Technical Appendix G

Air Quality & Health Impact Briefing Note

Back Lane Quarry

Air Quality and Health Briefing Note

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1 Air Quality and Health Briefing Note

1.1 Introduction

1.1.1 A Scoping Opinion Request was made by the Applicant on 29 September 2021 via preparation of a Scoping Report. Within this, it was proposed that human health will be considered within specific topic chapters as appropriate. A Scoping Opinion was received on 20 December 2021 in response to the Scoping Report prepared by the Applicant.

1.1.2 While the Scoping Opinion did not ask for a separate population and health ES chapter or Health Impact Assessment (HIA), the following points relating to human health were made:

- Given the concerns that have been raised in the local area regarding health impacts of dust, the assessment should also consider health related air quality issues. The Scoping Report only mentions PM_{10} impacts but from the health perspective, $PM_{2.5}$ should also be assessed. Given the small particle size, $PM_{2.5}$ dust particles can potentially be carried over a wider area than the 400 m distance quoted in the Scoping Report.
- Any assessment of $PM_{2.5}$ should take account of any levels provided in WHO guidance or any levels that may be contained in guidance published pursuant to the Environment Act 2021.

1.1.3 This air quality and health briefing note is intended to explore the concerns raised, and provide information to firstly distinguish between potential hazard and risk, explain how and where well-known hazards are addressed through mitigation measures, and offer additional narrative to put potential health risk into context.

1.1.4 The remainder of the document is structured follows:

- Section 1.2: Hazard vs Risk – explains the difference between a hazard and a credible risk to health, using the source-pathway-receptor model.
- Section 1.3: Project Overview – provides a summary of the proposed extension of time application relevant to the assessment of human health.
- Section 1.4: Baseline Health and Wellbeing – outline local demography, socio-economic and public health circumstance.
- Section 1.5: Baseline Air Quality – summarises the air quality monitoring provided in Chapter 11: Air Quality and Dust which support the health assessment.
- Section 1.6: Relevant Embedded Mitigation – outlines the relevant mitigation measures currently implemented on-site which would continue to be implemented over the extension of time.
- Section 1.7: Health Assessment – draws from and builds upon the assessment in Chapter 11: Air Quality and Dust to establish the potential impacts on human health.

- Section 1.8: Cumulative Assessment – provides a cumulative assessment of the proposed extension of time application at Back Lane Quarry in-combination with the proposed extension of time application at the adjacent Leapers Wood Quarry.
- Section 1.9: Summary and Conclusion – summarises and concludes on the potential impact on health and wellbeing from the proposed extension of time application.
- Annex A: Air Quality and Health Evidence Base – outlines the most up to health evidence base associated with air pollution.

1.2 Hazard vs Risk

1.2.1 When considering any potential health hazard, it is firstly important to differentiate between a hazard and a risk. A hazard is something with the potential to cause harm, while a risk is the likelihood of harm occurring. The distinction while subtle, is often confused or misapplied, and can lead to, or underpin incorrect and unfounded concern and risk perceptions.

1.2.2 Most elements, compounds and materials can be defined as hazardous, where even oxygen and water fall into this category, yet only become a risk when the following three components are present:

- a hazard source;
- a receptor; and
- a credible mode of exposure between the two.

1.2.3 If any one of these components is missing, there is no credible health risk. When all three are present, it is then the nature of the hazard, the mode and concentration of exposure, and the sensitivity of the receptor that will define any risk to health, and its significance, if any. A failure to consider the source pathway receptor model when exploring potential risks can often result in confusing hazard with risk, or inferring a significant health risk, when there is not.

1.2.4 The aim of the regulatory planning process is to disrupt the source-pathway-receptor linkage, thereby removing and reducing potential risk. It is then the purpose of environmental permitting to test and validate the protection of the environment, where a permit to operate will be issued (and can also be retracted) by the regulator if this is not the case.

1.3 Project Overview

1.3.1 The current site has been in operation as an active quarry for many decades.

1.3.2 The current site is accessed via Back Lane and sells approximately 1.1 million tonnes per annum (mtpa) of limestone aggregate. The current permissions for extraction and restoration of the site are to 29 April 2048 and 29 April 2049 respectively.

1.3.3 The planning application seeks permission to extend the extraction of limestone to a depth of -37m AOD. The sales of 1.1 mtpa would remain unchanged, therefore it would be necessary to seek permission to extend the extraction period. Assuming the current extraction rate would be maintained, this would require an extension to the extraction period to 31 December 2077 with restoration by 31 December 2078.

1.3.4 Currently, HGVs are required to leave the quarry via Back Lane, with the annual output and HGV movements maintained at current rates. There would be no change to the existing hours of operation, no new infrastructure is proposed on site, and access arrangements would remain as currently permitted. No other changes are proposed as part of the application.

1.4 Baseline Health and Wellbeing

Introduction

1.4.1 Different communities have varying susceptibility to health and wellbeing effects (both adverse and beneficial) as a result of social and demographic structure, behaviour and relative economic circumstance.

1.4.2 The aim of the following information is to outline the local health and socio-economic circumstance of the communities living within the Kellet ward to establish any existing health trend and relative sensitivity. It should be noted that the description of the whole population, and of the populations within the study area, do not exclude the probability that there will be some individuals or groups of people who do not conform to the overall profile.

Site location and setting

1.4.3 Back Lane Quarry is located within Lancaster City Council authority area, lying to the south-east of Carnforth in Lancashire.

1.4.4 The site is bounded to the north by the adjoining Leapers Wood Quarry operated by Tarmac Trading Ltd, to the east by woodland, to the south by agricultural land and to the west by woodland, with the M6 beyond.

