Caerphilly County Borough Council

HAFODYRYNYS, CAERPHILLY - WELTAG STAGE TWO REPORT

Consideration of Measures for Nitrogen Dioxide Reduction

70046187
OCTOBER 2018

PUBLIC

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FINAL - PUBLIC

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EXECUTIVE SUMMARY

The European Union Ambient Air Quality Directive (2008/50/EC) sets legally binding limits for concentrations of certain air pollutants in outdoor air, termed ‘limit values’. The Directive requires that Member States report annually on air quality within zones designated under the Directive and, where the concentration of pollutants in air exceeds limit values, to develop air quality plans that set out measures in order to attain the limit values. The only limit values that the UK currently fails to meet are those set in respect of nitrogen dioxide (NO_2).

In July 2017, the UK Government published its Air Quality Plan (the 2017 Plan) for tackling roadside NO_2 concentrations. The 2017 Plan set out details of the authorities responsible for delivering air quality improvements including devolved administrations and Local Authorities.

Caerphilly County Borough Council (CCBC) is exploring additional measures which could be implemented on the A472 to bring forward compliance with NO_2 Limit Values in the shortest possible time. With no intervention, the expected compliance date on the A472 is 2029.

A WelTAG Stage One appraisal has been undertaken and is reported under separate cover. The WelTAG Stage One assessment considered a long list of 30 measures and appraised the measures based on their ability to meet the objective. In total, 10 measures were shortlisted for a more detailed appraisal at Stage Two based on their ‘effectiveness’ at reducing NO_2, their timescales for implementation relative to the expected compliance data, and the feasibility of implementing the measure under the powers available to the Authority.

A more detailed appraisal has been undertaken at WelTAG Stage Two, with detailed air quality modelling which is underpinned by assumptions on likely impacts on traffic. This report presents the Stage Two: Outline Business Case of the WelTAG process for reducing the levels of NO_2 at Hafodyrynys Road Air Quality Management Area through a list of measures that are considered beneficial.

Following the Stage Two Appraisal, there are a set of short, medium, and long-term measures that have been recommended to reduce NO_2 at Hafodyrynys. Immediate measures include the low cost, short timeframe measures, and other low to medium costs measures that could be implemented in a temporary, and then permanent basis. For the A472 these include:

- **Measure 01**: Change Signal Timings at Crumlin Junction
- **Measure 27**: Air Quality Public Awareness Campaign

Medium Term Measures require further consultation and analysis to be undertaken prior to implementation. This includes:

- **Measure 13**: Peak Hour HGV Bans

Long Term Measures may be implemented on a permanent basis though would be required to undergo Stage Three (Business Case) appraisal. These are:

- **Measure 02**: Signalise the A472/B4471 Swyffryd Junction and introduce an eastbound queue detector
- **Measure 11:** Demolish Dwellings at Woodside Terrace and Re-align Road
- **Measure 26:** Clean Air Zone / Low Emission Zone

1. INTRODUCTION

1.1. CONTEXT

1.1.1. The European Union Ambient Air Quality Directive (2008/50/EC) sets legally binding limits for concentrations of certain air pollutants in outdoor air, termed 'limit values'. The Directive requires that Member States report annually on air quality within zones designated under the Directive and, where the concentration of pollutants in air exceeds limit values, to develop air quality plans that set out measures in order to attain the limit values. The only limit values that the UK currently fails to meet are those set in respect of nitrogen dioxide (NO_2).

1.1.2. In July 2017, the UK Government published its Air Quality Plan (the 2017 Plan) for tackling roadside NO_2 concentrations[1]. The 2017 Plan set out details of the authorities responsible for delivering air quality improvements including devolved administrations and Local Authorities.

1.1.3. Wales is divided into 4 zones under the Directive, the Hafodyrynys study falls in to the non-agglomeration zone of south Wales:

- Two urban agglomeration zones (Cardiff and Swansea)
- Two non-agglomeration zones (North Wales and South Wales)

1.1.4. Caerphilly County Borough Council (CCBC) is exploring additional measures which could be implemented on the A472 to bring forward compliance with NO_2 Limit Values in the shortest possible time.

1.1.5. WSP and Ricardo have been commissioned to undertake WelTAG Stage One (Strategic Outline case) and WelTAG Stage Two (Outline Business Case) appraisals of potential measures deliverable by CCBC for reducing NO_2 levels arising from traffic emissions at this location. As part of the Stage One appraisal, a long list of 30 measures were put forward. The 10 measures that met the criteria to pass at Stage One have been taken forward as part of the Stage Two WelTAG Outline Business Case.

