigned.

Table 3-1
Likelihood of Occurrence

Risk Category	Criteria
1	Frequency of winds (>3.1m/s) from the direction of the dust source on dry days are less than 3%
2	The frequency of winds (>3.1m/s) from the direction of the dust source on dry days are between 3% and 6%
3	The frequency of winds (>3.1m/s) from the direction of the dust source on dry days are between 6% and 9%
4	The frequency of winds (>3.1m/s) from the direction of the dust source on dry days are between 9% and 12%
5	The frequency of winds (>3.1m/s) from the direction of the dust source on dry days are between 12% and 15%
6	The frequency of winds (>3.1m/s) from the direction of the dust source on dry days are greater than 15%

3.2.2 Distance to Source Criterion

In assessing dust impacts, the distance from the source to the sensitive location is crucial, as airborne and deposited dust tend to settle out close to the emission source. Smaller dust particles remain airborne for longer, dispersing widely and depositing more slowly over a wider area.

The criteria for classifying the distance from receptor to source and thus assigning a rank value has been based on the various references to dust behaviour described above[18]. The rank classifications are presented below in Table 3-2.

Table 3-2
Distance to Source

Risk Category	Criteria
1	Receptor is more than 500m from the dust source
2	Receptor is between 300m and 500m from the dust source
3	Receptor is between 200m and 300m from the dust source
4	Receptor is between 100m and 200m from the dust source
5	Receptor is between 50m and 100m from the dust source
6	Receptor is less than 50m from the dust source

[18] A risk category is maintained for receptors in excess of 500m for circumstances where although a receptor is beyond 500m from the dust source, its sensitivity for example is seen sufficient enough for it to be taken onto a Tier 2 assessment. For example, a painting industry located at 510m from the boundary.

3.2.3 Evaluation of Risk

Once a rank value has been assigned to the frequency of exposure and distance to source, an overall risk can be evaluated by combining the two risk categories, along with consideration of the sensitivity of the receptor. For low sensitivity receptors the risk of dust impact are considered to be significantly lower than for medium and high sensitive receptors. Therefore a factor of 0.5 would be applied to the final risk evaluation ranking.

For each receptor, the relative magnitude of risk is given by identifying which of the score categories in Table 3-3 it falls into. This final evaluation represents the risk of dust impacts with current control and mitigation measures being employed on site.

Table 3-3
Risk Evaluation Ranking

Magnitude of Risk	Score
Insignificant	6 or less
Acceptable	8 to 12
Requires Further Mitigation	15 or more

4.0 BASELINE CONDITIONS AND SENSITIVE RECEPTORS

4.1 Site Setting

The proposed Hemerdon MWF is located within an area characterised by historic and current quarrying and mining operations, in particular on land to the north and north east.

The city centre of Plymouth is located approximately 10km to the south west of the proposed boundary, with the suburban areas of Plympton, Chaddlewood, Woodford, Longbridge and Leigham extending to approximately 2km south west of the proposed boundary.

The land surrounding the proposed Hemerdon MWF is rural with isolated residential properties and farm buildings. Most of the 'currently' residential properties within approximately 500m of the Hemerdon Mine site boundary are subject to a Section 52 Agreement[19] and as such will be demolished or be used for site operations (offices /storage). Areas of the surrounding moors and woods are protected habitats and include Special Areas of Conservation, Ancient Woodlands and County Wildlife Sites.

The sections below describe the receptor locations included in the assessment on the basis of H1 and other regulatory guidance.

4.2 Sensitive Receptors

Air quality objectives should apply to all locations where members of the public may be reasonably likely to be exposed to air pollution for the duration of the relevant objective. Longer term objectives such as the 24-hour or annual mean for PM_{10} should apply only at houses or other locations which the public can be expected to occupy on a continuous basis. These objectives do not apply to exposure at the workplace and should not apply to footpaths or other locations where members of the public are likely to be exposed for only a short period of time.

In relation to nuisance dust, locations with a high sensitivity to dust include hospitals and clinics, hi-tech industries, painting and furnishing and food processing. Locations classed as being moderately sensitive include schools, residential areas and food retailers. Table 4-1 below[20,21] shows examples of dust sensitive facilities.

Table 4-1
Dust Sensitive Receptors

High Sensitivity	Medium Sensitivity	Low Sensitivity
Hospitals and clinics Retirement homes Hi-tech industries Painting and furnishing Food processing	Schools and residential areas Food retailers Greenhouses and nurseries Horticultural land Offices	Farms Light and heavy industry Outdoor storage

The location of the sensitive receptors within 500m and the distances and direction of these receptors from the application site are shown in Drawing H1a and summarised below in Table 4-2. Drawing H1a identifies those 'current' receptors that are subject to the Section 52

[19] Pursuant to planning references: 9/42/49/0542/85/3, granted 1986 and 9/490405/91/3, granted 1991 and the subsequent Modification Order (Planning reference JS/SKC/A0577, issued 2010).

[20] Ireland M. (1992) "Dust: Does the EPA go far enough?", Quarry Management, pp23-24.

[21] ARUP (1995). *The Environmental Effects of Dust from Surface Mineral Workings*. Report on behalf of DEFRA. (HMSO), Environmental/Ove Arup & Partners.

Agreement which therefore have been excluded from the dust risk assessment on the basis that they not be present, all remaining dust sensitive receptors have been considered.

Table 4-2
Sensitive Receptor Locations

ID	Receptor	Type	Sensitivity to Dust	Distance from potential dust source (m)	Direction from potential dust source (˚)
DR1	Scrap Yard	Industrial	Low	550	185
DR2	Portworthy	Residential	Medium	340	305

Table Note: Distance and direction are given to potentially significant dust sources, not the installation boundary.

The H1 Guidance Note[22] states that ecological habitats should be screened against relevant standards if they are located within the following set distances from the facility:

- Special Protection Areas (SPAs), Special Areas of Conservation (SACs) or Ramsar sites within 10km of the installation; and
- Sites of Special Scientific Interest (SSSIs), National Nature Reserves (NNR), Local Nature Reserves (LNR), local wildlife sites and ancient woodland within 2km of the installation.

Relevant designated sites to this assessment are presented in Table 4-3.

Table 4-3
Nature Conservation Sites

Location	Name / Type	Terrestrial Habitat Information
SX710701	South Dartmoor Woods (SAC)	Old sessile oak woods with Ilex and Blechnum European Dry Heaths
SX590864	Dartmoor (SAC)	Northern Atlantic wet heaths with Erica tetralix European Dry Heaths Blanket Bogs Old sessile oak woods with Ilex and Blechnum
SX472506	Plymouth Sound and Estuaries (SAC)	Suppralittoral Rock (Shore Dock) Atlantic Salt Meadows Estuaries (Saltmarsh) Mudflats and Sandflats
SX552594	Fernhill Wood (AW)	APIS habitat type - Broad-leaved deciduous woodland
SX559598	Hooksbury Wood (AW + LWS)	APIS habitat type - Broad-leaved deciduous woodland
SX565605	Coleland Wood (AW)	APIS habitat type - Broad-leaved deciduous woodland
SX577592	Headon Down (LWS)	APIS habitat type - Dwarf Shrub Heath
SX572590	Small Hanger Waste (LWS)	APIS habitat type - Dwarf Shrub Heath
SX572596	CrownHill Down (LWS)	APIS habitat type - Dwarf Shrub Heath

4.3 Meteorological Conditions

The key factors determining the release of particulate of any given particle size from surface mining sites is the frequency and volume of rain and the frequency and strength of winds.