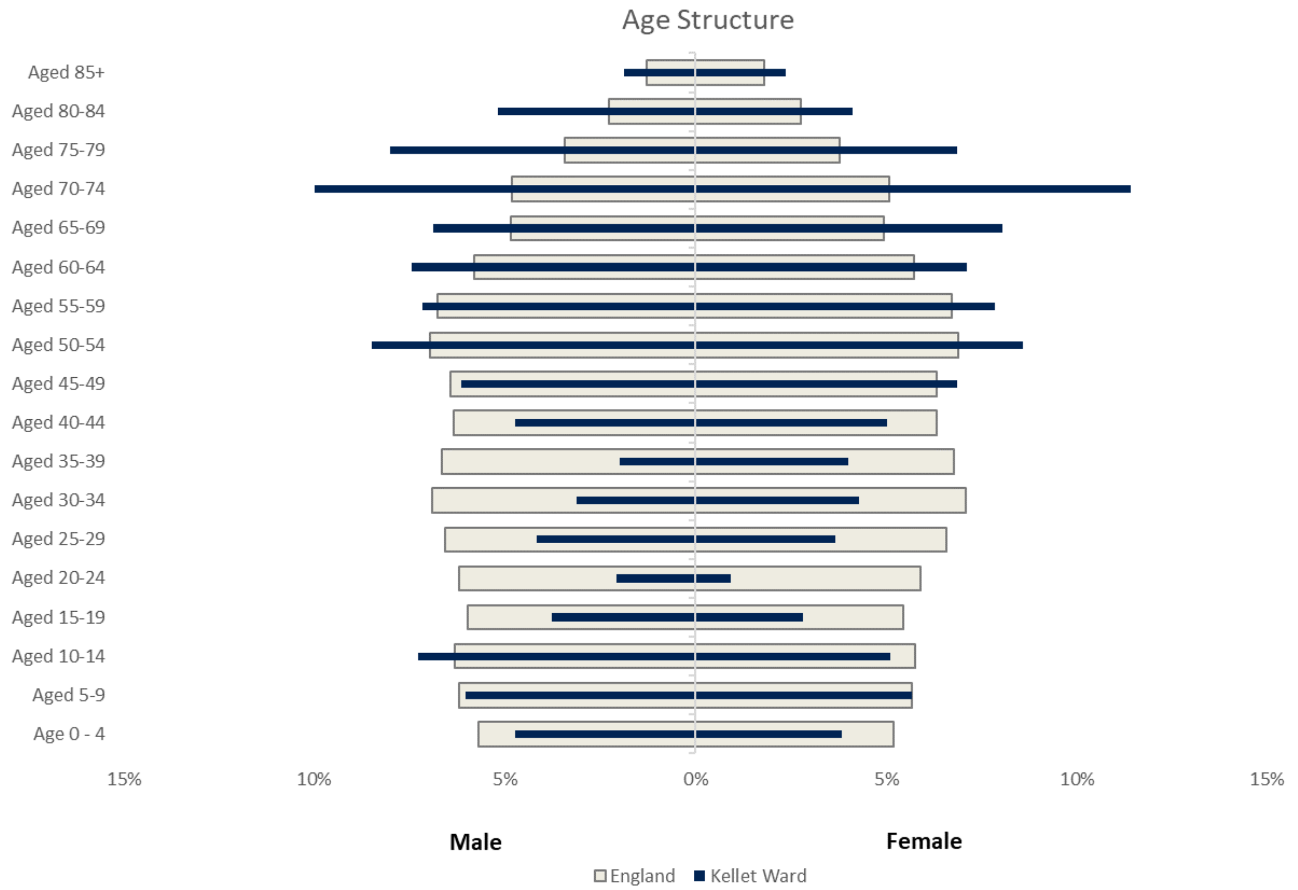
1.4.5 The nearest residential areas to the extraction area lie around 400m to the north-west on the edge of Carnforth, beyond the M6. Nether Kellet village lies 550m to the south of the quarry at its nearest point.

1.4.6 Carnforth is the nearest major settlement to the site, the town centre of which lies around 1.5km west of the site. Further afield, Lancaster city centre lies 8.5km to the south of the site.

Demography, deprivation and socio-economic circumstance

1.4.7 Figure 1.1 shows the age structure of Kellet ward in comparison to the England average. The population living within Kellet ward does not follow the same structure as the England average. For example, a total of 5% of the population living within Kellet ward are aged 15 to 24 (compared to the national average of 11%) and 34% are aged 65 and over (compared to the national average of 18%).

Figure 1.1: Age Structure of Kellet ward in comparison to England



Source: ONS (Office for National Statistics, n.d.)

1.4.8 Table 1.2 shows that all the socio-economic indicators analysed are better than all relevant comparators.

Table 1.1: Deprivation and socio-economic circumstance statistics

Indicator	Date	Kellet ward	Lancaster district	Lancashire county	England average
Deprivation and socio-economic circumstance					
Income deprivation, English Indices of Deprivation (%)	2019	4.8	12.9	13.3	12.9
Child poverty, English Indices of Deprivation (%)	2019	4.5	17.5	16.7	17.1
Older people in deprivation, English Indices of Deprivation (%)	2019	4.9	14.2	14.1	21.1
Fuel poverty (%)	2020 (modelled)	11.7	15.1	13.6	13.2
Unemployment (%)	2021-2022	2.5	4	4.6	5
Long term unemployment (%)	2021-2022	0	0.7	1.4	1.9

Indicator		Date	Kellet ward	Lancaster district	Lancashire county	England average
Key:						
	Better than the England average					
	Worse than the England average					

Source: OHID Local Health (Office for Health Improvement and Disparities, n.d.)

Physical health

1.4.9 Table 1.3 shows that life expectancy (LE) at birth for both males and females in Kellet ward is higher than all relevant comparators. County level is the lowest geography that the most recent statistics for healthy life expectancy (HLE) (i.e. the number of years spent in good health) are available for. HLE for females in Lancashire is also higher than the national average, while HLE for males is lower than the national average.