1.1.6. Where measures have been considered as not being deliverable by CCBC using its powers as Highway or Traffic Authority for the local road network, these will be considered further in the overarching Welsh Government appraisal which is independent of this study.

1.1.7. This report presents the Stage Two: Outline Business Case of the WelTAG process for reducing the levels of NO_2 at Hafodyrynys Road Air Quality Management Area through a list of measures that are considered beneficial.

1.2. STUDY AREA

1.2.1. The study area has been selected based on data from an air quality monitoring site, which is part of the UK Automatic Urban and Rural Network (AURN). This monitor complies with requirements detailed in the EU Directive (2008/50/EC) to report on the concentrations of particular pollutants in the atmosphere.

1.2.2. The A472 study corridor is the focus of this WelTAG study but it is acknowledged that the measures and their subsequent impacts may be realised beyond the identified area with NO_2 exceedances.

1.2.3. Hafodyrynys is a small village community, which lies just inside the Caerphilly County Borough Council boundary between Crumlin and Pontypool on the A472. Woodside Terrace is the row of houses that are situated in the foot of a high sided valley on the southern side of the A472, between Crumlin junction and Hafodyrynys village.

1.2.4. Woodside Terrace is a row of three storey terraced houses with entrances to the first floor from street level and a large supporting wall on the north side. Immediately adjacent to Woodside Terrace and also on the south side of the A472 is Woodside shops, a pair of semi-detached, two-storey properties and 'Yr Adfa', a detached property also two storeys in height.

[1] UK plan for tackling roadside nitrogen dioxide concentrations; Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/633269/air-quality-plan-overview.pdf - Accessed 10th November 2017

1.2.5. On top of the north side supporting wall there is a mixture of two storey semi-detached and detached housing.

1.2.6. The A472 is part of the strategic highway network and is a major commuter and cross-country freight route where traffic is known to become congested along Woodside Terrace, especially during the AM peak.

1.2.7. The A472 study corridor is located between the signal controlled junction with the A467 in Crumlin (west) and Hafodyrynys village (east), a distance of approximately 1.6km. Over this route there is a considerable increase in elevation (approximately 97m). The study corridor is illustrated in Figure 1.