[22] Horizontal Guidance Note H1 – Annex (f), Environment Agency, 2010.

4.3.1 Wind patterns

The meteorological data provider was consulted for the most appropriate data set for the area. The closest meteorological station with detailed wind data is at Plymouth, 10km to the south west. Data covering the period 2004 to 2008 (end) is presented in the windrose below, showing the frequency of wind speed and direction.

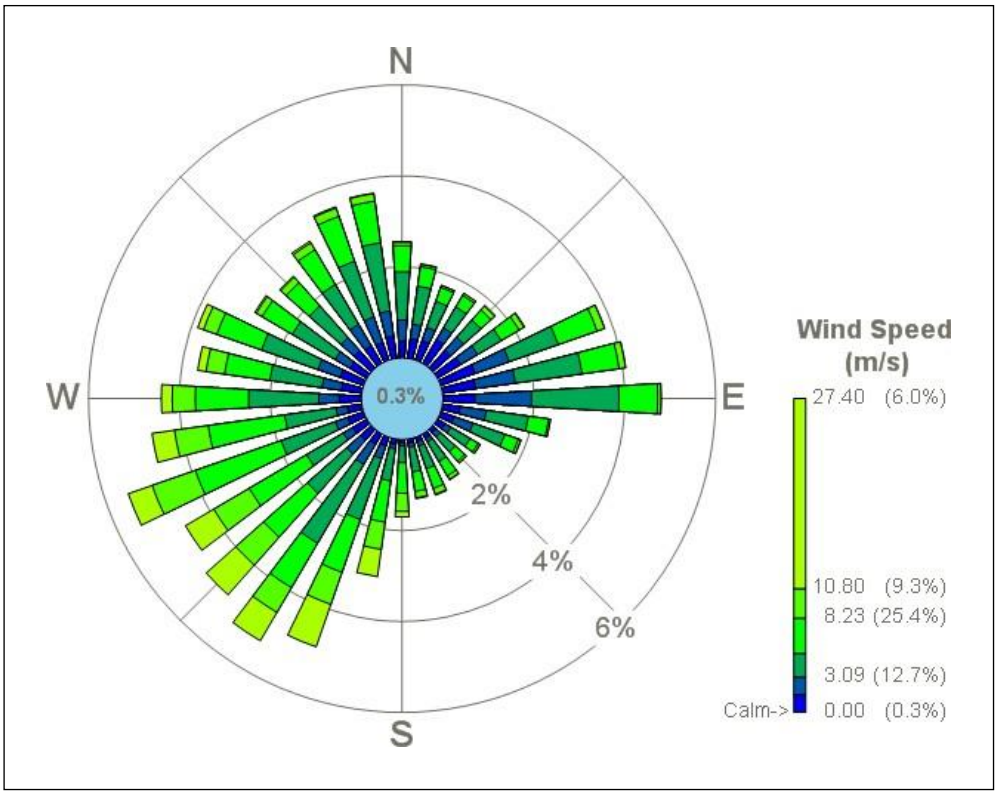

Figure 4-1
Windrose for Plymouth Mountbatten Meteorological Station (2004 – 2008)

It can be seen that there is a strong south westerly component. Medium to strong winds (greater than 3.1m/s) from the south west quarter (180º to 270º) account for approximately 32% of the hours in the year, however these prevailing 'tropical maritime' winds are those most frequently associated with rainfall. Winds from the north western quarter account for approximately 19% of total winds with winds from the south east being the least frequent to occur.

4.3.2 Precipitation

The average annual rainfall at Hemerdon according to the Centre for Ecology and Hydrology Flood Estimation Handbook is 1,326mm[23]. Average rainfall data (1971 – 2000) obtained for the area from the Meteorological Office website indicates that the average number of rainfall days per year is between 151 and 162 (days with rainfall >1mm), i.e. approximately 43%.

[23] FEH CD-ROM v3. Flood Estimation Handbook. Centre for Ecology and Hydrology, (2009)

Table 4-4
Rainfall Data

	Rainfall Range (mm)	Days of Rainfall Range (≥1mm)
Jan	160-220	17.0-18.0
Feb	120-160	13.5-14.5
Mar	110-150	13.0–14.0
Apr	80-100	10.5–11.0
May	65-80	10.5–11.0
Jun	80-100	9.5-10.5
Jul	70-90	8.5-9.5
Aug	80-100	10.0-11.0
Sep	110-140	11.5-12.5
Oct	140-180	14.0-15.0
Nov	140-180	16.0 -17.0
Dec	160-220	17.0-18.0
Annual	1200-1400	151.0-162.0

Table Note: Data taken from Regional mapped climate averages (www.metoffice.gov.uk/)

4.4 Baseline Air Quality

4.4.1 PM_{10}

Monitoring Data

The UK Automatic Urban and Rural Network (AURN) is a country-wide network of air quality monitoring stations operated on behalf of Defra. The closest monitoring station is located at Plymouth Centre. This monitor is classified as an 'urban background' and therefore will not be representative of the application site given its rural setting.

The majority of monitoring undertaken by South Hams District Council (SHDC) is concentrated about the population centres of Kingsbridge, Totnes, Ivybridge and Dean Prior (on the A38). Due to the distance from the installation these stations are not suitable for use to characterise the local air quality in the vicinity of the installation. However, automated (real-time) monitors have recently been located to the south and east of the installation to monitor combustion emissions from the Langage Combined Cycle Gas Turbine Power station.

The most recent published[24] results from the real-time monitor located in Sparkwell (which is approximately 1.4km to the south east) are presented in Table 4-5. No exceedences of air quality objectives were reported in 2011.

Table 4-5
Sparkwell Automated Monitor (µg/m^3)

	Objective	2011 Monitoring Results
PM_{10}	Annual mean	21.3 ^{3}
	24-hr mean	8 exceedences of 50µg/m 24-hour mean

A 3-month monitoring survey for PM_{10} commissioned by Wolf Minerals was completed between 29th July and 3rd November 2011 at Birchlands Farm. The reported findings state: '*a mean value of 13µg/m^3 (micrograms per cubic metre) was recorded for the period within a*

[24] 2012 Air Quality Updating and Screening Assessment for South Hams District Council (May 2012)

range between 3µg/m^3 and 35µg/m^3. As such there were no exceedences of the daily NAQS Objective for PM$_{10}$ during the 3 month duration of this phase'[25]. The monitoring results show a fair agreement with the Defra background of 12.4µg/m^3 as detailed below.