1.4.10 Within the Kellet ward, emergency hospital admissions for all causes, chronic obstructive pulmonary disease and hip fractures for those aged 65+ are better than all relevant comparators. In the absence of emergency hospital admissions data for cancer, statistics relating to incidence have been collected and show that cancer incidence in the Kellet ward is better than all relevant comparators.

1.4.11 Emergency hospital admissions for coronary heart disease, stroke and myocardial infarction in the Kellet ward are higher than the national average. However, when comparing to the district and county averages, emergency hospital admissions for coronary heart disease is better than both comparators, and emergency hospital admissions for myocardial infarction is lower than the district average but higher than the county average. Emergency hospital admissions for stroke is higher than both comparators.

Table 1.2: Life expectancy and physical health statistics

Indicator	Date	Kellet ward	Lancaster district	Lancashire county	England average
Life expectancy					
Life expectancy at birth for males	2016-2020	84.4	78.4	78.4	79.5
Life expectancy at birth for females	2016-2020	88.9	82.3	82.1	83.2
Healthy life expectancy for males	2012-14	n/a	n/a	61.4	63.1
Healthy life expectancy for females	2012-14	n/a	n/a	64	63.9
Hospital admissions/disease incidence					
Emergency hospital admissions for all causes (SAR)	2015-16 to 2019-20	81.8	100.8	105.3	100
Emergency hospital admissions for coronary heart disease (SAR)	2015-16 to 2019-20	112.4	127.6	122.8	100
Emergency hospital admissions for stroke (SAR)	2015-16 to 2019-20	105.5	100.3	100	100

Indicator	Date	Kellet ward	Lancaster district	Lancashire county	England average
Emergency hospital admissions for myocardial infarction (SAR)	2015-16 to 2019-20	127.9	153.4	117.7	100
Emergency hospital admissions for chronic obstructive pulmonary disease (SAR)	2015-16 to 2019-20	32.4	102.2	117.2	100
Incidence of all cancer (SIR)	2015-2019	89.3	102.1	100.5	100
Emergency hospital admissions for hip fracture in 65+ (SAR)	2015-16 to 2019-20	65.3	103.3	99.5	100
Mortality					
Deaths from all causes (SMR)	2016-2020	70.4	106.5	108.9	100
Deaths from cancer (SMR)	2016-2020	65	103	103	100
Deaths from circulatory disease (SMR)	2016-2020	69	104.7	108.3	100
Deaths from coronary heart disease (SMR)	2016-2020	65.6	116.5	119.3	100
Deaths from stroke (SMR)	2016-2020	74.3	104.3	106.5	100
Deaths from respiratory diseases (SMR)	2016-2020	95.5	114.6	122	100
Deaths from causes considered preventable, under 75 years (SMR)	2016-2020	37.7	123.1	117.7	100
Key:					
(green) Better than the England average					
(amber) Worse than the England average					

Source: OHID Local Health (Office for Health Improvement and Disparities, n.d.); OHID Fingertips (OHID, n.d.)

Mental health and behavioural risk factors

1.4.12 Table 1.4 shows that hospital stays for self-harm within the Kellet ward are higher than all relevant comparators. Lancaster district is the lowest geography that statistics for suicide rate are available for, and shows that suicide rate is higher than all relevant comparators.

1.4.13 When assessing lifestyle and behavioural risk factors, the percentage of overweight and obese children (Year 6) living in Kellet ward is better than all relevant comparators.

1.4.14 Adults who are classified as overweight or obese in Lancaster district (the lowest available geography) is higher than the national average and marginally lower than the county average. The percentage of physically active adults in Lancaster district is higher than all relevant comparators. The prevalence of smoking at 15 years old is higher all relevant comparators.

Table 1.3: Mental health, lifestyle and behavioural risk factor baseline statistics

Indicator	Date	Kellet ward	Lancaster district	Lancashire county	England average
Mental health					
Hospital stays for self-harm (SAR)	2016-17 to 2020-21	109.3	92.5	103	100
Suicide rate (per 100,000 population)	2018-2020	n/a	15.7	13.5	10.4
Lifestyle and behavioural risk factors					
Prevalence of overweight children, including obesity (Year 6) (%)	2017-18 to 2019-20	27.3	33.6	34.2	34.6
Prevalence of obesity, including severe obesity (Year 6) (%)	2017-18 to 2019-20	18.2	19.6	19.7	20.4
Smoking prevalence at 15 years (regular) (%)	2014	8.2	5.7	5.7	5.4
Hospital stays for alcohol-related harm, narrow definition (old method) (per 100,000 population)	2016-17 to 2020-21	59.2	111.7	100.5	100
Percentage of adults classified as overweight or obese	2020-21	n/a	66.1	66.6	63.5
Percentage of physically active adults	2020-21	n/a	68.8	65.9	65.9
Key:					
(green)	Better than the England average				
(amber)	Worse than the England average				

Source: OHID Local Health (Office for Health Improvement and Disparities, n.d.); OHID Fingertips (OHID, n.d.)

Conclusion

1.4.15 In conclusion, the Kellet ward has a more senior age demographic, and consequently a lower working age population, compared to the national average. Socio-economic deprivation is low in the Kellet ward compared to the national average.

1.4.16 Life expectancy in the Kellet ward is good for both males and females. Similarly, mortality rate in the Kellet ward is low compared to all relevant comparators. Data for emergency hospital admissions in the Kellet ward is more varied, whereby emergency hospital admissions for all causes collectively (and more specifically, chronic obstructive pulmonary disease; cancer; hip fractures in those aged 65+ years old) is also lower in the Kellet ward than all relevant comparators. Respiratory health in the area is good and there is no evidence of any impact from current operations.

