Modelling of fugitive emissions from a large hard rock quarry

John Bruce

Introduction

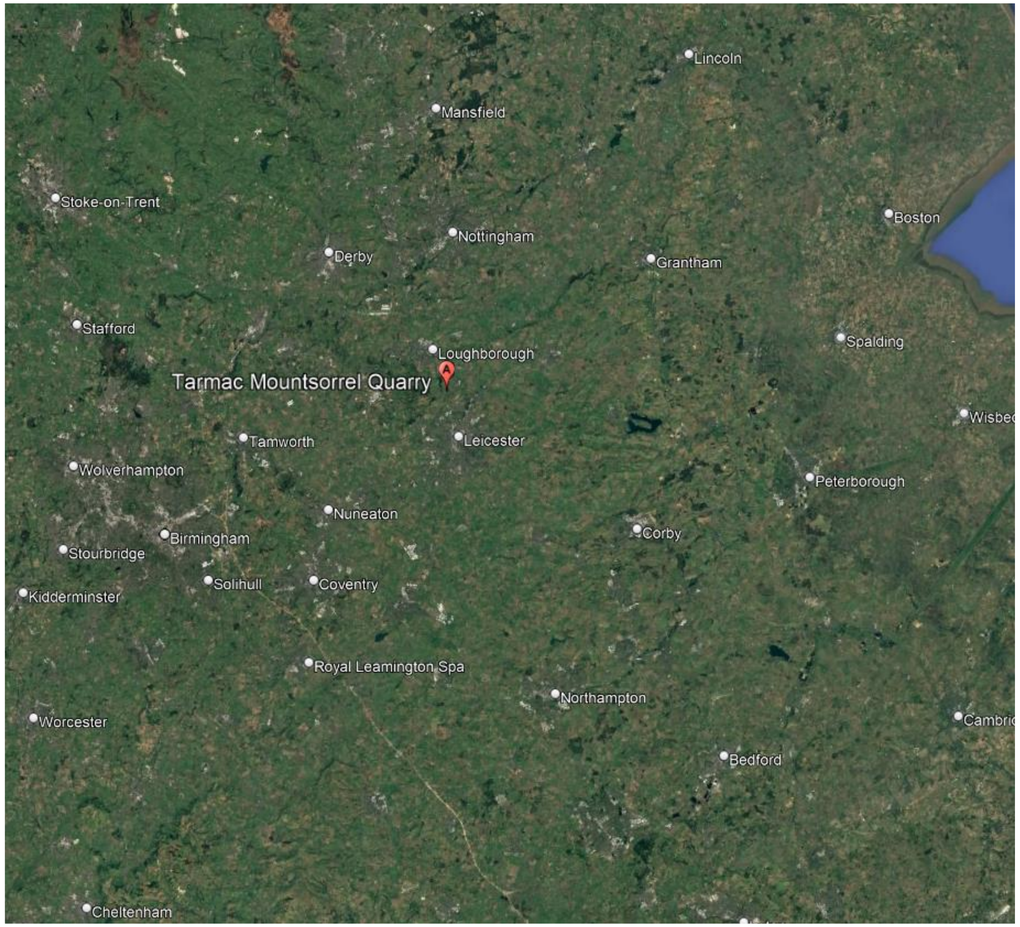
- Principal Consultant at DustScanAQ
- Knowledge Transfer Partnership researching dust dispersion modelling with DustScan at the University of Portsmouth
- PhD included calibration and adjustment of model results using dust monitoring from a mineral site
- Other colleagues that worked on this project: Daniel Quinn, Gordon Allison, Paul Eaton, Hugh Datson, Sarah Doyle

Overview

- Introduction to Mountsorrel Quarry and its air quality history
- Proposed development at Mountsorrel Quarry
- DustScanAQ’s approach to assessing emissions
- Model validation
- Assessment of Respirable Crystalline Silica (RCS)

Case Study: Mountsorrel Quarry

- DustScanAQ have been working closely with Tarmac at Mountsorrel Quarry, in Leicestershire, for many years on dust, odour and air-quality matters.
- The quarry produces approximately 4 million tonnes of granite per annum with reserves to last to 2037.