Defra Backgrounds

Background pollutant concentrations have been obtained from Defra UK Background Air Pollution Maps. These 1km grid resolution maps are based upon a 2010 base year verified against monitored concentrations from a large number of automatic monitoring stations across the Country with projection factors provided for future years. The annual mean PM$_{10}$ concentrations for the grid squares within 1km of the installation for 2013 are presented in Table 4-6 below.

Table 4-6
Estimated Annual Mean PM$_{10}$ Concentrations (µg/m^3)

Y	X	254500	255500	256500	257500	258500
61500		12.7	13.1	14.3	14.7	15.1
60500		12.8	12.9	14.2	17.5	15.0
59500		12.5	12.1	14.3	14.5	13.8
58500		12.7	12.4	12.2	12.4	12.3

4.4.2 Dust Deposition

Dust deposition monitoring was commissioned by Wolf Minerals at receptor locations in the vicinity of the installation. The monitoring programme ran between 12/08/2011 and 29/02/2012. A summary of reported[25] mean deposition levels is presented in Table 4-7.

Table 4-7
Dust deposition Rate

Location	12/08/2011 – 29/02/2012 Mean (mg/m^2/day)
Old Newnham Farm	23
Bude Farm House	24
Birchlands Farm	24
Bottle Hill Cottage	40
Mumford Cottage	34

The measured dust deposition rates are relatively low and accord with typical levels reported for 'open country'[26].

[25] Advance Environmental, Assessment of baseline dust and particulate matter in the vicinity of Hemerdon Tungsten Mine for Wolf Minerals Limited (February 2012)

[26] Good Practice Guide: Control and Measurement of Nuisance Dust and PM$_{10}$ from the Extractive Industries. Minerals Industry Research Organisation, (2011.)

5.0 SOURCE TERM

5.1 Description of Processes

The descriptions of processes in the sub-sections below relate to the waste management processes only and as such relate to the use of solid waste to construct the MWF embankment and the handling of slurried waste (tailings).

Figure 5-1 below provides a 'high level' process flow sheet for the proposed mining operations and Figure 5-2 illustrates the waste movements.

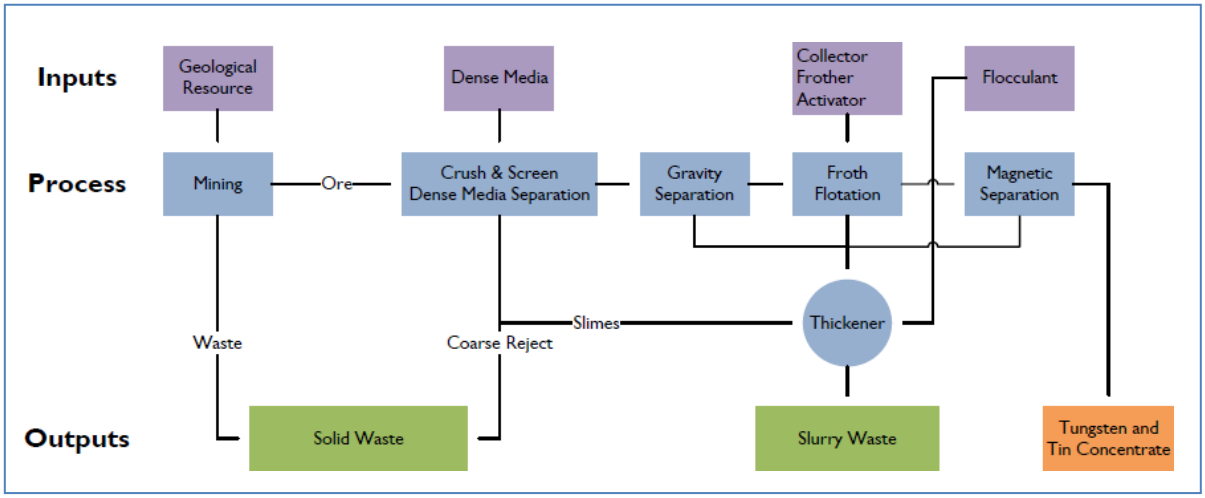

Figure 5-1
High Level Process Flow Sheet

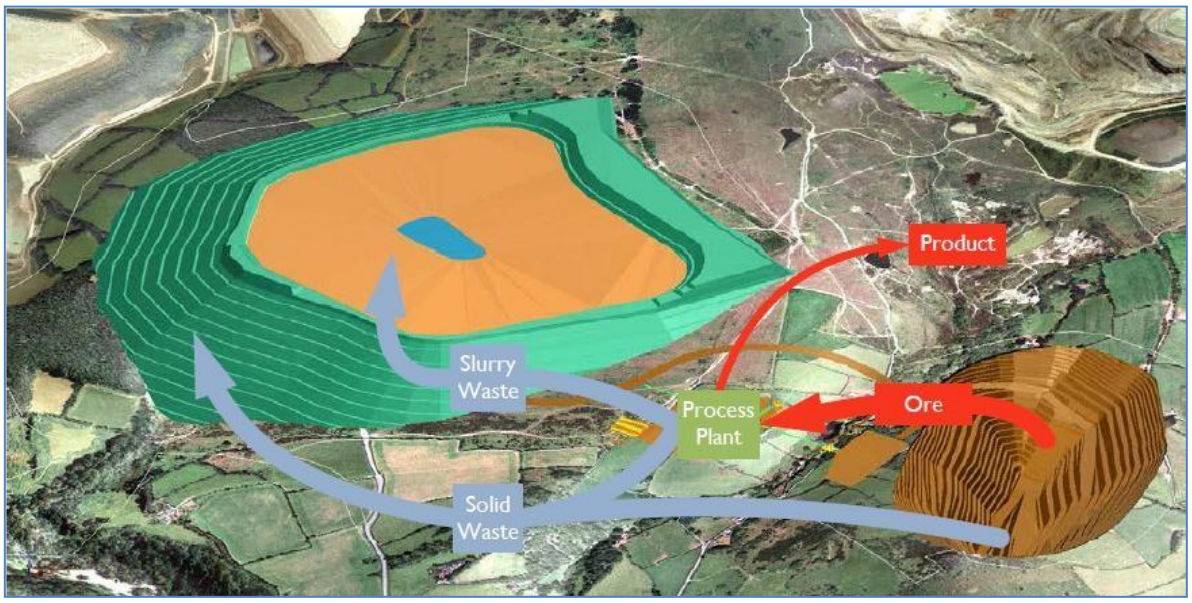

Figure 5-2
Conceptual Model of Waste Movement

5.1.1 Construction of MWF - Solid Waste Embankment

The mine waste (incorporating Run of Mine (ROM) waste and dense media separation (DMS) flotation rejects) will be used to construct the mine waste facility (MWF) embankment.

The fine tailings residues disposal area will be encapsulated by engineered containment embankments and engineered waste rock storage. Containment of the fine residues will require a zoned embankment construction, which will be raised to final height in a series of stages;

Zone A is an inner compacted zone (comprising roller compacted clayey mine waste (soft granite and/or Killas/clayey borrow fill). Zone B is an internal downstream zone located adjacent to Zone A comprising traffic compacted selected mine waste, 12m to 15m wide (soft granite and/or Killas), with a 1.0m compacted lift thickness. Zone B provides strength and a buttress to the low permeability upstream zone. This Zone is supported by Zone C.