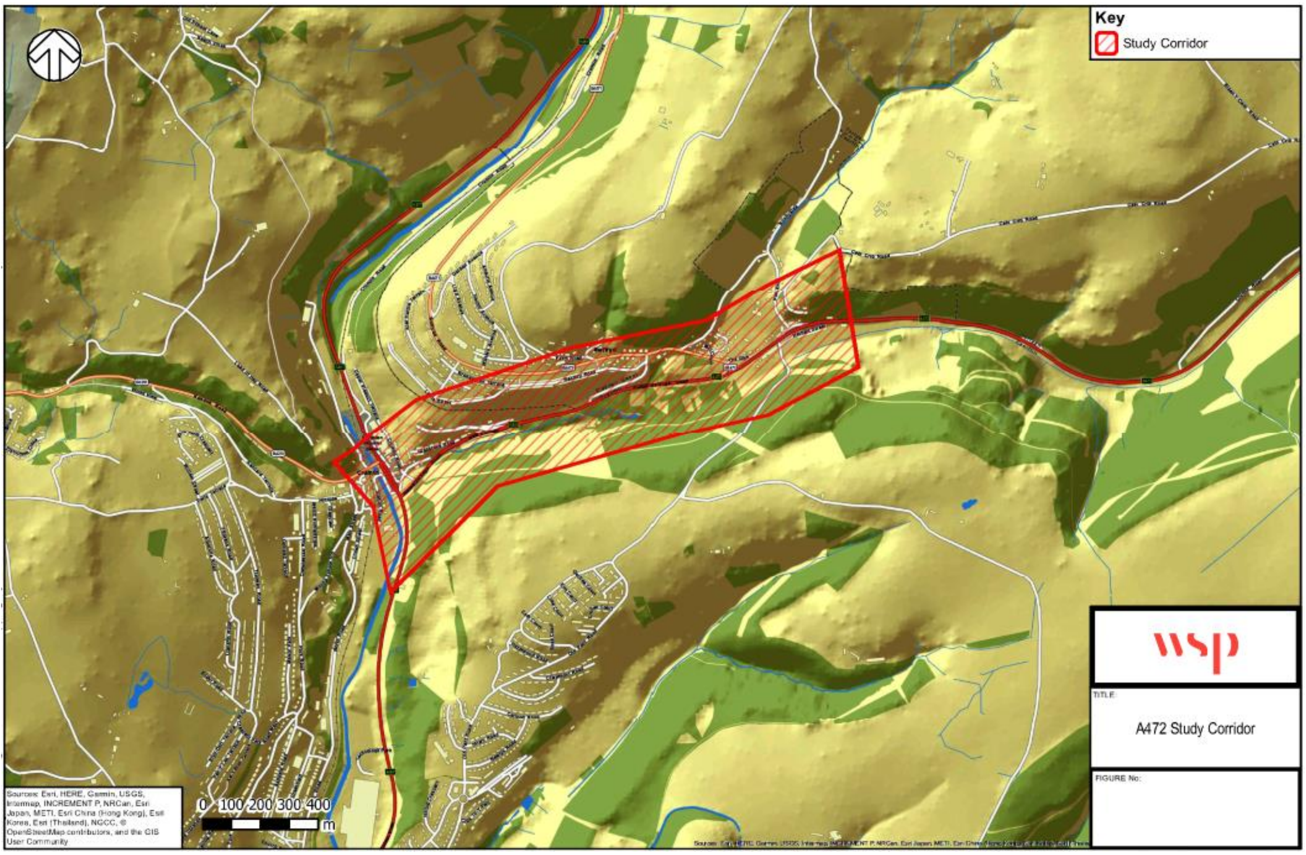

Figure 1: Study Corridor

1.3. APPROACH

1.3.1. WelTAG is the Welsh Transport Appraisal Guidance, and provides a framework for appraising changes to the transport network. The latest version of this guidance (WelTAG 2017[2]) has been used as the basis for this appraisal. As well as embedding the Well-being of Future Generations (Wales) Act 2015, WelTAG combines the principles of the HM Treasury Green Book and the Five Case Model for Better Business Cases, with WebTAG best practice for transport appraisal. The process covers the complete lifecycle of a proposed intervention, from problem identification to scheme design, and implementation and evaluation.

[2] Source: https://beta.gov.wales/sites/default/files/publications/2017-12/welsh-transport-appraisal-guidance.pdf Accessed February 2018

1.3.2. The contents of each Stage Report should follow the structure of the Five Cases Model used by the Welsh Government and HM Treasury. The Five Cases, as applied to transport appraisal, are summarised as follows:

- **Strategic case**: the case for change, fit with policies and well-being objectives
- **Transport case:** does the proposal offer good public value for money and maximise contribution to the well-being goals?
- **Financial case:** is the proposed spend affordable?
- **Commercial case:** how can the scheme be procured? Is it commercially viable?
- **Management case:** is the scheme achievable? Can it be delivered?

1.3.3. The WelTAG guidance states that the purpose of the Stage Two: Outline Business Case is to:

'examine in greater detail the short list of options (measures) for tackling the problem under consideration'.

1.3.4. As such, this Stage Two: Outline Business Case report:

- Determines whether there are any transport measures that can address the identified problem(s) and can be delivered;
- Selects a preferred measure(s) to be taken forward to Stage Three (the Full Business Case);
- Agrees the methods to be used to provide additional evidence where required for the Stage Three (Full Business Case) assessment;
- Identifies any legislative requirements that need to be met during the Stage Three (Full Business Case) assessment; and
- Documents the decisions of the Stage Two Review Group, and the basis for these decisions.

1.3.5. Whilst WelTAG provides a fixed framework for appraisal, the guidance acknowledges that the level of detail provided in the WelTAG reports should be proportionate to the impacts under consideration. All major impacts and issues that could have a significant influence on delivery should be presented, but the level of detail in any analytical work should be proportionate to the scale and significance of the impact and sufficiently accurate for the decisions that need to be made.

1.3.6. The objective of this study is to **carry out an initial investigation and identify potential measures deliverable by CCBC which will assist in bringing forward reductions in NO_2 in the shortest possible time to ensure compliance with the Air Quality Framework Directive requirements along the A472. Therefore, the transport case will focus on air quality and reflect the key considerations in relation to the EU Air Quality Directive and bringing forward compliance with limit values.**

1.4. REPORT STRUCTURE

1.4.1. The structure of this Stage Two report is as follows:

Chapter 2: Strategic case

This chapter presents a baseline of the existing situation, including an overview of legislation and policies and a description of the current EU Limit Value compliance status. It outlines the objective and the EU Air Quality Directive and includes an evidence-based description of the current problem. A brief commentary is provided regarding the development of the long list of measures and how they plan to address the current problem. Information is provided on how the Goals, Objectives and Ways of Work have been considered.