1.4.17 Mental health indicators show a higher burden of poor mental health in the Kellet ward compared to all relevant comparators. Behavioural risk factors are mixed, whereby the proportion of children who are overweight, hospital stays for alcohol related harm and physically active adults in the Kellet ward are better than average, but all other indicators are worse than the national average.

1.4.18 Overall, it is not considered that the population living within the local study is particularly sensitive to environmental and/or socio-economic changes associated with the proposed development.

However, this does not exclude the probability that there will be some individuals or groups of people who do not conform to the overall profile.

1.5 Baseline Air Quality

1.5.1 An assessment of baseline conditions is provided in ES Chapter 11: Air Quality and Dust. To establish baseline air quality conditions, ES Chapter 11: Air Quality and Dust details PM_{10} undertook short-term monitoring at the following two locations:

- Helks Wood Farm, 260m east of Back Lane Quarry; and
- 800m northeast of Leapers Wood Quarry and 1 km from Back Lane Quarry (selected by the Parish Council as being representative of potential exposure within the Over Kellet community.

1.5.2 The results of daily PM_{10} monitoring at both locations are provided in ES Figure 11.6.1 and summarised in Table 1.4. Blackpool Marton and Preston Automatic Urban and Rural Network (AURNs) are also provided as comparators.

Table 1.4: Daily PM_{10} monitoring results summary

Measure	Helks Wood Farm (µg/m^3)	Over Kellet (µg/m^3)	Blackpool Marton AURN (µg/m^3)	Preston AURN (µg/m^3)
Minimum	0.86	1.17	3	4
Maximum	29.16	9.96	29	31
Mean	5.91	2.98	11.16	12.32
Median	4.01	2.52	9	11
Mode	2.61	2.61	8	8

1.5.3 Results show that maximum daily average PM_{10} recorded over the monitoring period at Helks Wood Farm and Over Kellet monitoring stations remain well within AQS objective thresholds set to be protective of the environment and human health (40 µg/m^3).

1.5.4 The monitor at Over Kellet was also able to provide simultaneous measurements of other pollutants, including PM_1 and $PM_{2.5}$, which are summarised in Table 1.4.

Table 1.5: Daily PM_1 and $PM_{2.5}$ monitoring results summary

Measure	PM1	PM2.5
Minimum	0.66	0.87
Maximum	6.57	8.19
Mean	1.91	2.35
Median	1.44	1.83
Mode	1.38	2.10

1.5.5 Results show that maximum daily average $PM_{2.5}$ recorded over the monitoring period at Over Kellet monitoring station remains well within AQS objective thresholds set to be protective of the environment and human health (20 µg/m^3).

1.5.6 With reference to the aspirational WHO annual mean guideline level for $PM_{2.5}$ of 5 µg/m^3, a level unachievable in most urban areas, while the maximum daily average $PM_{2.5}$ exceeds this figure, the average figures provided (mean, median and mode) are all compliant. This suggests that monitoring over a yearly period to establish annual mean $PM_{2.5}$ would also remain compliant.

1.6 Relevant Embedded Mitigation

1.6.1 As previously discussed, planning and mitigation measures adopted as part of the proposed development inherently focus on precursors to health and wellbeing outcomes (such as dust and particulate matter), thereby providing an opportunity for intervention to prevent any adverse health impacts.

1.6.2 As previously stated, a hazard does not necessarily constitute a risk. While respirable dust from quarries is hazardous in nature, the hazard is well-known and understood, and can be effectively controlled at the source to disrupt the source-pathway-receptor linkage.

1.6.3 As detailed in ES Chapter 11: Air Quality and Dust, provided that appropriate mitigation measures are implemented, dust generation would be negligible. The following measures, which are already being implemented on site, are recommended to continue being implemented:

- the adoption of best practicable means;
- mobile plant are to be regularly serviced and equipped with effective exhausts;
- haul roads are adequately maintained;
- vehicle speed control on access and other trafficked areas to reduce fugitive dust;
- ensure that all commercial vehicles pass through a wheel washing facility prior to leaving the site to prevent the deposition of material onto the public highway;
- all vehicles leaving the site onto the public highway shall be suitably sheeted;
- in the unlikely event that dust or mud from the site has been deposited on the public highway, a road sweeper will be employed;
- regular inspections (and logging) of the public highway in order to identify the need for any cleaning requirements;
- loading and unloading of vehicles should ensure drop heights are minimised;
- water sprays or surface binders will be utilised to maintain damp surfaces on exposed tip and stockpile faces, and any exposed friable surfaces during dry and windy weather;
- use of filtration equipment on the exhaust emissions from drill rigs and the removal of any loose material from the area of blast prior to detonation;
- appropriate training of site employees in order to ensure that they are conversant with the site dust control strategy;
- staff induction will include awareness of track-out of dust or mud from the site and to report signs of materials deposited on the public highway.

1.7 Health Assessment

Introduction

1.7.1 As stated in ES Chapter 11: Air Quality and Dust, dust can be generated by numerous activities associated with mining and quarrying, such as:

- soil stripping and overburden removal;
- the extraction of the limestone;
- transportation of material on-site;
- material processing;
- wind erosion from dry, unvegetated surfaces; and
- vehicle movements and their exhaust emissions.

1.7.2 The planning application seeks permission for continued extraction of limestone to a depth of -37m AOD. There would be no lateral extension and no change to the sales of aggregate (1.1 mtpa), HGV movements, hours of operation, on site infrastructure or access. As a result, the most sensitive locations for potential dust impact will be the same as for the existing operations, albeit dependent on the specific operational phase of the development.

1.7.3 The remainder of this section reviews each of the potential dust generating activities from a health and wellbeing perspective, including how these may change from existing operations due to the extension of time application.

Soil stripping and overburden removal

1.7.4 As stated in ES Chapter 11: Air Quality and Dust, as there would be no lateral extension of the quarry, there potential for dust emissions from soil stripping or overburden removal would be negligible.