Zone C will be constructed using traffic compacted general mine waste (DMS rejects, Killas, hard granite and others), with a 1.5m compacted lift thickness which provides bulk, strength and a buttress to the inner two zones.

The ROM waste, that is the rock surrounding the ore, is mostly oxidised and fresh killas slate and a smaller proportion of kaolinised and fresh granite. The run of mine waste will range in size from primarily gravel and cobble within a sandy silty matrix through to boulders in excess of 1m. This material is largely non-mineralised and testwork has been conducted on samples of killas close to the main mineralised zone to confirm this. The ROM waste will be transported to the MWF using 50t to 80t mine trucks.

The DMS flotation reject is kaolinised and fresh granite that is non-mineralised. It has been crushed and screened to be in the size range >0.5mm to <9.5mm. The DMS rejects will be transported to the MWF using 50t to 80t mine trucks.

5.1.2 Tailings (slurry waste) Handling

Tailings slurry will be pumped from the processing plant to the MWF via an overland pipeline. At the MWF, the tailings line will split into two lines to form a slurry deposition ring main located around the perimeter of the MWF.

The gravity circuit rejects and the froth flotation rejects will be slurried to 55 – 60% solids (w/w) and pumped to the MWF.

The following operating considerations have been incorporated into the design of the MWF options:

- the tailings deposition pipeline will be installed around the full circumference of the facility to allow tailings deposition at any desired location. Deposition will be undertaken simultaneously from several opened spigots to promote low velocity discharge;
- slurried tailings will be discharged simultaneously from adjacent spigots using the sub-aerial method where the discharge is exposed to air, (not under water). The location of the open discharge points are moved in a methodical manner, on an ‘as required’ basis, to ensure there is an even development of sloped tailings beaches to the decant area. The deposition regime is aimed at maintaining the water pond adjacent to and around the decant structure;
- sloped tailings beaches are developed due to the change in velocity at the discharge point such that due to a reduction in velocity the coarser fraction of the tailings solids

settle out near the discharge point. Further away from the discharge point smaller sized particles drop out of suspension with the finest materials (usually clay sized materials) being located near the decant;

- tailings discharge will be sequenced such that the water pond is maintained around the decant structure; and
- the top surface of the tailings storage will assume the form of an inverted truncated prism. The facility could contain a considerable body of water following a precipitation event (i.e. rainstorm or following snow melt). The minimum operational freeboard will be maintained at 0.5m. The total freeboard above 'normal' pond level should be 1m.

5.2 Dust Sources

Processes or activities associated with the MWF that may result in the generation and release of dusts include:

- haul traffic on unpaved roads;
- construction of embankment, i.e. rock unloading, compaction etc;
- wind raised dust from the embankment surface; and
- wind raised dust from the MWF surface (i.e. beached tailings).

5.2.1 Haul Roads

Haul roads have been found to account for the majority of dust emissions from mining operations[27,28,29,30]. The United States Environmental Protection Agency's (EPA) emissions factors (known as AP42) for unpaved haul roads has shown that haul trucks generate approximately 78%-97% of total dust emissions from a surface mining site.

There is therefore a clear advantage which can be gained from effective mitigation of haul road dust and the methods required are neither costly nor labour intensive, particularly for a site such as Hemerdon with a high annual rainfall.

Emissions from the haul roads are minimised through:

- regular maintenance (including grading);
- limiting vehicle speeds; and
- use of watering systems (bowsers / water truck).

These methods are highly effective at minimising dust release from the site haul roads with the use of water likely to provide a substantial reduction in emissions of dust and PM_{10}. Revised estimates within AP42 indicate that watering haul roads may reduce particle emissions by up to 97%. A reduction of >95% is therefore realistic for watered haul roads, based on routine watering at regular intervals[31].

[27] W.R. REED AND J.A. ORGANISCAK. (2008) Haul Road Dust Control Fugitive dust characteristics from surface mine haul roads and methods of control

[28] Subrato Sinhaa, S.P. Banerjee (1997) Characterization of haul road dust in an Indian opencast iron ore mine Atmospheric Environment. Volume 31, Issue 17, September 1997, Pages 2809–2814

[29] Gillies, J.A., V. Etyemezian, H. Kuhns, D. Nikolic, D.A. Gillete, (2005). Effect of Vehicle Characteristics on Unpaved Road Dust Emissions. Atmospheric Environment, 39, 2341- 2347.

[30] Williams, D.S., Manoj, K.S., Ross, J., (2008) Particulate Matter Emission by a Vehicle Running on Unpaved Road. 2008. Atmospheric Environment, 42, 3899-3905.

[31] *Reed et al* indicates that wetting haul roads has been demonstrated to have a significant mitigation effect for over 3 hours dependent upon ambient conditions.

5.2.2 Construction of embankment

The ROM waste rock to be dumped is coarse but uncrushed rock and may range in size from gravel and fines through to boulders in excess of 1m diameter. Standard mitigation for rock dumping points is the application of water to limit dust as necessary.

The DMS rejects is a finer granular material in the size range >0.5mm to <9.5mm. It is collected wet from the process and should not generate dust during transport or dumping.

5.2.3 Wind raised dust from the embankment surface

The ROM waste will range in size from gravel and fines through to boulders, as a result there is the potential for fine (e.g. <silt sized) particles to be entrained with the bulk rock. However given the extraction method, i.e. hydraulic excavator with transport by mine truck, the proportion of very fine material in each initial load is likely to be very low.

The DMS rejects (particle size range of >0.5mm to <9.5mm, i.e. coarse sand to gravel), will have been subject to a de-slime process prior to leaving the processing plant, consequently the proportion of very fine material is limited (the slime is handled in the slurried waste stream). The DMS rejects are initially handled wet and will be enclosed within the coarser rock to minimise the potential for it to become a dust source once it has dried out.

The surface area and type of surface exposed to wind erosion will change as the MWF embankment is developed. During early development the embankment would be of limited size with buffer distances to the installation boundary at their maximum. Temporary hydro-seeding of grasses may be used where surfaces are to be covered by subsequent stages of construction. During latter stages, as the surface area increases and the buffer distance to the installation boundary decreases erosion potential would be minimised by the permanent rehabilitation of exposed surfaces.

Given the particle size distribution of the solid waste material used in the embankment construction, i.e. predominantly coarse sand and larger, there is low potential for dispersion of dusts by suspension (which affects particles of less than 0.1mm), with the most likely dispersion method being as a result of ‘creep’, i.e. larger particles (>0.5mm) rolling across the surface only a few meters.

5.2.4 Wind raised dust from the MWF surface (i.e. beached tailings)

The tailings will comprise predominantly the gravity rejects (accounting for approximately 90% by weight) but also include slimes reject, froth flotation rejects and magnetic reject. The gravity reject is kaolinised and fresh granite that has been ground to a size of 300µm, i.e. a fine to medium sand. There exists potential for significant proportion of fines (i.e. silt sized) material to be entrained in the slurry.