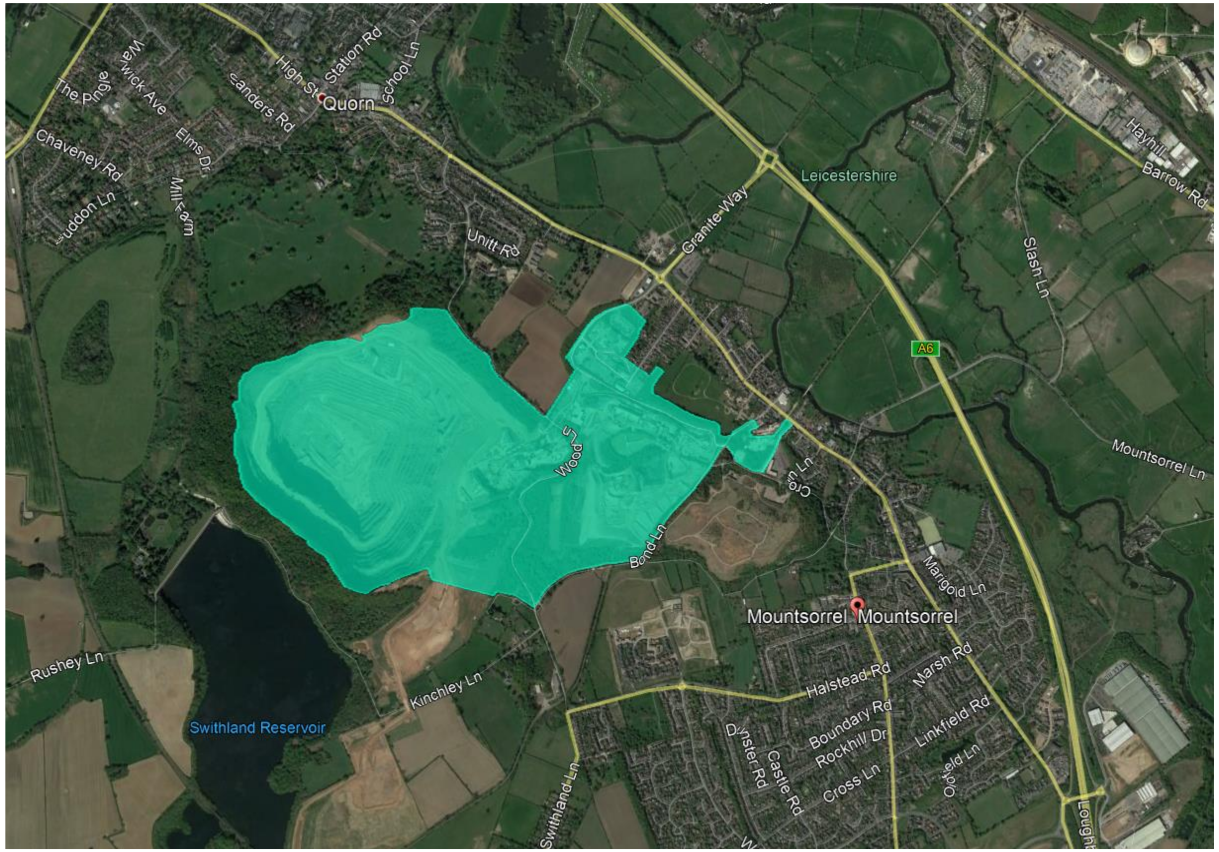


Mountsorrel Quarry

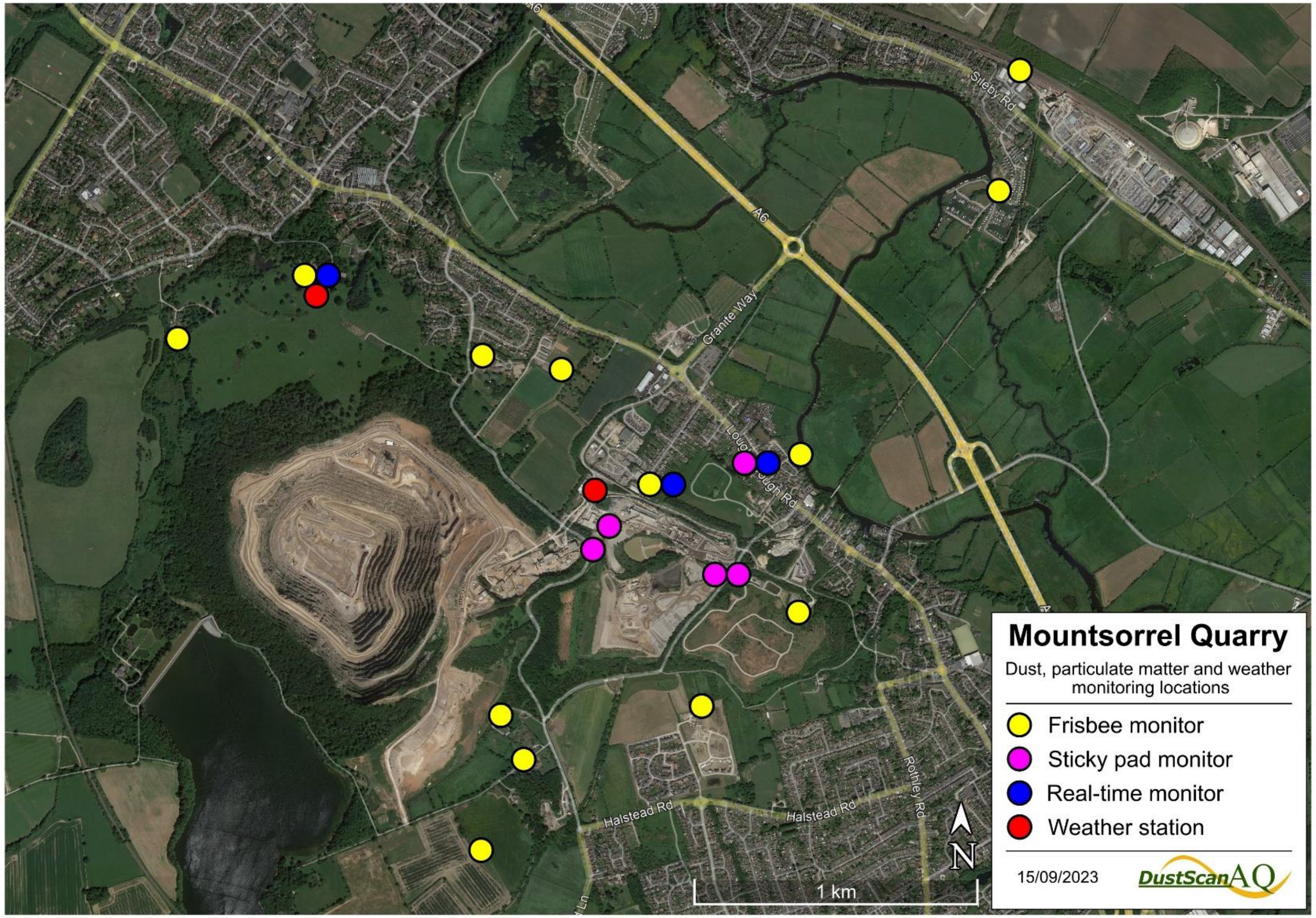
- Blasting of approx. 10,000 m^3 at midday every weekday
- Dump truck trips to processing
- Crushing, screening and concrete batching
- Large mineral storage area

Mountsorrel AQMA

- An AQMA was declared for PM_{10} by Charnwood Borough Council in 2011 for the area comprising the quarry and some residential properties in the neighbourhood.
- Revoked September 2024



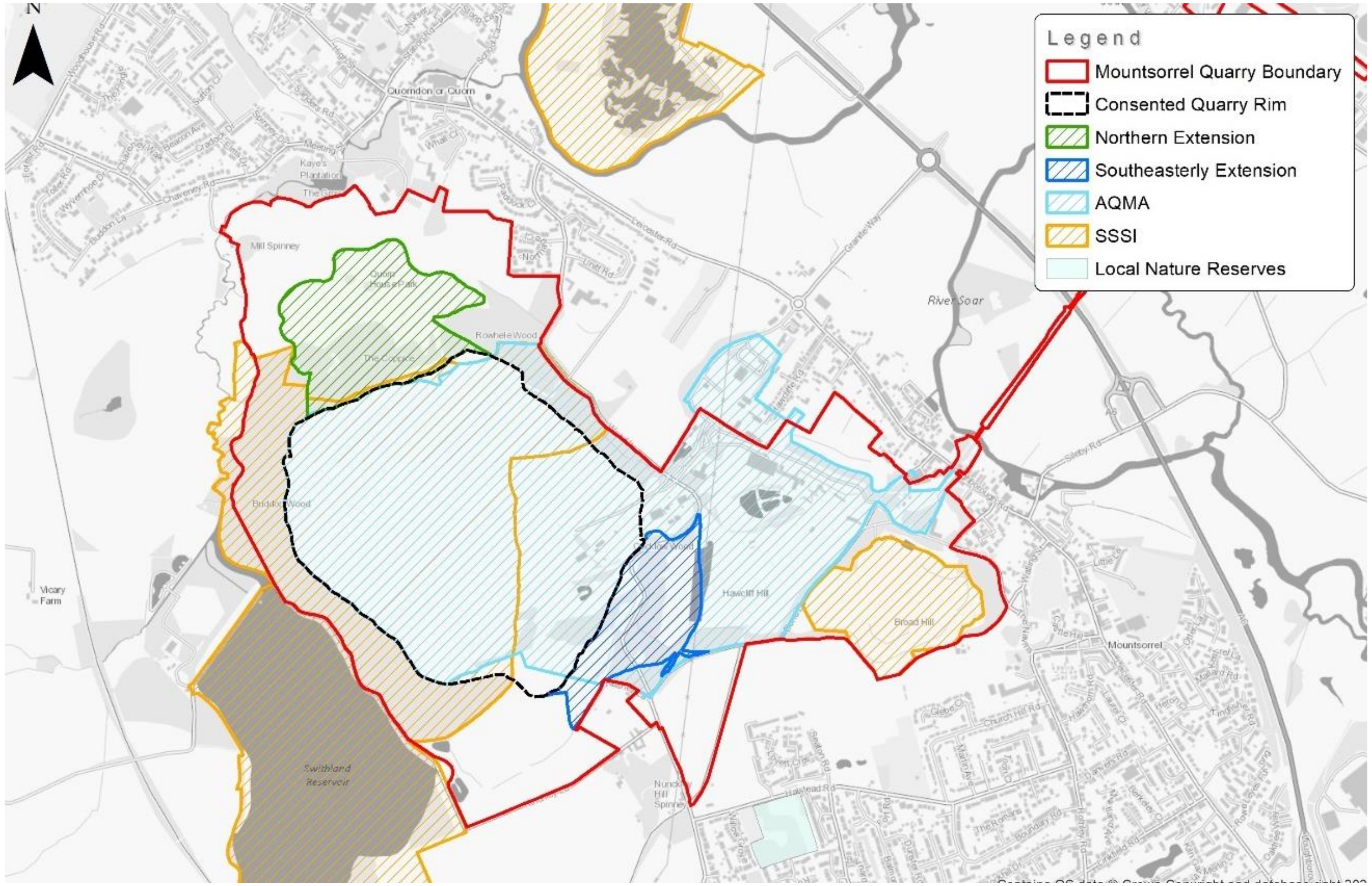
Mountsorrel Dust Monitoring



- Frisbee monitoring since 2012
- Sticky pad monitoring since 2014
- Real-time monitoring since 2017
- DustScan supply a bespoke PM predictor tool with daily $_{10}$advice

Mountsorrel Quarry Extension Proposal

- Tarmac applying to extend the quarry to extend its operational life.
- Extending towards residential receptors to the north and southeast.