Chapter 3: Transport case

This chapter provides a summary of the appraisal against the objective through consideration of the key criteria. Therefore, the transport case will focus on air quality and reflect the key considerations in relation to the EU Air Quality Directive and bringing forward compliance with limit values.

Chapter 4: Financial case

This chapter provides a high-level analysis of potential funding mechanisms for delivery.

Chapter 5: Commercial case

This chapter includes a description as to whether the measures are commercially viable, and provides an analysis as to whether measures could be packaged together for a phased delivery.

Chapter 6: Management case

This chapter identifies the WelTAG Review Group and the delivery arrangements of any potential measures.

1.4.2. The conclusion of this Stage Two report includes a list of preferred measures, or package of measures which should be taken forward to Stage Three (Full Business Case), based on their ability to solve the problem, their fit with the objective, and their impacts, deliverability and robustness under uncertainty.

2. STRATEGIC CASE

2.1. LEGISLATIVE AND POLICY CONTEXT

2.1.1. This Chapter of the WelTAG Stage Two report builds upon the Strategic Case included as part of the WelTAG Stage One. It provides a narrative of how the short list of measures was derived and considers in greater detail how each measure addresses the problem.

2.1.2. To avoid repetition, a list of the key policies have been included within this section. For further detail, please refer to the Stage One (Strategic Outline Case) report.

2.2. UK AND WELSH LEGISLATION AND POLICY SUMMARY

- Air Quality Standards (Wales) Regulations 2010 (Welsh Statutory Instrument No 1433 (W.126))
- The Environment (Wales) Act 2016
- Planning Policy Wales (PPW)
- Technical Advice Notes (TANs)
- Local Air Quality Management (LAQM) Policy Guidance in Wales
- The Wales Transport Strategy (which is currently under review and will be published in draft for consultation during 2018)
- National Transport Finance Plan
- The Well-being of Future Generations (Wales) Act
- Taking Wales Forward 2016
- Prosperity for all 2017
- One Wales: One Planet (2009)
- One Wales: Connecting the Nation – The Wales Transport Strategy (WTS) (2008)
- Welsh WFGA National Indicators
- WFGA WG Objectives (November 2017)
- Planning (Wales) Act (2015)
- Highways Act 1980

2.3. REGIONAL SUMMARY

- The South-East Wales Valleys Local Transport Plan (LTP) - 2015

2.4. LOCAL SUMMARY

- Caerphilly Local Development Plan (LDP)
- CCBC's 2017 Air Quality Progress Report

AIR QUALITY

2.4.1. Caerphilly County Borough Council, like many other urban areas, experience elevated levels of Nitrogen Dioxide (NO_2) due mainly to road transport emissions. As such the Council (CCBC) has designated two Air Quality Management Areas (AQMA) across the Borough where concentrations of NO_2 breach Government, health-based air quality objectives and has undertaken reviews of current and predicted levels in the future, including assessments of measures to reduce pollution levels.

2.4.2. The automatic monitoring site at Woodside Terrace was installed on the 29th November 2011 (Figure 2). This section undertakes an analysis of data measured during the period 1st January 2012 to 31st December 2017. All years had data capture of 93% or greater, providing valid data for all years considered. No meteorological data are collected at the site however modelled wind direction and wind speed data are derived for the site.

2.4.3. Measured weather data from Cardiff Airport were input to a weather model which took account of topography over a 11km x 9km area centred on Hafodyrynys.

Figure 2: Hafodyrynys Air Quality Monitoring Site (green box)

2.4.4. The PCM model projections presented in support of the 2017 Plan indicate that annual mean NO_2 concentrations on the section of the A472 under consideration will reach compliance with air quality limit values by 2026. However this was based on 2015 monitoring data and since then there has been no reduction in NO_2 levels. Using national projection factors which account for the effect of improved emissions from the turnover in the vehicle fleet, the estimated year of compliance is 2029 from a 2017 baseline, as shown in Table 1 (i.e. projected concentrations at or below 40µg/m^3).