The beached tailings will be maintained in a saturated state by progressive placement from spigots around the perimeter of the pond. Upon deposition the tailings are approximately 45% water with the long term moisture content estimated to be around 20%. The placement method provides for even placement and ensures the coarser material is beached at the perimeter of the tailings pond and the very fine material is deposited in the centre of the pond which will remain submerged in normal operating conditions. As a result, the potential dust source is largely limited to the coarser beached material.

5.3 Dust Composition

5.3.1 Run of Mine Waste

The ROM waste material is killas shale and granite (greisenised and kaolinised). The ore mineralisation is chiefly within the granite, which will be processed for the recovery of Wolframite and Cassiterite (i.e. the tungsten and tin minerals). Relatively small amounts of ore mineralisation extend into the surrounding killas (slate). On this basis iron arsenic sulphide (arsenopyrite), and hydrated arsenic compounds are unlikely to be present in significant concentrations within dusts associated with the ROM waste used in construction of the MWF solid waste embankment.

Due to the processing method, the DMS rejects may exhibit elevated concentrations of arsenic compounds and other metals in comparison to the ROM waste rock. The elemental breakdown of the DMS rejects is presented in Table 5-1.

5.3.2 Tailings (Slurry Waste)

Laboratory simulated test-work using composite granite samples obtained from the site has broadly produced the slurry waste (tailings) indicated at the end of the process. Subsequently, multi-elemental dry weight analyses of these tailings has been undertaken and produced by AMEC. Table 5-1 summarises the concentrations for the pollutants of concern with the earth's crustal average to provide context (full results are presented in Appendix 4B-1).

Table 5-1
Summary of Elemental Analyses (ppm)

	DMS Rejects	Composite Tails	Earth's Crustal Average
As	150	920	**1.8**
Cd	<1	<1	**0.2**
Cr	210	90	**100**
Cu	24	98	**55**
Pb	2	4	**12.5**
Hg	<1	<1	**0.08**
Mo	3	4	**1.5**
Ni	8	10	**75**
Se	2	2	**0.05**
Zn	13	34	**70**

5.3.3 Summary

Table 5-2 below presents a summary of the dust source categories at the installation and the potential emission types requiring assessment.

Table 5-2
Dust Sources and Potential Emission Types

Source	Ambient PM_{10} increases	Dust deposition	Metals deposition
Un-paved roads	y	y	n
Construction of embankment	y	y	n
Wind erosion of embankment	y	y	y
Wind erosion of tailings	y	y	y

6.0 DUST IMPACT ASSESSMENT

6.1 PM_{10}

The baseline monitoring indicates that PM_{10} concentrations in the area of the MWF are well below the Air Quality Standard at 21.3µg/m^3 (annual average). According to the LAQM.TG(09) guidance further assessment is only required if relevant receptors (houses, schools etc) are classified as 'near', given the baseline concentration 'near' is defined as within 200m in the guidance. There are no sensitive receptors within 200m.

Given the available 'headspace' of c19µg/m^3 PM_{10} it is highly unlikely that levels of dust would exceed the Air Quality Standard, even on the conservative assumption that the installation contributed a 5µg/m^3 increase at receptor locations.

The risk of exceedences of Air Quality Standards for PM_{10} at receptor locations is therefore considered to be negligible.

6.2 Nuisance Dust

Table 6-1 presents the variables that effect the magnitude of dust risk for each receptor within approximately 500m, Table 6-2 presents the evaluation of these variables on the basis of the dust risk matrix described in Section 3.2. Due to the distance, the high frequency of rainfall and the low frequency of winds affecting the receptors, the risks are judged to be insignificant at the scrap yard and Portworthy.

Table 6-1
Dust Risk Assessment Variables

Receptor	Distance to dust source (m)	Wind direction (start)	Wind direction (end)	Frequency (% of year)	Frequency (% of year) when dry*
Scrap Yard	550	50	330	13.0	7.4
Portworthy	340	70	160	13.6	7.7

Table 6-2
Dust Nuisance Risk Matrix

Receptor	Receptor sensitivity	Distance Score	Frequency Score	Overall Score	Overall Risk
Scrap Yard	0.5	2	3	3	Insignificant
Portworthy	1	2	3	6	Insignificant

6.3 Effects of Dust on Ecological Receptors

The potential for dust impacts on sensitive ecological systems can be associated with the chemical effects of the dust and physical effects of the deposited material on plants. This section addresses the likelihood and magnitude of dust deposition on account of the location of the ecological receptors and the prevailing meteorological conditions. The following sub-sections then address the effects of alkalinity/acidity, metal content, and deposition rate.

As described above in Section 3.2, the effects of dust deposition are generally only experienced within 100m of mineral workings, although particles of between >10µm and <30µm may travel 250m to 500m. Therefore those habitats in excess of 500m (see Table 4-3) have been screened out of further assessment, and only the following sites have been considered further:

- Coleland Wood, Hooksbury Wood, Fernhill Wood, (which are Ancient Re-planted Woodlands); and
- Small Hanger Waste and Crownhill Down comprising Lowland Heathlands and Dry Acidic Grasslands[32]**Error! Bookmark not defined.** designated as County Wildlife Sites.

Table 6-3 and Table 6-4 below present the variables that affect the magnitude of potential dust impacts, i.e. distance from the MWF (as a whole) and from the beached tailings, frequency of winds from the direction of the dust source incorporating the frequency of precipitation. The beached tailings have been assessed in isolation due to the fact that they are considered a greater dust risk than the MWF embankment.

It should be noted that the indicative frequency (presented in Table 6-3 and Table 6-4) at which the designated habitat is downwind applies to the designated area as a whole and not to specific discrete areas. As a result the indicative frequencies are likely to represent an over-estimate. Given the extent of Crownhill Down along the eastern boundary the site has been divided north and south.

Table 6-3
Indicative Frequency of Potential Dust Events (entire MWF)

Receptor Reference	Distance to any dust source (m)	Wind direction (start)	Wind direction (end)	Frequency (% of year)	Frequency (% of year) when dry*
Coleland Wood	55	120	230	24.2	13.8
Hooksbury Wood	<20	20	160	18.0	10.3
Fernhill Wood	280	40	130	13.7	7.8
Small Hanger Waste	<20	200	330	42.3	24.1
Crownhill Down (north)	<20	160	250	28.6	16.3
Crownhill Down (south)	<20	180	330	46.0	26.2

From the analysis it is evident that due to their location to the north and west the Ancient Re-Planted Woodlands are likely to be affected by winds from the direction of the MWF relatively infrequently when precipitation is taken into account. Given the prevailing winds (see Figure 4-1), Small Hanger Waste and Crownhill Down will be subject to winds from the direction of the site most frequently. Whilst these sites are close to the MWF embankment the potential for the MWF to generate dusts likely to become suspended is limited due to the physical nature and particle size of the waste material. On this basis the predicted magnitude of dust deposition on these receptors is considered to be low.