The “Standard” Approach

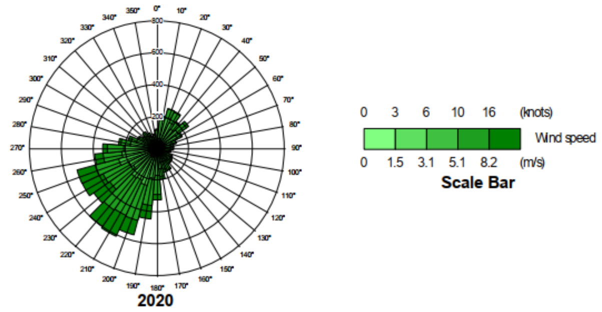
- Uses risk matrix-based analysis
- Relies heavily on professional judgement of the assessor
- No numerical outputs

B: Mineral Extraction

LARGE	SMALL
Large working area	Small working area
High energy extraction methods	Low energy extraction methods
Material of high dust potential	Material of low dust
Potential high extraction rate	Low extraction rate

		Residual Source Emissions		
		Small	Medium	Large
Pathway Effectiveness	Highly effective pathway	Low Risk	Medium Risk	High Risk
	Moderately effective pathway	Negligible Risk	Low Risk	Medium Risk
	Ineffective pathway	Negligible Risk	Negligible Risk	Low Risk

	Receptor Sensitivity		
	Low	Medium	High
High Risk	Slight Adverse Effect	Moderate Adverse Effect	Substantial Adverse Effect
Medium Risk	Negligible Effect	Slight Adverse Effect	Moderate Adverse Effect
Low Risk	Negligible Effect	Negligible Risk	Slight Adverse Effect
Negligible Risk	Negligible Effect	Negligible Effect	Negligible Effect



Pathway effectiveness	Dust impact risk	Magnitude of dust effects
Ineffective	Low Risk	Slight Adverse Effect
Ineffective	Low Risk	Slight Adverse Effect
Ineffective	Low Risk	Slight Adverse Effect
Ineffective	Low Risk	Slight Adverse Effect
Moderately Effective	Medium Risk	Moderate Adverse Effect
Moderately Effective	Medium Risk	Moderate Adverse Effect
Ineffective	Low Risk	Negligible Effect

DustScanAQ

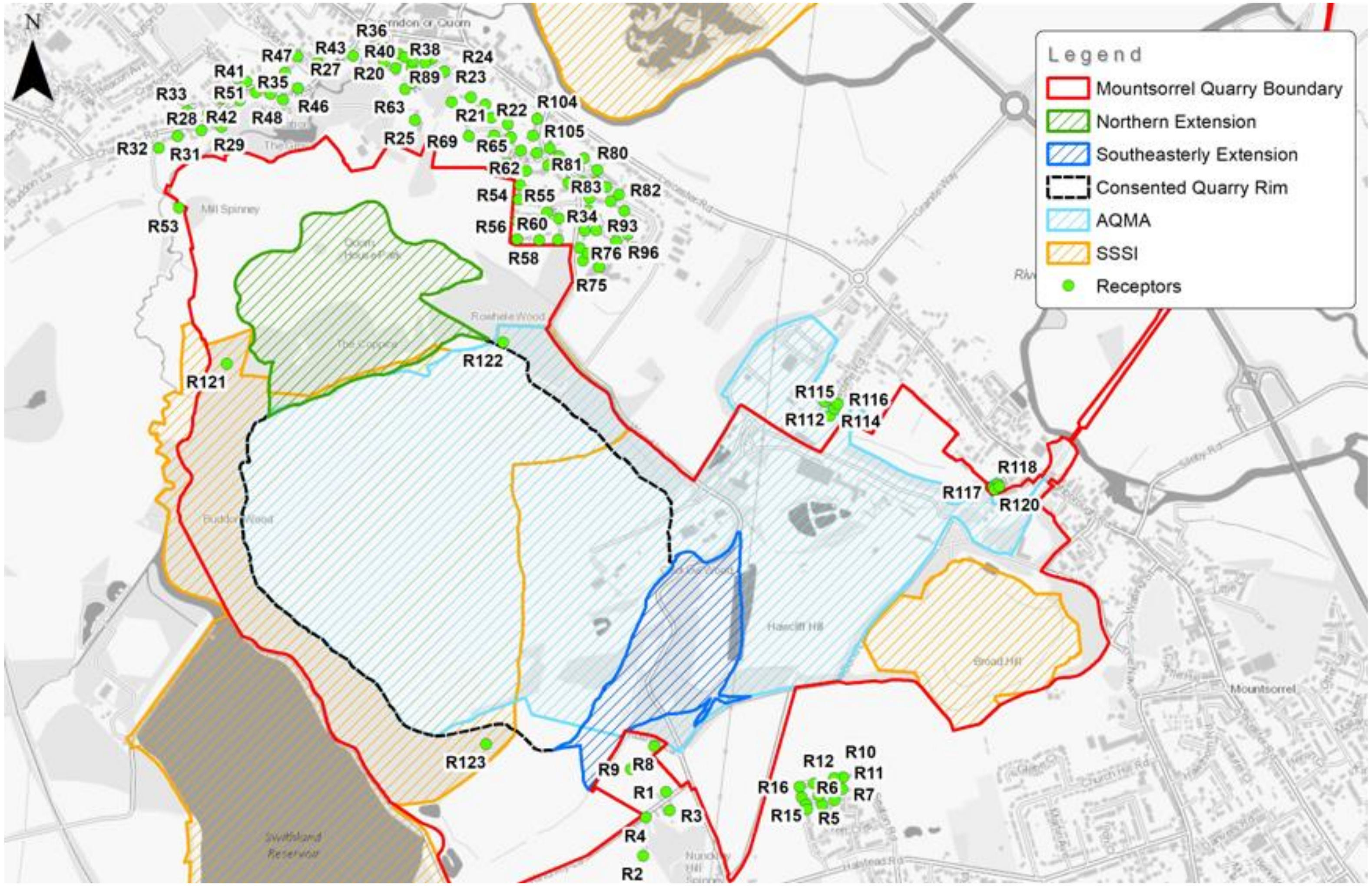
DustScanAQ Approach

- Computational modelling assessment using ADMS6 ran side-by-side with IAQM-style assessment
- Verified the model using a 2019 baseline and real-time and passive dust measurements
- Modelled single future years as snapshots for the northern and southeasterly extensions to assess the maximal impacts for the nearest receptors against a ‘Do Minimum’ scenario
- For each scenario, conservatively assumed 100% of extraction was happening in the extension area – in-reality extraction will be split between both extension areas in varying proportions over time.
- Model outputted $PM_{2.5}$, PM_{10}, PM_{30} (deposited) and Respirable Crystalline Silica (RCS).