1.7.5 On the basis that the potential for dust emissions during this phase is negligible, there is no significant change in hazard concentration or exposure to receptors, and no associated risk to health.

Mineral extraction

1.7.6 As stated in ES Chapter 11: Air Quality and Dust, it is not proposed to modify current working practices which include the mechanical extraction of the limestone undertaken by drilling, blasting and removal of rock from working phases by hydraulic excavators.

1.7.7 The total production of limestone from the proposed operations remains at approximately 1.1 mtpa (as currently consented); front end loaders will continue to load the extracted stone into dump trucks, and the excavated material will be taken to the existing processing plant (Phases A to C) or a mobile plant adjacent to the active quarry face (Phases D and E).

1.7.8 While mineral extraction activities will continue to have the potential to generate dust emissions, as stated in Section 1.5 (Relevant Embedded Mitigation), provided that appropriate mitigation measures are implemented, dust generation should be negligible.

1.7.9 The potential hazard profile therefore remains the same as the currently operating facility, with no change in hazard nature, concentration, exposure pathways or receptors. On this basis, there would be no change in health risk.

Mineral processing

1.7.10 As stated in ES Chapter 11: Air Quality and Dust, mineral will be processed, temporarily stockpiled and loaded into HGVs for transport off site.

1.7.11 The location of stockpiled aggregate would not differ to existing operations, and is dependent on where extraction activities are occurring. During Phases A to C the extracted mineral will continue to be processed on-site at the existing processing plant. During Phases D and E, the extracted mineral will be processed using a mobile plant and temporarily stocked within the void prior to exportation.

1.7.12 While mineral extraction activities will continue to have the potential to generate dust emissions, taking into consideration the implementation of mitigation measures outlined in Section 1.5 (Relevant Embedded Mitigation), dust generation should be negligible.

1.7.13 The potential hazard profile therefore remains the same as the currently operating facility, with no change in hazard nature, concentration, exposure pathways or receptors. On this basis, there would be no change in health risk.

Wind erosion from dry, unvegetated surfaces

1.7.14 As stated in ES Chapter 11: Air Quality and Dust, there is the potential for roadways and unvegetated surfaces to produce dust emissions during dry, windy conditions. This presents no change from existing operations. As a result, the associated potential impact on health also remains unchanged.

Vehicle movements and their exhaust emissions

1.7.15 As stated in ES Chapter 11: Air Quality and Dust, the transportation of material from the working face to the primary crusher will continue to utilise dump trucks. The movement of these along internal haul roads can be the most significant source of dust generation. In addition, uncleaned vehicles leaving the site have the potential to deposit mud and dirt along the access road and public highway; subsequent vehicle movements have the potential to produce an impact from re-suspended dust.

1.7.16 While on and off-site vehicle movements will continue to have the potential to generate dust emissions, as stated in Section 1.5 (Relevant Embedded Mitigation), provided that appropriate mitigation measures are implemented, dust generation and associated exposure would be negligible.

1.7.17 Regarding exhaust emissions, the proposed extension of time application would not result in any change to the current annual quantities of mineral exported. Therefore, HGV vehicle movements associated with exporting aggregate remain unchanged. As there will be no additional traffic on the public highway, the impact associated with current exhaust emissions will be neutral.

1.7.18 The potential hazard profile therefore remains the same as the currently operating facility, with no change in hazard nature, concentration, exposure pathways or receptors. On this basis, there would be no potential change in health risk.

Restoration of site

1.7.19 As stated in ES Chapter 11: Air Quality and Dust, the restoration of the site to create a large water body with associated wildlife habitats and leisure land uses should not result in any notable additional impact upon the local air quality or dust environment. As a result, there would be no impact on human health.

1.8 Cumulative Assessment

1.8.1 The only development considered within the cumulative assessment is Leapers Wood Quarry, which is located to the north of the Back Lane development site and operated by Tarmac.

1.8.2 As with the application for Back Lane Quarry, the application at Leapers Wood Quarry would not include any lateral extension to the workings, and the annual outputs of aggregate would remain the same as is currently consented.

1.8.3 As a result, it can be concluded that with implementation of the appropriate mitigation measures already in place, the impact on air quality would be negligible, and the associated impact on health would therefore also be negligible.

1.9 Summary and Conclusion

1.9.1 Public health statistics show that respiratory health in the area is good and there is no evidence of any impact from current operations.

1.9.2 There are a range of mitigation measures which are currently being implemented at the Back Lane Quarry site and contribute to baseline air quality in the local area remaining well within AQS objective thresholds set to be protective of the environment and human health.

1.9.3 Provided that appropriate mitigation measures continue to be implemented, dust generation from the continuation of activities would be negligible and there would be no change in health risk.

Annex A – Air Quality and Health Evidence Base

Air Quality and Health Evidence Base

Introduction

1.9.4 This health evidence base relates to short and long term exposure to key air pollutants (particulate matter and nitrogen dioxide), and is largely based on the evidence presented in a publication from King's College London (Williams, Evangelopoulos, Katsouyanni, & Walton, 2019) which seeks to provide summary statements for decision makers on potential risk to the public, applicable to the UK.

1.9.5 In their report, Williams et al. (2019) only present concentration response functions[1] (CRFs) for specific health outcomes for which they consider the evidence to be persuasive and adequately quantified. The Williams et al. (2019) report excludes CRFs associated with general all-cause mortality, for which a considerable amount of work has already been done; while this is the case, all-cause mortality has still been included for totality as analysis on this health endpoint has been included in the quantitative health assessment.