Site Location	**NO_2 Predicted Baseline Concentration (µg/m^3)**				
	2017	**2020**	**2023**	**2026**	**2029**
A472 (Woodside Terrace)	70	61.1	51.8	44.8	39.7

Table 1: Predicted Maximum NO_2 Concentrations at the A472 – No interventions

2.4.5. Figure 3 shows the trend in exceedances of the annual and hourly NO_2 limit values. Since monitoring began the site has been out of compliance with both limit values every year. The annual mean concentration has remained relatively static, fluctuating just 3 µg/m^3 over the period. In contrast the number of hourly exceedances has fluctuated quite significantly, with the highest number of exceedances in 2012 (137) and 2017 (132) and the lowest in 2014 (75) when the roadworks was on-going and traffic flows impeded.

2.4.6. Figure 4 shows the temporal trends in concentrations for hours of the day, days of the week, and months of the year. This analysis clearly shows the influence of traffic on concentrations with the highest concentrations recorded during rush hour on weekday mornings between 6am and 7am and the second highest during afternoon rush hour around 5pm. Also, of interest is the strong seasonal influence with winter months having significantly higher concentrations than the summer months.

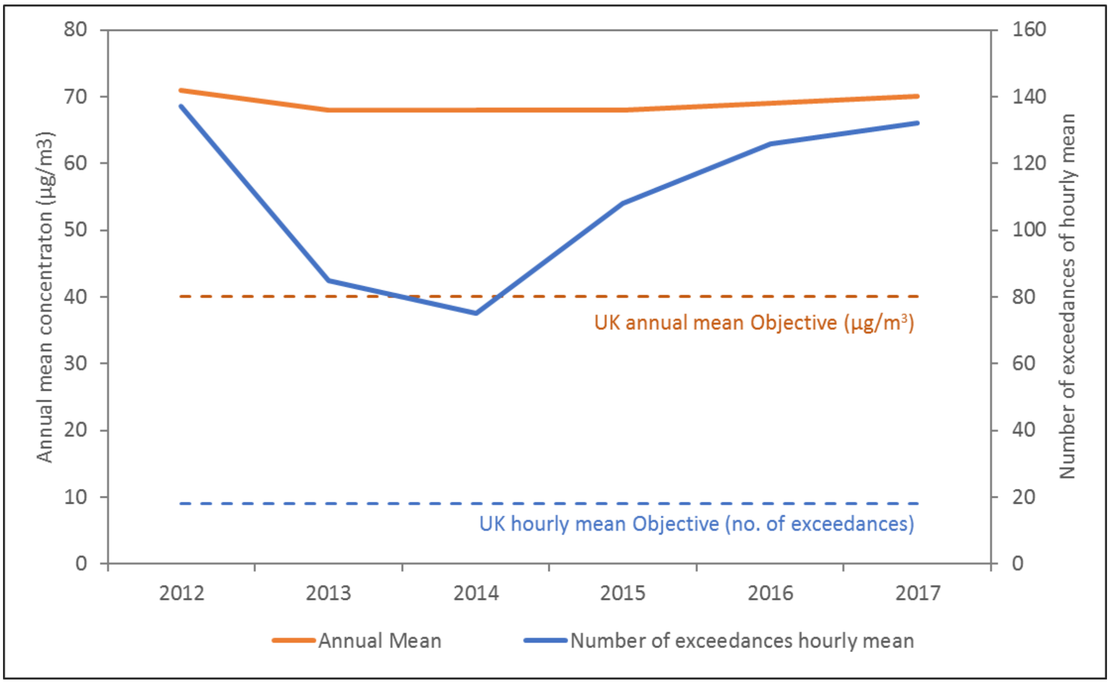

Figure 3: Trends in exceedances of the two NO_2 Objectives

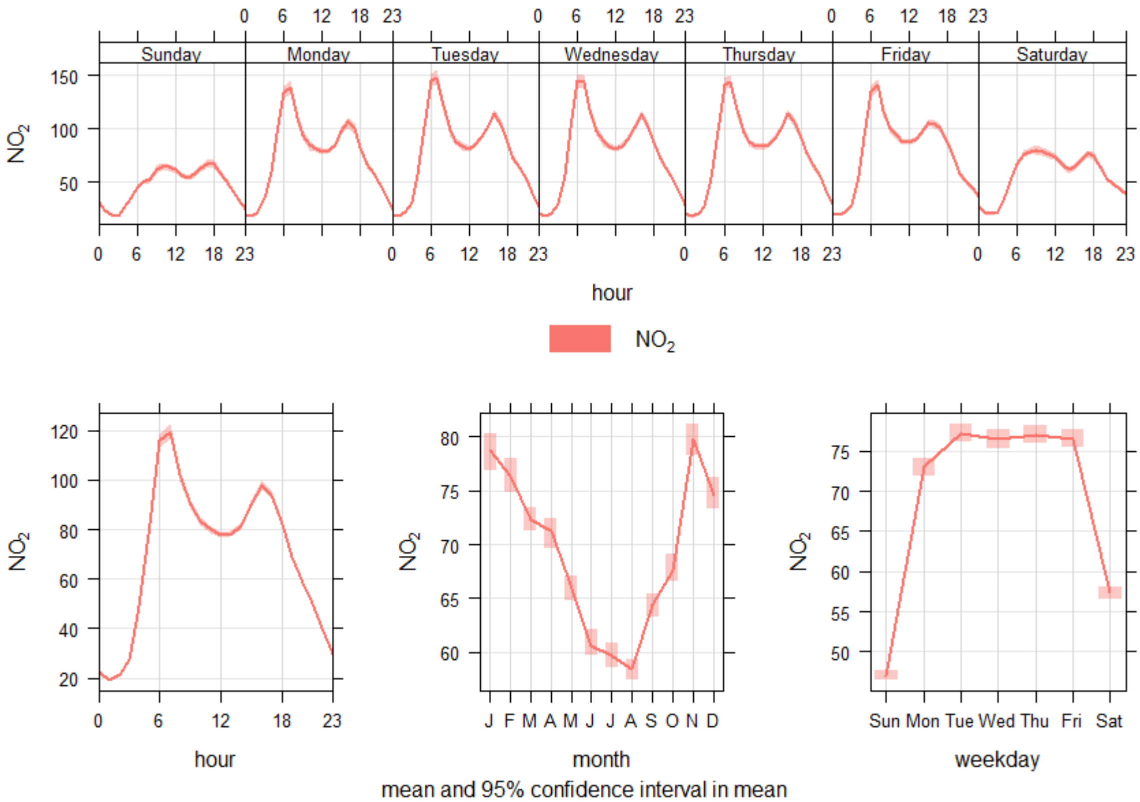

Figure 4: Temporal variation in NO_2 concentrations – average of all years

2.4.7. Figure 5 shows the range in maximum hourly concentrations for 2017. The highest exceedances occurred during January and February, again highlighting the seasonal trends evident.