DustScanAQ

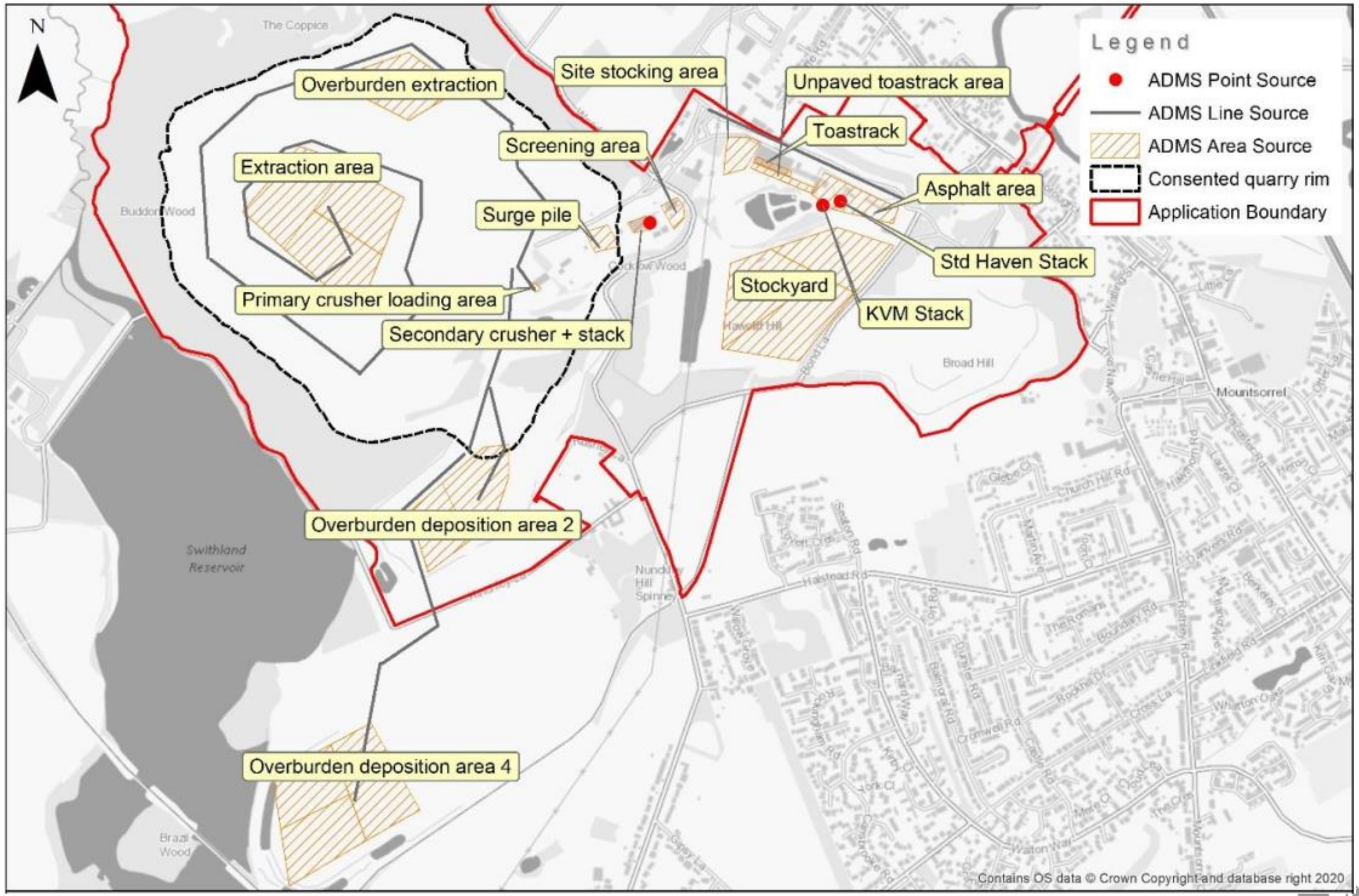
Receptors

- Objective list of relevant receptors obtained from AddressBase.



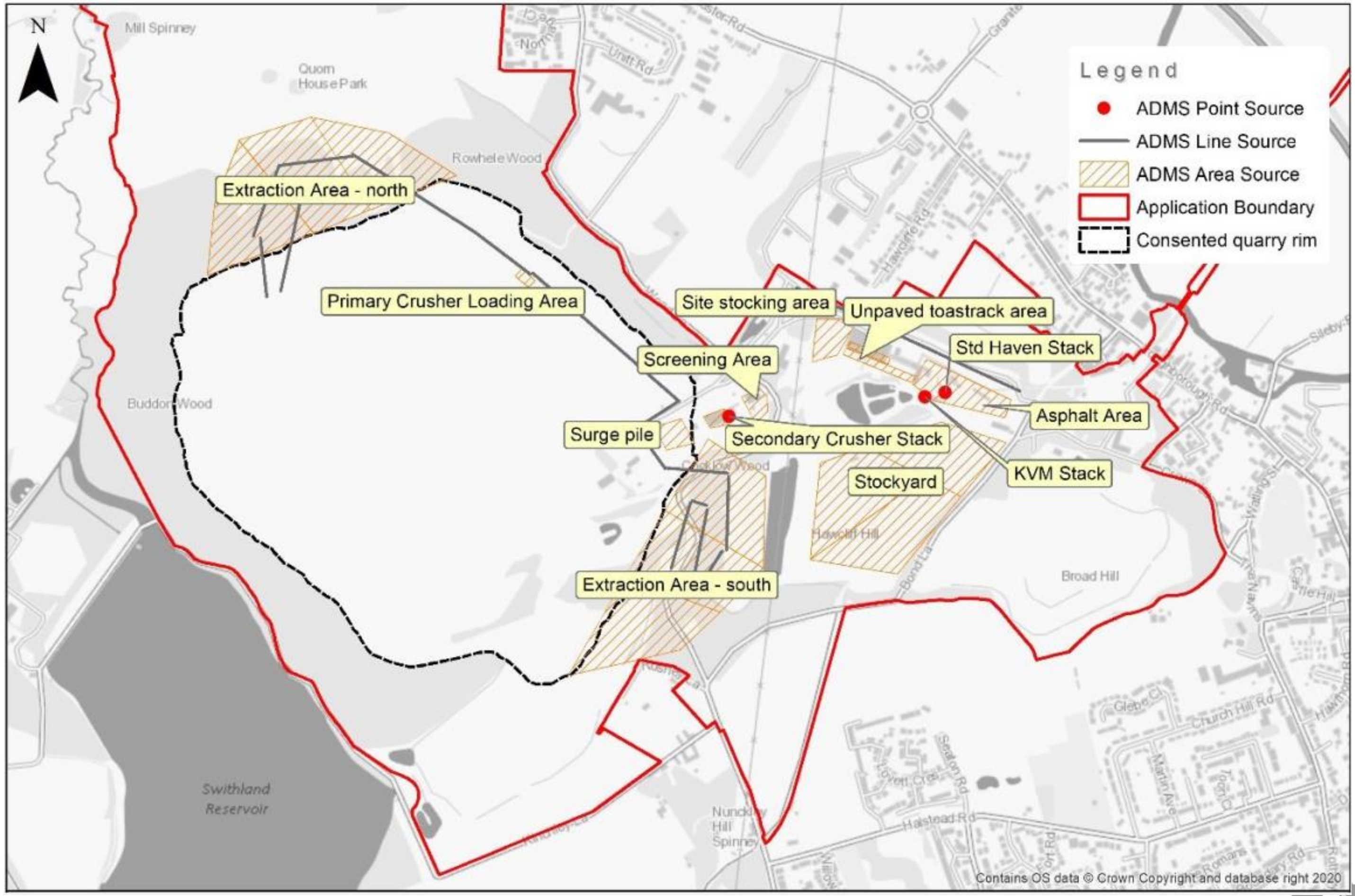
DustScanAQ

ADMS Model Sources – Base Model



- **Area Sources**
  - Overburden stripping
  - Blasting
  - Extraction
  - Stockpiles
  - Crushing
  - Screening
- **Line Sources**
  - Paved Roads
  - Unpaved Roads
- **Point Sources**
  - Asphalt batching