Table 6-4
Indicative Frequency of Potential Dust Events (Beached Tailings)

Receptor Reference	Distance to any dust source (m)	Wind direction (start)	Wind direction (end)	Frequency (% of year)	Frequency (% of year) when dry*
Coleland Wood	340	140	200	10.8	6.2
Hooksbury Wood	580	50	120	12.3	7.0
Fernhill Wood	880	50	110	11.6	6.6
Small Hanger Waste	240	250	330	17.9	10.2
Crownhill Down (north)	300	190	230	17.7	10.1
Crownhill Down (south)	250	220	320	32.4	18.5

[32] according to Natural England ‘nature on the map’.

The beached tailings will have a greater potential for generating dusts with the potential to become airborne, however the beached tailings area is a much greater distance from receptors (see Table 6-4) in excess of 200m. The significant buffer distance is a mitigating factor, promoting greater dilution of any raised dusts, and resulting in a low risk of dust deposition at the Ancient Re-planted Woodlands.

It is evident that a higher level of risk exists for Crownhill Down. The northern areas are a greater distance from the tailings area and likely to be affected approximately half as frequently as the southern area. As such, application of dust control measures in this area will require greater vigilance and will be targeted in the dust monitoring programme.

6.3.1 Chemical Effects of Dust

pH

A majority of the research undertaken has focussed on the chemical effects of alkaline dusts, such as those from limestone quarries. A summary of a review of available research on behalf of the DETR concluded that:

> *"the issue of dust on ecological receptors is largely confined to the associated chemical effect of dust, and particularly the effect of acidic or alkaline dust influencing vegetation through soils."*

The waste characterisation analyses[33,34] have found that:

- pH values range between 5.9 and 7.4, but are predominantly near-neutral or slightly alkaline. The lowest pH (5.9) is from the kaolinised granite sample. Test work completed to simulate a damp environment where wet and oxidising conditions can lead to heavy metal leaching and mobilisation into ground and run-off waters, confirmed the low acid formation potential.
- alkalinity values expressed as bicarbonate alkalinity or total alkalinity as $CaCO_3$ are low.

As the waste is not considered highly alkaline or acidic, and given the stand-off distance between the beached tailings areas and the ecological receptors limiting the potential for deposition, the risk of significant effects as a result of acid or alkaline dusts is considered low.

Metals

There are no established critical load values for heavy metals at present in the UK. The development of effects-based critical loads for heavy metals in soils and freshwaters is currently subject to research. As a result the assessment of potential risks has been undertaken on the basis of a literature review for published critical load ranges. Two published reports have been used in the assessment, described below:

- The primary resource is a report for a project undertaken on behalf of Defra[35] to develop improved models and mapping procedures for critical loads in the UK. This

[33] Wolf Minerals, *Hemerdon Project Waste Management Plan* (September 2011)

[34] Al Control Laboratories, MCERTS Report 209786 (25th January 2013)

[35] Ashmore et al. *Further Development of an Effects (Critical Loads) Based Approach for Cadmium, Copper, Lead and Zinc*. Final Report for Defra (EPG 1/3/188, November 2004)

report provides critical loads for cadmium, copper, lead and zinc on a 1km resolution map of the UK.

- The secondary resource, used for metals omitted in the above report[36], is a report produced in response to a Convention of Long-Range Transboundary Air Pollution initiative and provides critical loads based on a 50km resolution map.

The critical load ranges have been used, in conjunction with the tailings metal content analysis, to establish a total dust deposition rate threshold below which the risk is negligible, i.e. below the level at which there are no known effects according to present knowledge (presented in Table 6-5). The tailings metal content analysis has been used in the deposition rate threshold calculation this is considered a precautionary approach on the basis that any dust deposited is highly unlikely to comprise solely tailings and would be diluted by other dusts.

The findings indicate that in general very high deposition rates are required to exceed the critical loads provided by the literature. The metal requiring the lowest total dust deposition rate to exceed the critical load is arsenic at 89mg/m^2/day.

Dusts containing elevated metal concentrations are only likely in the DMS rejects and the tailings. The DMS rejects contained within the MWF embankment are only considered to have a low potential for generation of airborne dusts as a result of wind action for the reasons explained in Section 5.2 (i.e. the gravel sized nature of the DMS rejects is only likely to result in 'creep' rather than dust saltation or suspension in significant quantities). As such the main risk of dust containing metals leaving the site is as a result of wind erosion of the beached tailings surface.

Considering the nature of the source, i.e. a relatively coarse material on a level surface not subject to mechanical agitation such as vehicles, and the stand-off distance in excess of 200m between the beached tailings area and the closest ecological receptors outside the installation boundary (i.e. Crownhill Down), the risk of dust depositing at levels likely to exceed the deposition thresholds is considered to be low.

Table 6-5
Dust Deposition Thresholds Based on Waste Composition Analysis

Metal	Critical Load (or range) (mg/m^2/day)	Tailings Content (mg/kg)	Dust Deposition Effects Threshold (mg/m^2/day)	Reference Source
Cd	0.0014 - 0.0027	1	1370 - 2740	Ashmore et al (2004)
Pb	0.0041 - 0.0082	8	514 - 1027	Ashmore et al (2004)
Cu	0.0274 - 0.0685	98	280 - 699	Ashmore et al (2004)
Ni	0.0274 - 0.0685	110	249 - 623	Ashmore et al (2004)
Zn	0.0685 - 0.2740	34	2015 - 8058	Ashmore et al (2004)
Cr	0.0329	290	113	Reinds et al (2006)
As	0.0822	920	89	Reinds et al (2006)
Se	0.0014 - 0.0016	4	342 - 411	Reinds et al (2006)

[36] G.J. Reinds J.E. Groenenberg W. de Vries. *Critical Loads of copper, nickel, zinc, arsenic, chromium and selenium for terrestrial ecosystems at a European scale*. Alterra-rapport 1355 Alterra, Wageningen, (2006)

6.3.2 Physical Effects of Dust Deposition

The physical effects of dust can be associated with blockage and damage to stomata (for small particle size 8-12µm), shading, and abrasion.

Interim Advice Note (IAN) prepared as a supplement to the Design Manual for Roads and Bridges[37] suggests that only dust deposition levels above 1000 mg/m^2/day are likely to affect sensitive ecological receptors. This level of dust deposition is approximately five times greater than the level at which most dust deposition may start to cause a perceptible nuisance to humans. Furthermore, it is stated that most species appear to be unaffected until dust deposition rates are at levels considerably higher than this[38]. Given the nature of the MWF embankment construction materials and the stand-off distance from the beached tailings area the risk of dust depositing in quantities likely to cause physical effects is considered to be low.

6.4 Dust Deposition and Soil Quality Criteria

The H1 guidance includes maximum deposition rates (MDR – mg/m^2/day) that are intended to be protective of soils. The MDR's are derived from Soil Quality Criteria that are taken from '*Code of Practice for Agriculture Use of Sewage Sludge*'[39] and therefore protective of soils for agricultural use. The MDR in H1 is defined as '*the quantity of pollutant which can be added to the soil daily over 50 years before the selected soil quality criteria is exceeded*'.