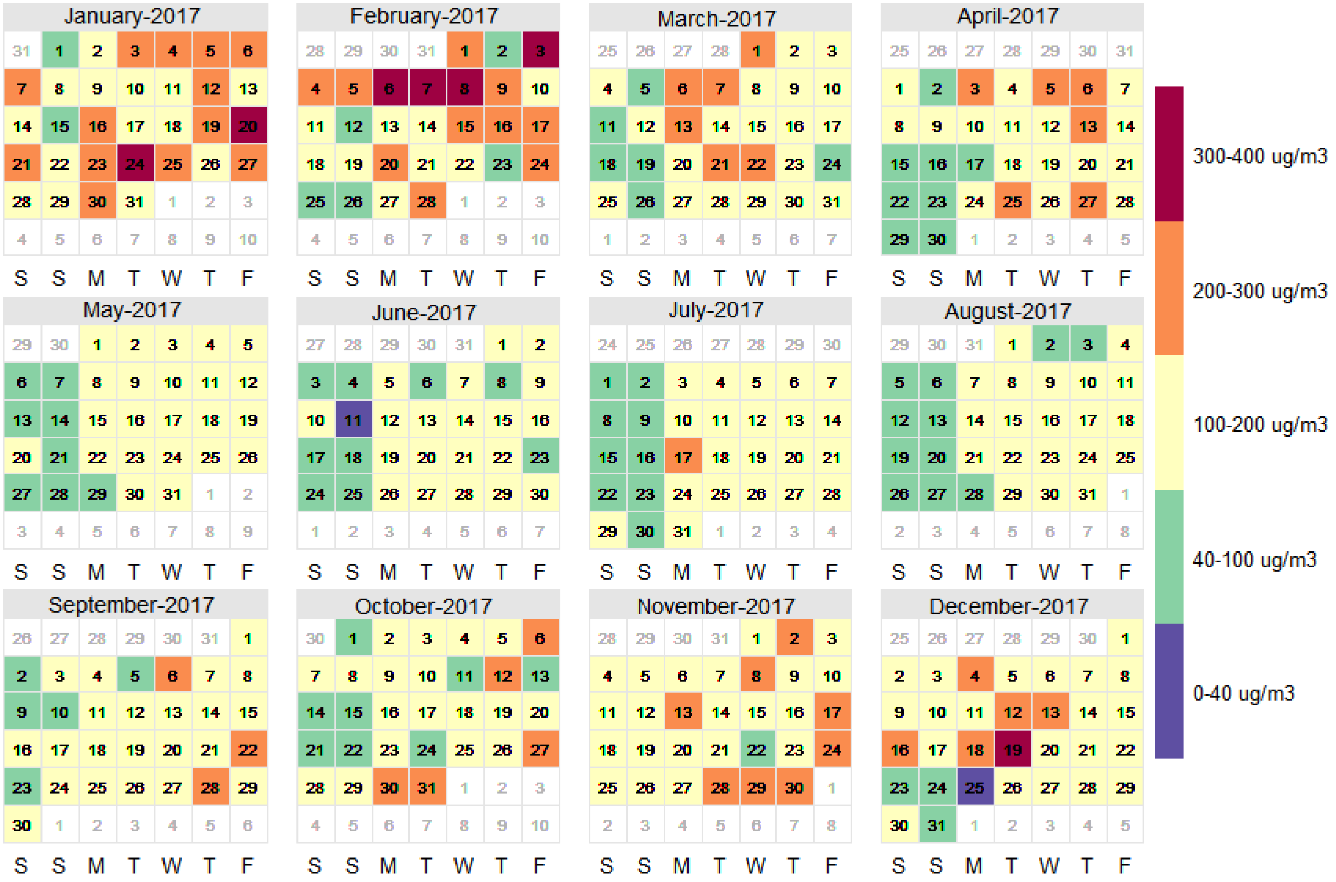

Figure 5: Calendar plot of maximum hourly concentrations, 2017

2.4.8. Figure 6 presents the trends in monthly mean concentrations for all years (left) and by season (right). The trends for spring, summer and autumn are fairly level and consistent but the concentration trends during winter vary greatly year on year. This suggests that winter conditions could be influencing the change in hourly exceedances.