ADMS Model Sources – Future Model

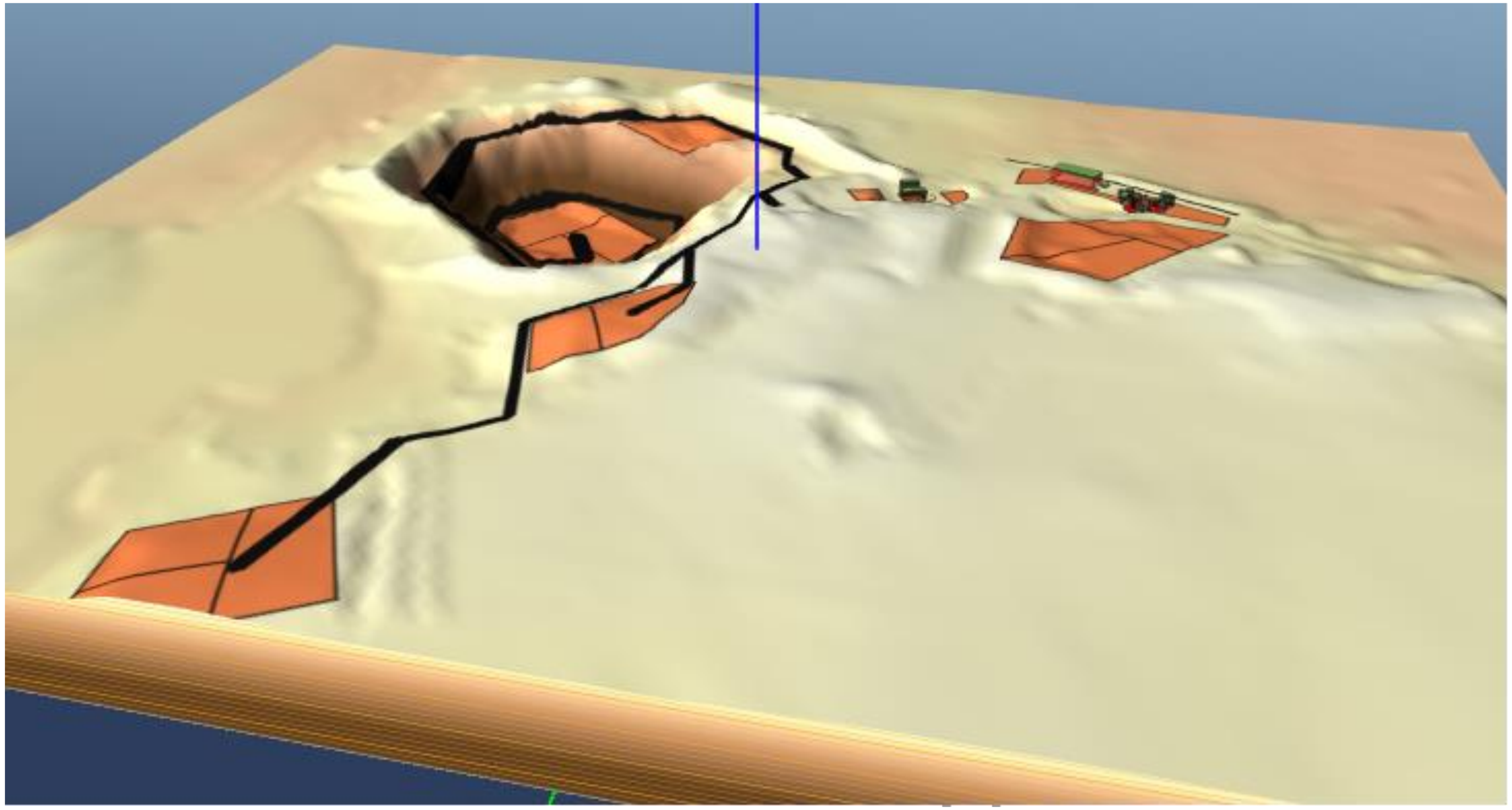


- **Area Sources**
  - ~~Overburden stripping~~
  - *Blasting and extraction (new locations)*
  - Stockpiles
  - *Crushing (new location)*
  - Screening
- **Line Sources**
  - Paved Roads
  - *Unpaved Roads*
- **Point Sources**
  - Asphalt batching

DustScanAQ

ADMS Model – terrain data

- Detailed drone topography terrain data supplied by the operator for both current and future scenarios
- Merged with OS Terrain 50 data



Emissions

- Emissions mostly calculated using US EPA AP 42:
  - 11.9 Western Surface Coal Mining
  - 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing
  - 13.2.1 Paved roads
  - 13.2.2 Unpaved roads
  - 13.2.4 Aggregate Handling and Storage Piles
  - NPI guidance used for wind erosion from stockpiles
  - Stack emissions provided by the operator
- TSP (PM_{30}), PM_{10} and $PM_{2.5}$
- Variables impacting emissions:
  - Silt loading (roads)
  - Mean vehicle weight
  - Number of vehicle movements
  - Quarry throughput
  - Mean wind speed
  - Moisture content
- All time variable emissions by hour and day of the week

Industrial unpaved roads example:

$$E = k\,(s/12)^a\,(W/3)^b$$

Constant	Industrial Roads (Equation 1a)		
	PM-2.5	PM-10	PM-30*
k (lb/VMT)	0.15	1.5	4.9

E = size-specific emission factor (lb/VMT)
s = surface material silt content (%)
W = mean vehicle weight (tons)

1 lb/VMT = 281.9 g/VKT

Model Validation – PM_{10} and $PM_{2.5}$

- Emissions sources carefully calibrated using monitoring results
- No adjustment factors required

Site	Quorn House Background (µg/m³)	Hawcliffe Road Monitored (µg/m³)	Hawcliffe Road Modelled (µg/m³)
PM_{10}	8.37	13.67	13.75
$PM_{2.5}$	6.10	7.35	6.96