The MWF is anticipated to be completed and restored within 15 years, on this basis the MDR's (which are based on a 50 years of deposition) have been modified in order to calculate a deposition threshold below which the Soil Quality Criteria will not be exceeded. The tailings metal content analysis has been used in the deposition rate threshold calculation this is considered a precautionary approach on the basis that any dust deposited is highly unlikely to comprise solely tailings and would be diluted by other dusts.

Table 6-6
MDR Based on Waste Composition Analysis

Metal	H1 MDR (mg/m^2/day) (based on 50yrs)	Adjusted MDR (mg/m^2/day) (based on 15yrs)	Tailings Content (mg/kg)	Total Dust Deposition Threshold (mg/m^2/day)
Arsenic	0.02	0.07	920	72
Cadmium	0.009	0.03	1	30000
Chromium	1.5	5.00	290	17241
Copper	0.25	0.83	98	8503
Lead	1.1	3.67	8	458333
Mercury	0.004	0.01	1	13333
Molybdenum	0.016	0.05	13	4103
Nickel	0.11	0.37	110	3333
Selenium	0.012	0.04	4	10000
Zinc	0.48	1.60	34	47059

The findings indicate that in general very high deposition rates are required to exceed the critical loads provided by the literature. The metal requiring the lowest total dust deposition

[37] Volume 11, Section 3, part 1 of the Design Manual for Roads and Bridges (and now incorporated into HA207/07).

[38] Farmer A.M. (1991) *The Effects of Dust on Vegetation – A Review.* Environmental Pollution **79**. Pp 63-75

[39] Department of the Environment, Code of Practice for Agricultural Use of Sewage Sludge (1989).

rate to exceed the Soil Quality Criteria is arsenic at 72mg/m^2/day for 15 years. For the reasons described in Section 6.3.1 (sub-section *Metals*) the risk of dust depositing at levels likely to exceed the deposition thresholds is considered to be low.

7.0 DUST CONTROL AND MITIGATION MEASURES

The dust assessment presented in this report has been used in order to develop an appropriate Dust Management Plan (DMP) in combination with best practice guidance as follows:

- Report to The Mineral Industry Research Organisation (MIRO), Good practice guide: control and measurement of nuisance dust and PM10 from the extractive industries AEAT/ENV/R3140 Issue 1 (February 2011);
- Institute of Air Quality Management (UK) Dust and Air Emissions Mitigation Measures (2012)[40];
- Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities (January 2009)[41]

The principal mechanisms of formulating and continually improving a DMP are presented in Figure 7-1.

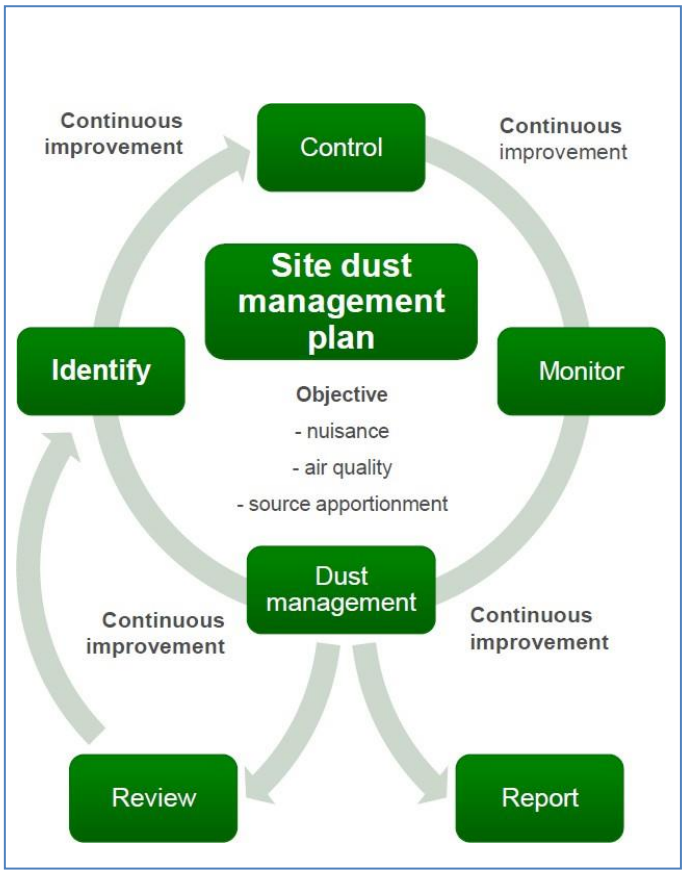

Figure 7-1
Dust Management Plan Process[42]

[40] http://www.iaqm.co.uk/guidance.html

[41] Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities (January 2009)

[42] Reproduced from - Report to The Mineral Industry Research Organisation (MIRO), *Good practice guide: control and measurement of nuisance dust and PM_{10} from the extractive industries* AEAT/ENV/R3140 Issue 1 (February 2011)

Sections 5.0 of this report identifies possible sources of dust attributable to the site and contributory factors that influence dust generation and their potential impact. The remaining components of the DMP are set out below:

- Control – Section 7.1
- Monitor – Section 7.2
- Manage – Section 7.3
- Review and Report – Section 7.4

7.1 Dust Control Measures

The key method of controlling dust emissions is through good process and site design and subsequent good housekeeping, i.e., 'avoidance', is the key method of controlling dust emissions.

The control hierarchy has been based on:

- good operating and management practices to avoid emissions arising from activities;
- good process design or revision to minimise emissions;
- abatement or control to reduce dust emissions, e.g., use of water bowsers and sprays; and
- disrupting the emission pathway to sensitive receptors, i.e., shielding receptors through the use of earth banks or vegetative screening.

The dust control measures have been defined on the basis of the findings of the dust risk assessment and with reference to Planning Permission Modification Order and Best Available Techniques (as defined within the BREF Note).

The key dust suppressant technique is application of water on haul roads and use of sprays in operating areas of the embankment or tailings storage area. The managed application of water without chemical additives is considered capable of suppressing dust sufficiently, i.e. visual monitoring will ensure that water is applied in sufficient volumes and frequency to abate dust generation. The application of chemical additives to either encourage binding of particles or leave a protective residue on surfaces to limit dust generation will be retained as an option for contingency actions but not applied routinely.

Dust Control measures are set out in these are set out in Table 7-1 below.

The Planning Permission Modification Order and Best Available Techniques are discussed in the sections below.

7.1.1 Modification Order (Planning Permission) Controls on Dust

The Modification Order, approved in January 2011, updated the planning conditions in line with legislative changes since 1986. Within the Modification Order Conditions 11, 31, 32, and 33 specifically relate to the control of dust [43]. These conditions cover all aspects of the wider mining operation, those that relate to activities at the MWF are discussed below and have been incorporated into the dust management plan for the MWF (the Conditions 11, 31, 32, and 33 are re-produced in full in Appendix 4B-2).