1.9.6 As detailed in Williams et al. (2019), their preliminary work considered CRFs defined for specific health outcomes in the WHO HRAPIE exercise (WHO, 2013) and in the reports of the UK advisory group COMEAP or other consensus assessments. Where Williams et al. (2019) felt there was no better evidence than that included in WHO HRAPIE exercise, in the reports of the UK advisory group COMEAP or other consensus assessments, these estimates are presented. Where this is not the case, Williams et al. (2019) chose health outcomes for which the evidence is considered to be persuasive and adequately quantified, using robust science involving statistical significance and well-characterised studies.

1.9.7 It should be noted that since the publication of the Williams et al. (2019) report, COMEAP have released various reports (COMEAP, 2020; COMEAP, 2022; COMEAP, 2022), which have also been reviewed and included in this health evidence base.

Short-term exposure health effects

1.9.8 Short-term exposure to air pollution is associated with a range of adverse health outcomes, primarily experienced by individuals who are already vulnerable due to existing chronic or acute disease (Atkinson, Kang, Anderson, Mills, & Walton, 2014).

1.9.9 While studies relating to health effects associated with short-term exposures are based on daily concentrations, if there is no threshold for an effect (as is currently assumed), performing calculations on the annual mean as opposed to the daily mean is arithmetically equivalent to performing calculations for each day of the year and adding them up (Walton, et al., 2015).

[1] Concentration response function – defined as a statistical estimate of the relationship between exposure to pollutants and health outcomes

Respiratory and cardiovascular hospital admissions (incidence)

1.9.10 Atkinson et al. (2014) undertook a systematic review and meta-analysis of 110 peer-reviewed time series studies to assess the evidence for associations between exposure to $PM_{2.5,}$ cardiovascular and respiratory disease related hospital admissions. The majority of studies analysed were conducted in North America and Europe with a small number of studies in other regions of the world; while some level of heterogeneity in results for respiratory-related hospital admissions were identified between World Health Organisation (WHO) regions[2] (associated with varying sensitivities and health care systems worldwide), short-term associations occur worldwide which supports the generalisation of cohort-based estimates globally. Overall, Atkinson et al. (2014) found that $PM_{2.5}$ concentrations were positively associated with increased risk of admission for respiratory diseases (0.96% [0.63-2.58] per 10µg/m^3). In the same study, $PM_{2.5}$ concentrations were positively associated with increased risk of admission for cardiovascular diseases (0.90% [0.26-1.53] per 10µg/m^3), with no heterogeneity between WHO regions.

1.9.11 The Air Pollution and Health: A European and North American Approach (APHENA) project, conducted by Katsouyanni, et al. (2009), was based on data collected by three groups of investigators for three earlier studies. It was found that estimates of the effect of PM_{10} on hospital admissions for respiratory disease varied across the regions analysed (namely, Canada, US and Europe). Heterogeneity across regions will to some extent be affected by differing source mixtures, sociodemographic and health characteristics of each population. Overall, Katsouyanni, et al. (2009) found that daily increases in PM_{10} were positively associated with increases in risk of admission for respiratory diseases (ICD-9: 460-519) in the European region (0.60% [0.25-0.95] per 10µg/m^3) and cardiovascular diseases (ICD-9: 390-429) in the European region (0.60% [0.20-1.00] per 10µg/m^3), noting that a higher proportion of older persons and higher rates of unemployment in the study population was associated with increased PM_{10} risk estimates.

1.9.12 As stated by Mills et al. (2015), short-term exposure to NO_2 has been associated with adverse health effects. However, the causality of adverse health associations of NO_2 has been a matter of debate since there are close correlations between NO_2 and other traffic-related pollutants, some of which are more plausible toxicants. Despite this, recent reviews have concluded that the evidence linking NO_2 with health effects has sufficiently strengthened the likelihood of a causal relationship. Mills et al. (2015) identified positive associations between 24h NO_2 and admissions to hospital for all-age all respiratory diseases in the European region (0.52% [0.09-0.95] per 10µg/m^3). Positive associations were also identified for all-age all cardiovascular hospital admissions in the European region (0.42% [0.23-0.62] per 10µg/m^3).

COPD hospital admissions (incidence)

1.9.13 As stated by Moore et al. (2016), COPD is a group of progressive lung diseases that causes obstructed airflow from the lungs (ICD-10: J44.1-J44.9). While the effect of environmental

[2] WHO regions comprise: African Region (AFRO); Region of the Americas (PAHO); South-East Asia Region (SEARO); European Region (EURO); Eastern Mediterranean Region (EMRO); and Western Pacific Region (WPRO)

exposure is not clear, exacerbations of COPD are a common cause of adult emergency hospital admissions whereby patients may experience more frequent and severe exacerbations as the disease worsens.

1.9.14 Regarding the relationship between COPD-related hospital admissions and exposure to PM_{10}, of the 31 studies analysed by Moore et al. (2016), a positive association was found in 28 where the association was significant in 15. In addition, evidence of a nonlinear relationship where higher effects were reported at higher concentrations. While high heterogeneity was found between studies and there is evidence of a nonlinear relationship, the overall effect of exposure to PM_{10} on COPD-related hospital admissions in the European region is marginal (OR, 1.01 [1.00-1.01] per 10µg/m^3).

1.9.15 Moore et al. (2016) state that heterogeneity remained high when analysing $PM_{2.5}$, due to the lack of available outdoor measurements for this pollutant. Of the 12 studies analysed, a positive association was found in 10; however, the association was only significant in 4. As with PM_{10}, evidence of a nonlinear relationship where higher effects were reported at higher concentrations. Overall, a stronger relationship was found between COPD-related hospital admissions and $PM_{2.5}$ exposure (OR, 1.02 [0.99-1.04] per 10µg/m^3) compared to PM_{10}. However, due to the limited number of included studies, results should be interpreted with caution.