DustScanAQ

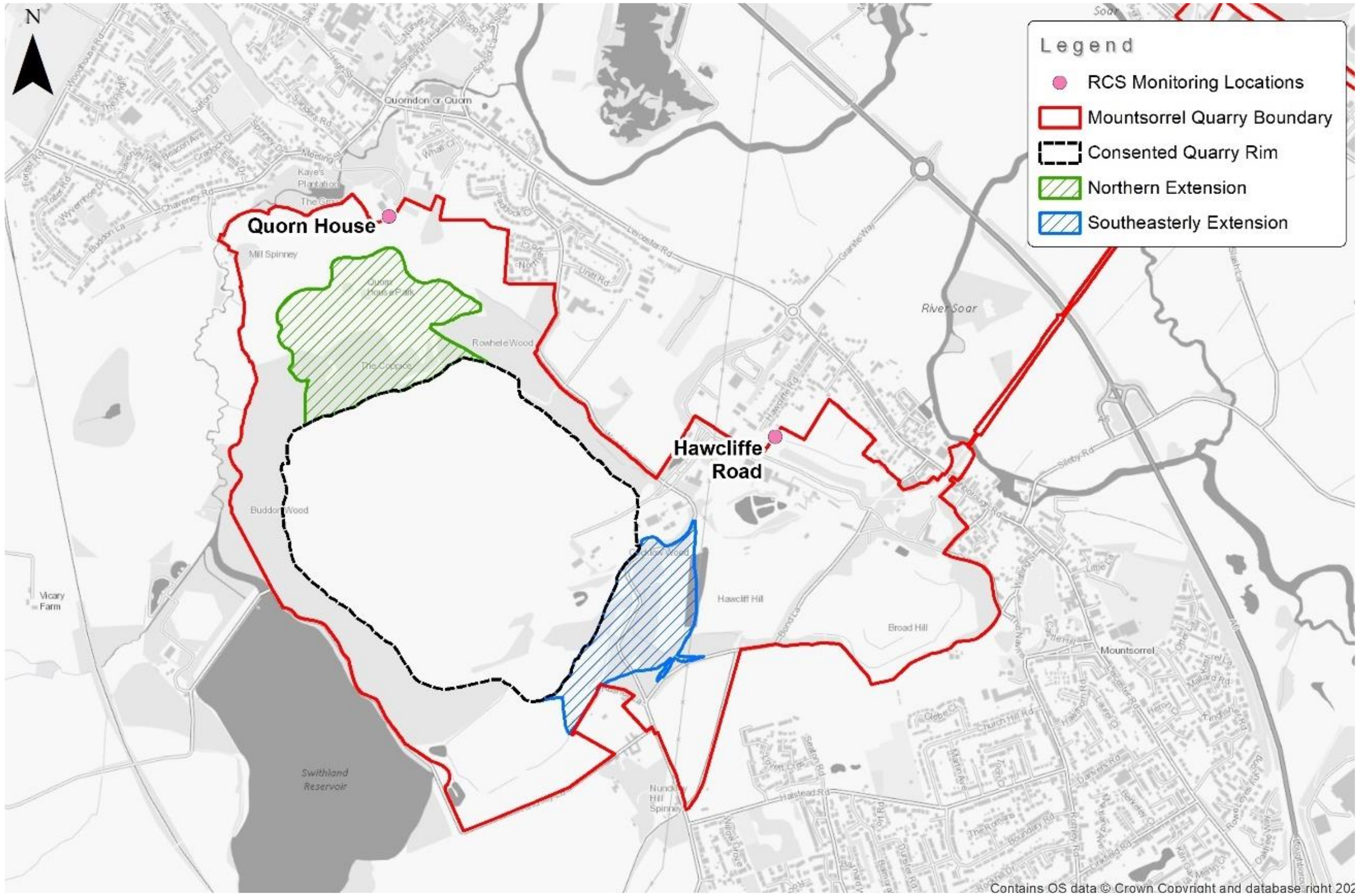
Model Validation – Dust Deposition

- Background added of 20 mg/m^2/day
- Adjustment factor applied of 1.5
- All results within +-50%

Site Name	Monitored Average Deposition (mg/m^2)	Modelled Average Deposition (mg/m^2)	% Difference
Stn 13	19.5	37.2	-48%
Stn 3	27.5	30.2	-9%
Stn 4B	37.8	58.5	-35%
Stn 4A	75.5	50.8	48%
Stn 9	146.1	112.6	30%
Stn 5	25.0	35.6	-30%
Stn 10	48.3	33.3	45%
Stn 1A	39.2	38.0	3%
Stn 1	34.2	56.8	-40%
Stn 1B	26.6	30.7	-13%
Stn 11	49.9	50.0	0%

RCS - Environmental Monitoring

- PM_4 collected on filter using DS500X gravimetric sampler
- Filters analysed for RCS using X-Ray Diffraction (XRD)
- Two monitoring campaigns: winter 2020/21 and summer 2021
- Highest weekly concentration: 0.72 µg/m^3 at Hawcliffe Road
- 100% of results at Quorn House below detection limit (0.1 µg/m^3)
- Background taken to be 0.1µg/m^3, derived from monitoring results from Quorn House (background location)



RCS - Occupational Monitoring

Summary of RCS occupational exposure survey results, May 2022 – March 2023.

OE samples taken	110
Personal samples	56
Static samples	54
RCS as % respirable dust (all samples)	22.5%
RCS as % respirable dust (personal samples)	21.2%
RCS as % respirable dust (static samples)	23.8%
RCS as % respirable dust (static sample highest area exc. railhead – quarry)	28%

Outcome:

RCS conservatively modelled as 28% of $PM_{2.5}$

Model Validation - RCS

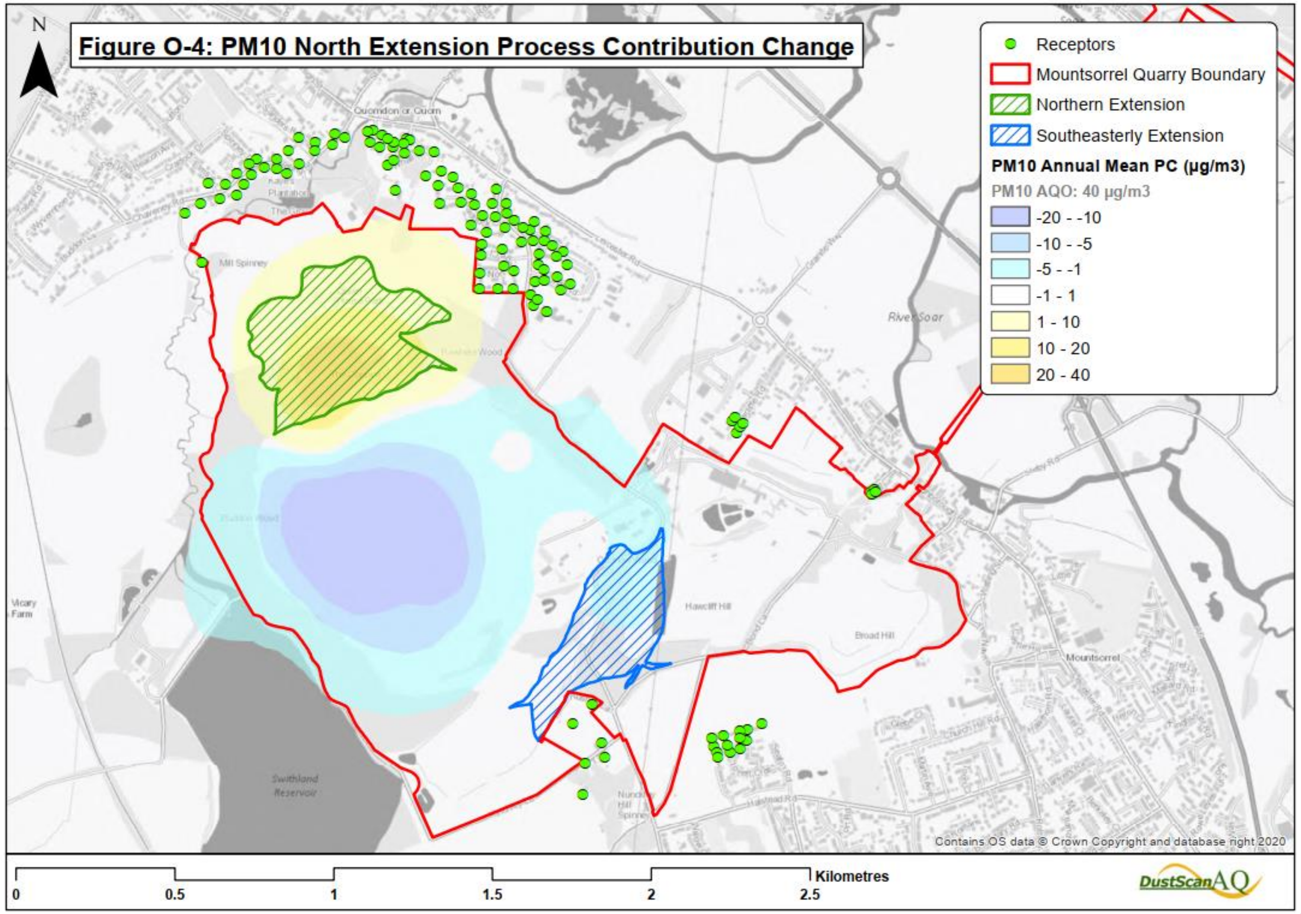
- Model results close to monitored values
- No adjustment factor required
- Likely overestimating at areas where modelled values are low