[43] Modification Order S97 Town and Country Planning Act 1990, Relating to Hemerdon Mine Plympton, Plymouth, Devon. Devon County Council, 29th November 2010

- Condition 11 of the Modification Order limits the undertaking of operations that give rise to dust to daylight hours from Monday to Saturday excluding public holidays.
- Condition 31 requires dust emissions from the development to be minimised, with various measures being prescribed. Those that relate to the MWF include use of sprays (or more effective dust control if available) during handling of potentially dusty materials and methods to limit dust generation from vehicle transport. The design of the plant and facilities incorporates the prescribed features, e.g. wheel washing facilities, all weather road surfaces, and use of water sprays on MWF.
- Condition 32 requires the adoption of best practicable means to minimise the propagation of dust including PM_{10}. The condition also imposes dust deposition rate triggers (i.e. '*200 mg/m^2/day after commencement of the development, and previously the annual deposition rate was less than 50 mg/m^2/day*') above which the operator would be required to take remedial actions.
- Condition 33 requires an approved scheme of monitoring (comprising directional flux and deposition rate measurements) to be implemented and the reporting of the results to the MPA at 6 monthly intervals.

7.1.2 Best Available Techniques

Best Available Techniques are set out the European BAT Reference Document (BREF) on '*Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities'.* The Environment Agency guidance note EPR 6.14 requires operators to '*provide justification where* [it is proposed] *to use alternatives to the standards set out or referred to in this document or where no technical standard is provided'.*

The BAT options for dust prevention set out in Section 4.3.4 of the BREF note have been reviewed and used in defining dust management techniques. The justification for selection of BAT options is presented in Appendix 4B-3.

Table 7-1
Dust Control Measures

Aspect	Potential Impact	Management Actions / Control Measures	Responsible Persons	Implementation Date
Materials handling operations during MWF embankment construction	PM_{10} exposure and dust deposition.	Minimise drop heights when unloading material. Protect from exposure to wind where possible. Use of water sprays to moisten material being handled. Rock loading and dumping points will be wetted down to limit dust. The waste rock to be dumped is coarse but uncrushed rock. The DMS is a finer granular material, but is collected wet from the process and should not generate dust during transport or dumping. It will be enclosed within the coarser rock to ensure it does not become a dust source once it has dried out.	Environmental Manager Site Foreman	On-going during Operation.
Stockpiles	PM_{10} exposure and dust deposition.	Seed surfaces of completed mounds of overburden and top soil (restoration materials). Use of salvaged vegetation or stabilising emulsion where required. Limit mechanical disturbance, i.e. demarcate boundaries to limit vehicle track over. Shield from wind, e.g., through the use of tree planting or screening. Use of water sprays to moisten surfaces during dry weather.		
Tailings Handling	PM_{10} exposure and dust deposition.	The beached tailings will be maintained in a saturated state by progressive placement from spigots around the perimeter of the pond. This is the intended placement method for even placement and ensures the coarser material is beached at the perimeter of the tailings pond and the very fine material is deposited in the centre of the pond which will remain submerged in normal operating conditions.		
Wind erosion	PM_{10} exposure and dust deposition.	Prompt re-vegetation of exposed soils and other erodible materials.		

Aspect	Potential Impact	Management Actions / Control Measures	Responsible Persons	Implementation Date
		Clearing and opening-up of new areas only when absolutely necessary. Progressive rehabilitation of disturbed areas and temporary hydro seeding of soil dumps to stabilise the surface. Trees, bushes and hedges to be planted as appropriate to form wind breaks/dust screens		
Vehicle activity on unpaved roads and on-site	PM_{10} exposure and dust deposition.	Minimise on-site transportation distances. Use of water sprays to moisten road surfaces during dry weather. (consideration given to chemical suppressants if required). Restrict vehicle speeds through signage/staff training. Frequent condition inspection to determine areas requiring re-grading.		

7.2 Monitoring

The monitoring strategy has been developed to address the needs of the site in the context of its locality based on the findings of this risk assessment.

7.2.1 Monitoring Approach

The monitoring approach includes three elements:

- visual dust monitoring; and
- dust deposition measurements and directional dust flux measurements.

Dust deposition measurement would be carried out in accordance with methods detailed in Environment Agency M17 guidance. This requires exposure of a standard dust bucket for a month, with weighing (and chemical analysis, if necessary) of the dust collected.

7.2.2 Locations

Visual monitoring for significant dust generation and potential dusts dispersing in the direction of receptors will be undertaken continually by all staff and any issues reported to the site foreman or environmental manager for actions to be implemented.

Baseline measurements have been undertaken at locations described in Section 4.4.

Dust deposition monitoring locations will be established in proximity to the MWF in order to monitor the effectiveness of dust control measures. Detailed locations will be established prior to commencement of operations, as they will be situated on the basis of safe site access and security.

7.3 Management Actions and Trigger Levels

Management actions may be 'triggered' by a range of feedback mechanisms, including:

- visual monitoring indicating dust leaving site boundary in quantities likely to cause nuisance;
- measurements exceeding established trigger levels (200mg/m^2/day): and
- complaints received from members of the public.

Management actions will have the objective of investigating the incident and preventing any continuing issue by putting in place additional control or management measures to prevent re-occurrence of incident / exceedences and updating the DMP. Investigations will include but not be limited to:

- review of meteorological conditions at time of incident /exceedences
- review of site activities at time of incident /exceedences
- review of control measures and management actions at time of incident /exceedences.

Management actions specific to particular areas of the operation are set out in Table 7-2.

Table 7-2
Management Actions

Source	Management Actions
Materials Handling	• cease operations until corrective action can be taken, or adverse weather conditions change; • implement corrective action, such as the use of water sprays, or temporarily

Source	Management Actions
	relocate the area of work until the wind direction or other adverse weather conditions change; • record the event and remedial works in the site log book.
Mining Waste Facility	in the case of dump construction, operations will cease until corrective action can be taken, or adverse weather conditions change; • implement corrective action, such as the use of water sprays, or temporarily relocate the area of work until the wind direction or other adverse weather conditions change; • in the case of dust from the deposited tailings, if appropriate spigots on the section of the tailings which is causing the problem will be opened. This will quickly flood the area preventing further dust emissions. In the even the tailings are not being pumped, a water mist system will be activated to drop dust from the air. • record the event and remedial works in the site log book.
Vehicle Movements	• implement corrective action, such as the use of the water bowser on the dusty area of road or repair to a damaged haul road surface; • on tarmac or concrete roads organise road sweeping; • ensure vehicles are obeying the site speed limit; • record the event and remedial works in the site log book.

7.4 Reporting and Review

Dust reporting and review will be undertaken internally on a monthly and annual basis.

Monthly reviews will incorporate review of dust monitoring reports in order to enable timely response to emerging dust management issues. Review will include meteorological conditions with a bearing on dust generation and dispersion. Reporting will include recommended actions if appropriate.

Dust monitoring results will be reported to the MPA every 6-months in accordance with planning conditions.

An annual review will be undertaken and incorporate:

- compilation and review of all monitoring data;
- compilation and review of dust issues and management actions taken;
- recommendations for updating management and control measures; and
- updating of the DMP.

8.0 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 Wolf Minerals; 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.

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