1.9.16 For NO_2, a positive association was reported in 25 of 27 studies analysed by Moore et al. (2016), with a significant association reported in 11. Similar to results for PM_{10} and $PM_{2.5}$, high heterogeneity and evidence of a nonlinear relationship were reported. Overall, the effect of exposure to NO_2 on COPD-related hospital admissions is higher than that for PM (OR, 1.03 [1.02-1.05] per 10µg/m^3).

Asthma admissions (incidence)

1.9.17 Studies show that hospital admissions relating to asthma (IDC10: J45) are higher on days when pollution is higher. Part of a Health Impact Assessment (HIA) looking at the effects of air pollution on asthma in London undertaken by Walton et al. (2019), included meta-analyses. The purpose of the meta-analyses was to provide representative concentration-response functions to apply in HIA calculations used to provide a modelled estimate of the impact of air pollution on child asthma admissions (for exposure to $PM_{2.5}$ and NO_2) and adult asthma admissions (for exposure to NO_2) at current levels in London, compared to if air pollution was reduced to the WHO Guideline level.

1.9.18 Results from the meta-analysis undertaken by Walton et al. (2019) state the global summary estimate for child asthma hospital admissions associated with $PM_{2.5}$ exposure as RR, 1.029 [1.016-1.042] per 10µg/m^3. The relationship between child asthma hospital admissions associated with NO_2 is stronger, whereby the global summary estimate is RR, 1.036 [1.018-1.054] per 10µg/m^3.

1.9.19 The global summary estimate for adult asthma hospital admissions associated with NO_2 is RR, 1.012 [1.001-1.023] per 10µg/m^3. No risk ratio is provided for the impact of NO_2 on adult asthma hospital admissions as the 4 studies analysed in the looking at the meta-analyses undertaken by Walton et al. (2019) suggest no association.

1.9.20 The APHEA (Air Pollution and Health: a European Approach) project (Atkinson et al., 2001) was initiated in 1993 with the aim of investigating whether there was epidemiological evidence for an adverse short-term effect of air pollution on respiratory health by studying eight European cities.

1.9.21 Summary results found a positive relationship between exposure to PM_{10} and emergency asthma hospital admissions for children (1.2% [0.2-2.3] per 10µg/m^3) and adults (1.1% [0.3-1.8] per 10µg/m^3).

Long-term exposure health effects

Childhood asthma (prevalence)

1.9.22 Asthma is the most common chronic disease in children worldwide. While there is a clear relationship between asthma exacerbations and exposure to air pollution, it is still unclear whether long-term exposure to air pollution affects asthma prevalence in children (Mölter, et al., 2015). As a result, Molter et al. (2015) analysed the association between the prevalence of childhood asthma and a range of traffic-related air pollutants (including NO_2, PM_{10} and $PM_{2.5}$).

1.9.23 Molter et al. (2015) found that the relationship between asthma prevalence at age 8–10 years and long-term exposure to air pollution at the birth address was positive for NO_2 (OR, 1.10 [0.81–1.49] per 10 µg/m^3) and $PM_{2.5}$ (OR, 1.23 [0.78–1.95] per 5 µg/m^3), but not for PM_{10} (OR, 0.88 [0.63–1.24] per 10 µg/m^3). However, none of the identified relationships were significant.

Lung cancer (incidence)

1.9.24 Ambient air pollution is suspected to cause lung cancer. A prospective analysis of data obtained by the European Study of Cohorts for Air Pollution Effects used data from 17 cohort studies based in nine European countries undertaken by Raaschou-Nielsen et al. (2013) showed a statistically significant association between risk of lung cancer risk and exposure to PM_{10} (HR, 1.22 [1.03-1.45] per 10 µg/m^3) and risk of lung cancer risk and exposure to $PM_{2.5}$ (HR, 1.39 [0.91-2.13] per 10 µg/m^3). The results showed no association between lung cancer NO_2.

Myocardial infarction and unstable angina (incidence and mortality)

1.9.25 Several cohort studies have reported that long term exposure to air pollution is associated with cardiovascular mortality. However, the specific relationship between long-term exposure to air pollution on the incidence of acute coronary events (i.e. myocardial infarction and unstable angina[3]) is less consistent (Cesaroni, et al., 2014). As a result, Cesaroni et al. (2014) further investigated this relationship through a prospective cohort study where participants (free from previous coronary heart events) were enrolled from 1997 to 2007 and followed for an average of 11.5 years.

[3] Unstable angina – a condition in which your heart does not get enough blood flow/oxygen, and which may lead to a heart attack

1.9.26 International classification of diseases (ICD) codes selected for analysis included those for "acute myocardial infarction" or "other acute and sub-acute forms of ischemic heart disease" (ICD-10: I21, I23, I20.0, I24) in principal diagnoses of hospital discharges. In addition, people who died outside from ischaemic heart diseases, according to the death certificates were considered (ICD-10: I20-I25) (Cesaroni, et al., 2014).

1.9.27 Cesaroni et al. (2014) found positive and significant relationships between an increased risk of acute coronary events (myocardial infarction and unstable angina) and long-term exposure to PM_{10} (HR, 1.12 [1.01-1.25] per 10 μg/m^3). Positive but non-significant associations were found with other pollutants, including $PM_{2.5}$ (HR, 1.13 [0.98-1.30] per 5 μg/m^3) and NO_2 (HR, 1.03 [0.97-1.08] per 10 μg/m^3).

<u>Stroke – cerebrovascular disease (incidence)</u>

1.9.28 As few studies have investigated effects of air pollution on the incidence of cerebrovascular events, Stafoggia et al. (2014) assessed the association between long-term exposure to multiple air pollutants and the incidence of stroke events in Europe.

1.9.29 A positive but not statistically significant relationship was found between stroke incidence and exposure to $PM_{2.5}$ (HR, 1.19 [0.88-1.62] per 5 μg/m^3) and PM_{10} (HR, 1.11 [0.90-1.36] per 10 μg/m^3). NO_2 was also analysed, however, no evidence of an effect was reported.