Site Name	Monitored RCS (µg/m³) – 2020/2021	Modelled RCS (µg/m³) – Baseline 2019	Modelled RCS (µg/m³) – DS North	Modelled RCS (µg/m³) – DS South
Hawcliffe Road	0.26 (winter)	0.33	0.30	0.34
	0.37 (summer)			
Quorn House	0.11 (winter)	0.14	0.17	0.12
	0.10 (summer)			

DustScanAQ

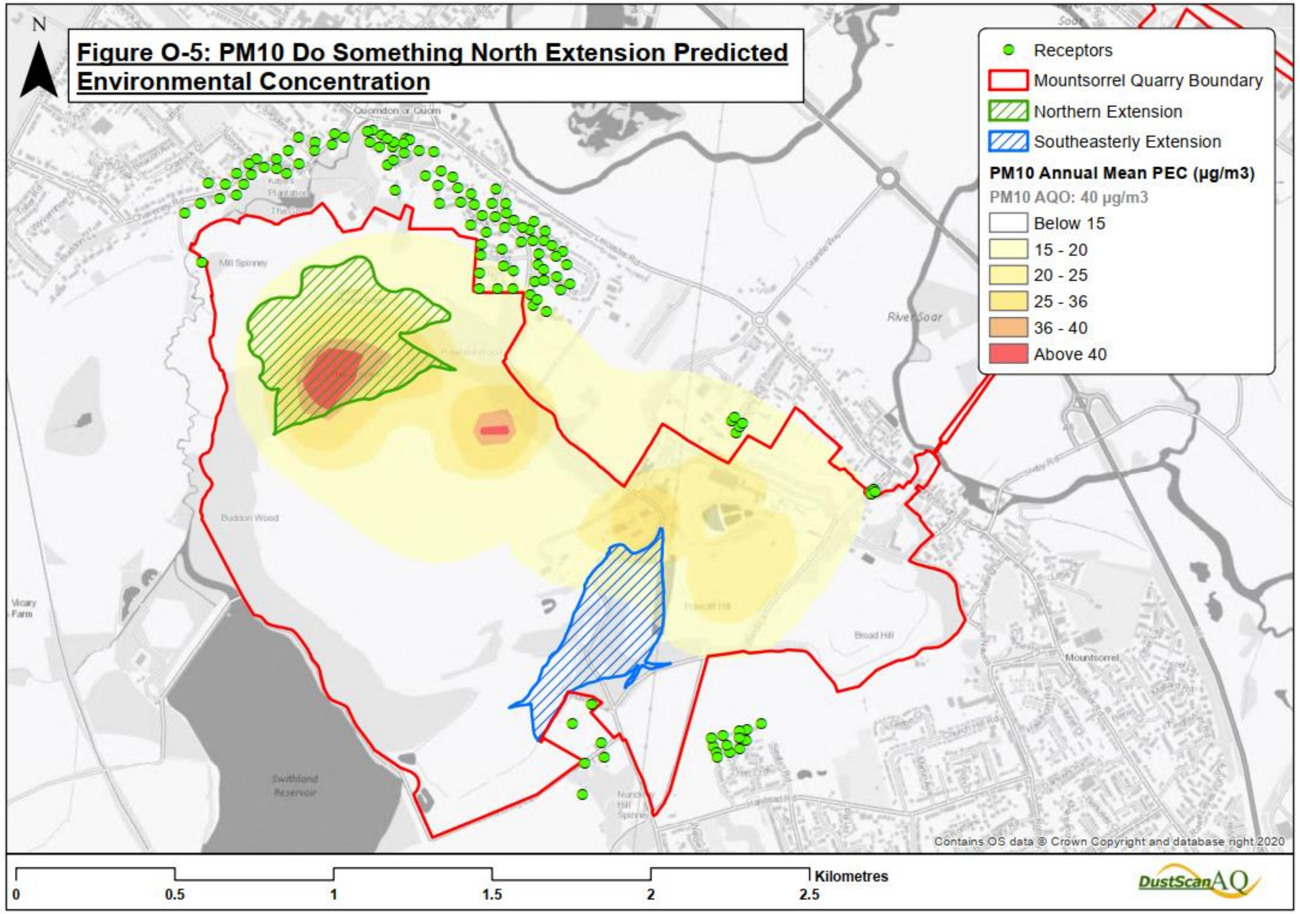
Results – PM_{10} and $PM_{2.5}$

- Max PM_{10} PC 2.93 µg/m^3
- Max $PM_{2.5}$ PC 0.42 µg/m^3
- Max PM_{10} PEC 17.50 µg/m^3
- Max $PM_{2.5}$ PEC 8.55 µg/m^3
- Contour plots for all scenarios (50 in total)



Results – PM_{10} and $PM_{2.5}$

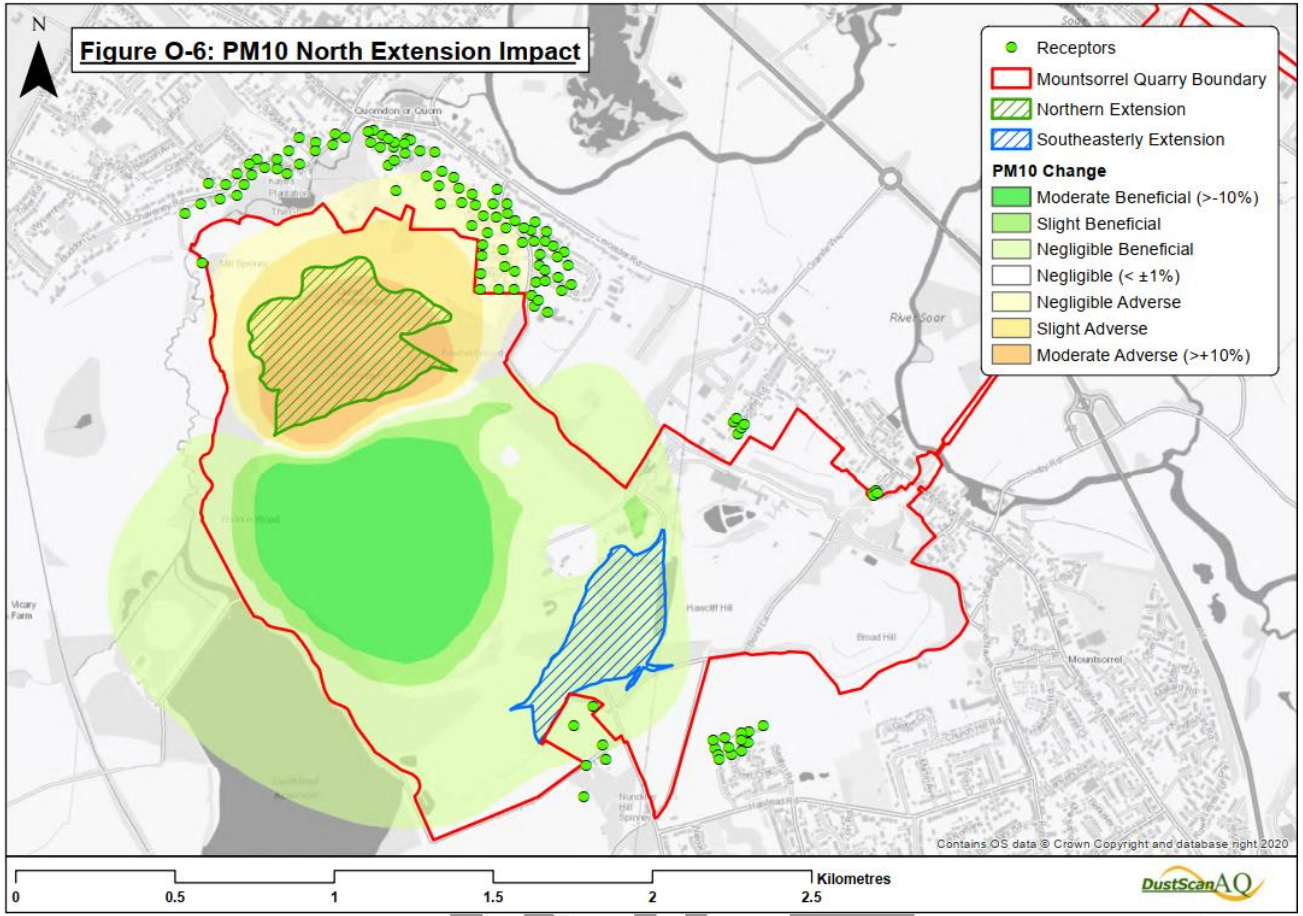
- Max PM_{10} PC 2.93 µg/m^3
- Max $PM_{2.5}$ PC 0.42 µg/m^3
- Max PM_{10} PEC 17.50 µg/m^3
- Max $PM_{2.5}$ PEC 8.55 µg/m^3
- Contour plots for all scenarios (50 in total)



DustScanAQ

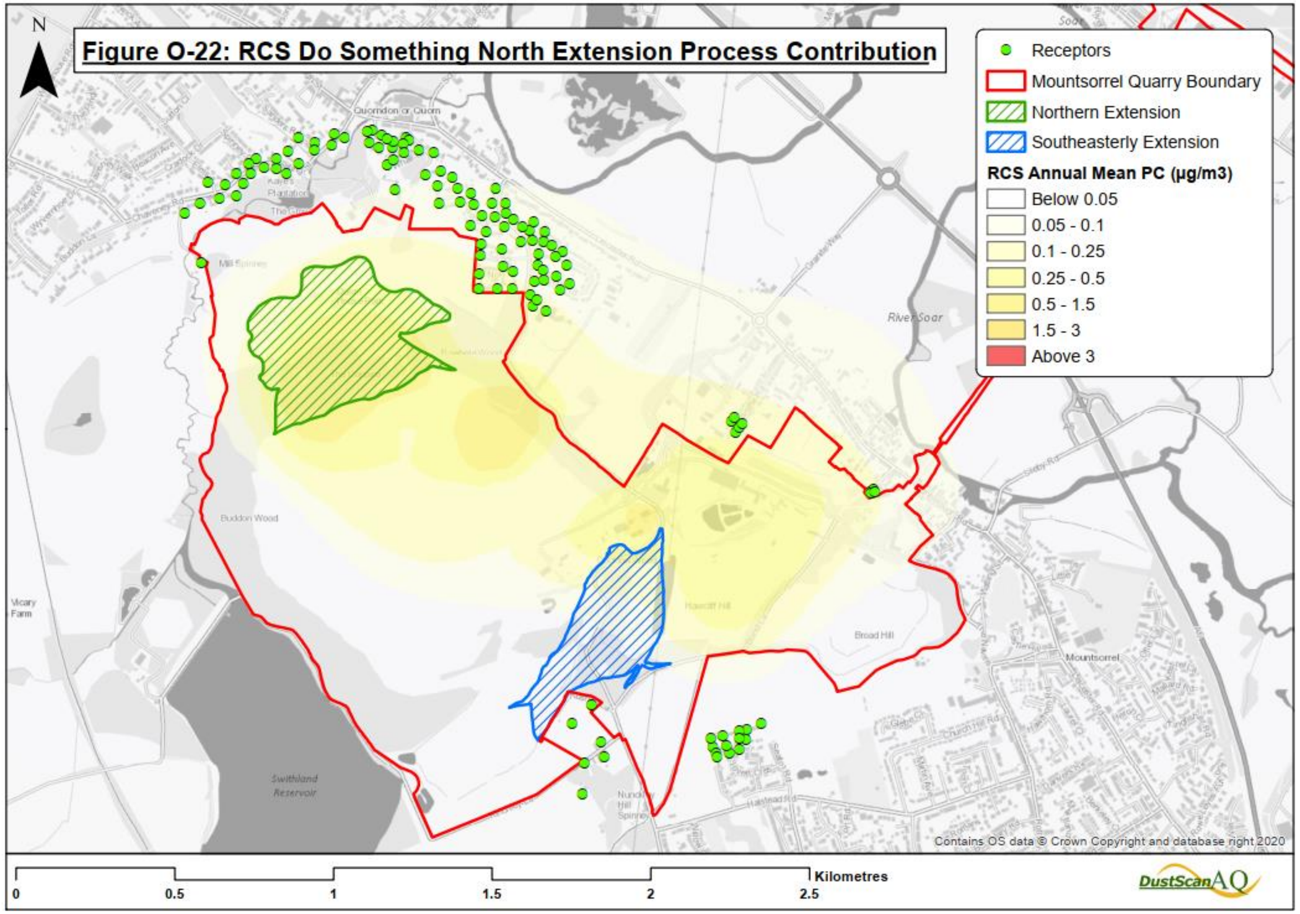
Results – PM_{10} and $PM_{2.5}$

- Max PM_{10} 90.4th percentile 17.38 µg/m^3
- Some 'slight' impacts for PM_{10} and $PM_{2.5}$ but mostly negligible



Results - RCS

- Results compared against Californian RCS reference exposure level (3 µg/m^3)
- Max RCS contribution at a receptor 0.119 µg/m^3 (PEC 0.263 µg/m^3)
- Max RCS PEC 0.300 µg/m^3
- Contour plots for all scenarios



Results – dust deposition

- Highest deposition rate contribution estimated at 66.6 mg/m^2/day
- Highest PEC 105.3 mg/m^2/day
- Results compare favourably to a corresponding IAQM risk-based approach

No.	Receptor	Maximum magnitude of dust effect	Maximum predicted annual average deposition (mg/m^2/day) – Do Minimum	Maximum predicted annual average deposition (mg/m^2/day) – northern extension	Maximum predicted annual average deposition (mg/m^2/day) – south-easterly extension
R1	1 Kinchley Lane	Slight Adverse Effect	31.6	26.6	39.8
R2	12 Kinchley Lane	Slight Adverse Effect	27.9	24.7	30.8
R3	2 Kinchley Lane	Slight Adverse Effect	30.1	25.9	36.0
R4	8 Kinchley Lane	Slight Adverse Effect	30.1	25.7	35.0
R5	32 Lovett Crescent	Negligible Effect	27.6	25.0	29.9
R6	37 Lovett Crescent	Negligible Effect	27.5	25.0	29.9
R7	45 Lovett Crescent	Negligible Effect	28.1	25.3	30.7
R8	2 Rushey Lane	Moderate Adverse Effect	36.6	28.4	66.6
R9	4 Rushey Lane	Moderate Adverse Effect	34.3	27.1	45.3

Outcomes

- Quarry planning is subject to increasd public interest – recent petition to Senedd for 1000 meter mandatory buffer zone
- Assessment provides quantitative assessment of proposed development
- Very high level of intricate detail required by the operator and a significant piece of work
- Model accuracy is good as calibrated using a comprehensive monitoring dataset
- Dust monitoring data is often not available
- IAQM guidance assessment still provided similar results for disamenity dust and is currently under review

Future Work

- The advent of low-cost PM Sensors and more dust monitoring data means that the old AP42 factors could be improved on, and acquired in the UK temperate climate
- An inverse modelling technique developed by the model software developer could be applied to field datasets acquired for specific activities, where source apportionment is used to disaggregate the source contribution

DustScanAQ

Any Questions?

John Bruce
johnb@dustscan.co.uk