<u>All-cause mortality</u>

1.9.30 As previously stated, the study that this literature is based on deals with specific health outcomes rather than mortality, for which a considerable amount of work has already been done. As a result, the all-cause natural mortality risk ratios in the 30+ age category (i.e. adult population) for NO_2 and $PM_{2.5}$ included in the WHO HRAPIE exercise remain appropriate.

1.9.31 However, it should be noted that the WHO HRAPIE exercise notes that there is potential overlap between the $PM_{2.5}$ and NO_2 CRFs. While the size of this overlap is uncertain and has only been examined in a few studies, there are findings of overlaps up to 33%. As a result, a -33% penalty should be applied to the upper bound, lower bound and central NO_2 CRF to account for the overlap.

1.9.32 In addition, the WHO HRAPIE exercise suggests that the NO_2 CRF should be calculated for levels of NO_2 above 20 μg/m^3 due to observations in Naess et al. (2007), whereby in the oldest age group assessed (71-90 years) the increase in risk was linear between 20-60 μg/m^3, and Cesaroni et al. (2013), whereby a statistically significant linear CRF of NO_2 and natural mortality was detected above 20 μg/m^3. However, discussions amongst people in the field ranged all the way from there should not be a cut-off at all to calculations should be done as if the same slope reaches a threshold of zero at 20 μg/m^3 as it is unclear of the methodology intended if doing a burden calculation of an absolute concentration that is above 20 μg/m^3 and there is concern that interpretations of this would underestimate the effect compared with the original data (Walton, et al., 2015).

Summary of health evidence base

1.9.33 Table A.1 provides a summary of the risk ratios, odds ratios, hazard ratios and percentage risks referred to above.

Table A.1: Summary of health evidence base

Health outcome	Type of metric	Lower bound CRF	Central CRF	Upper bound CRF	μg/m³ increase	Source
All cause mortality						
All-cause (natural) mortality ($PM_{2.5}$)	RR	1.06	1.08	1.09	Per 10 μg/m³	COMEAP (2022)
All-cause (natural) mortality (NO_2)	RR	1.031	1.055	1.08	Per 10 μg/m³	WHO HRAPIE (2013)
Chronic obstructive pulmonary disease						
COPD hospital admissions (PM_{10})	OR	1.00	1.01	1.01	Per 10 μg/m³	Moore et al. (2016)
COPD hospital admissions ($PM_{2.5}$)	OR	0.99	1.02	1.04	Per 10 μg/m³	Moore et al. (2016)
COPD hospital admissions (NO_2)	OR	1.02	1.03	1.05	Per 10 μg/m³	Moore et al. (2016)
Child asthma						
Child asthma hospital admissions ($PM_{2.5}$)	RR	1.016	1.029	1.042	Per 10 μg/m³	Walton et al. (2019)
Child asthma hospital admissions (NO_2)	RR	1.018	1.036	1.054	Per 10 μg/m³	Walton et al. (2019)
Child asthma hospital admissions (PM_{10})	% risk	0.20	1.20	2.30	Per 10 μg/m³	Atkinson et al. (2001)
Adult asthma						
Adult asthma hospital admissions (NO_2)	RR	1.001	1.012	1.023	Per 10 μg/m³	Walton et al. (2019)
Adult asthma hospital admissions (PM_{10})	% risk	0.30	0.00	1.80	Per 10 μg/m³	Atkinson et al. (2001)
Lung cancer						
Lung cancer incidence (PM_{10})	HR	1.03	1.22	1.45	Per 10 μg/m³	Raaschou-Nielsen et al. (2013)
Lung cancer incidence ($PM_{2.5}$)	HR	0.91	1.39	2.13	Per 10 μg/m³	Raaschou-Nielsen et al. (2013)
Myocardial infarction						
Myocardial infarction and unstable angina (PM_{10})	HR	1.01	1.12	1.25	Per 10 μg/m³	Cesaroni et al. (2014)
Myocardial infarction and unstable angina ($PM_{2.5}$)	HR	0.98	1.13	1.30	Per 5 μg/m³	Cesaroni et al. (2014)
Myocardial infarction and unstable angina (NO_2)	HR	0.97	1.03	1.08	Per 10 μg/m³	Cesaroni et al. (2014)
Stroke incidence						

Health outcome	Type of metric	Lower bound CRF	Central CRF	Upper bound CRF	µg/m^3 increase	Source
Stroke incidence (PM_{10})	HR	0.90	1.11	1.36	Per 10 µg/m^3	Stafoggia et al. (2014)
Stroke incidence ($PM_{2.5}$)	HR	0.88	1.19	1.62	Per 5 µg/m^3	Stafoggia et al. (2014)
Respiratory disease hospital admissions						
Respiratory disease hospital admissions ($PM_{2.5}$)	% risk	0.63	0.96	2.58	Per 10 µg/m^3	Atkinson et al. (2014)
Respiratory disease hospital admissions (PM_{10})	% risk	0.25	0.60	0.95	Per 10 µg/m^3	Katsouyanni et al. (2009)
Respiratory disease hospital admissions (NO_2)	% risk	0.09	0.52	0.95	Per 10 µg/m^3	Mills et al. (2015)
Cardiovascular disease hospital admissions						
Cardiovascular disease hospital admissions ($PM_{2.5}$)	% risk	0.26	0.90	1.53	Per 10 µg/m^3	Atkinson et al. (2014)
Cardiovascular disease hospital admissions (PM_{10})	% risk	0.20	0.60	1.00	Per 10 µg/m^3	Katsouyanni et al. (2009)
Cardiovascular disease hospital admissions (NO_2)	% risk	0.23	0.42	0.62	Per 10 µg/m^3	Mills et al. (2015)

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