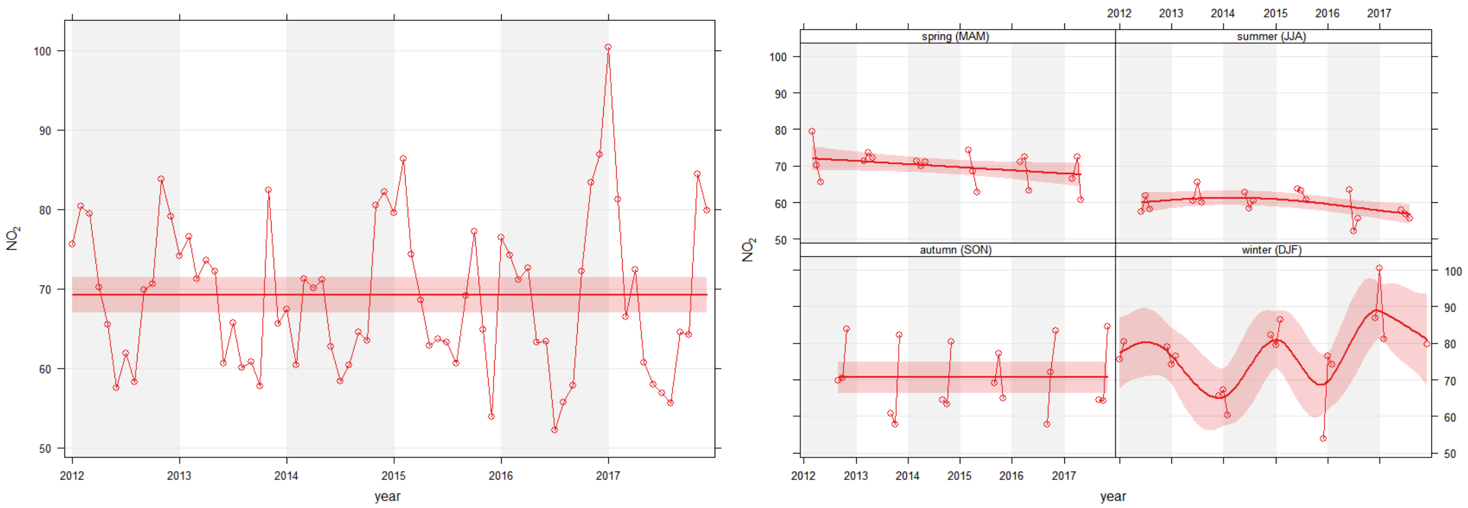

Figure 6: Trends in monthly mean NO_2 concentrations for all data and by season

2.4.9. The key influencing factor for exceedances of the objectives is clearly seasonal. The drivers for this are likely to be a combination of meteorology (low temperatures, temperature inversions, wind speeds) and seasonal emission sources (cold starts, domestic heating). To investigate further, some additional analysis has been undertaken.

2.4.10. Firstly, the data has been analysed to investigate emission sources which are contributing to the high concentrations during the winter months. For example, if domestic heating were a significant source it would be expected that high concentrations would be seen outside of peak rush hour periods during colder temperatures. Figure 7 shows average concentrations as a function of hour of the day and temperature.

2.4.11. This clearly shows that the highest concentrations occur during the morning peak rush hour approximately around 7am to 8 am at lower average temperatures (below 10 ºC). This is likely a result of a combination of cold weather delaying engine/catalyst warm-up and lower pollutant dispersion at low temperatures. Some degree of elevated average concentrations occurs throughout the day until the end of evening peak rush hour. There is little evidence of a signature from domestic sources, which would be expected to produce higher concentrations extended into the evening hours.

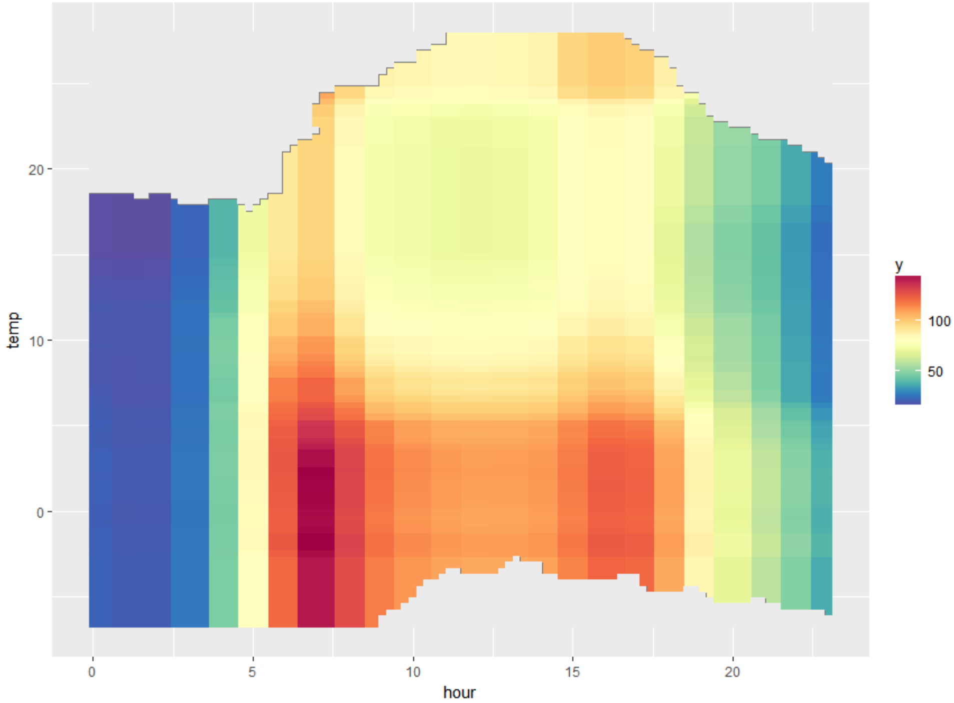

Figure 7: Plot showing average concentrations of NO_2 (y) by hour of the day and temperature

2.4.12. The other issue to investigate is the fluctuation in hourly exceedances from year to year. This could be driven by fluctuation in emissions and/or meteorology. To analyse emission fluctuations, it would be necessary to have traffic count data for each year by month which is not currently available. To investigate the meteorological impact the effect of temperature and wind speed on concentrations is analysed.

2.4.13. Figure 8 shows average monthly temperature and NO_2 concentrations and Figure 9 shows a scatterplot of all concentrations greater than 200 µg/m^3 versus temperature.

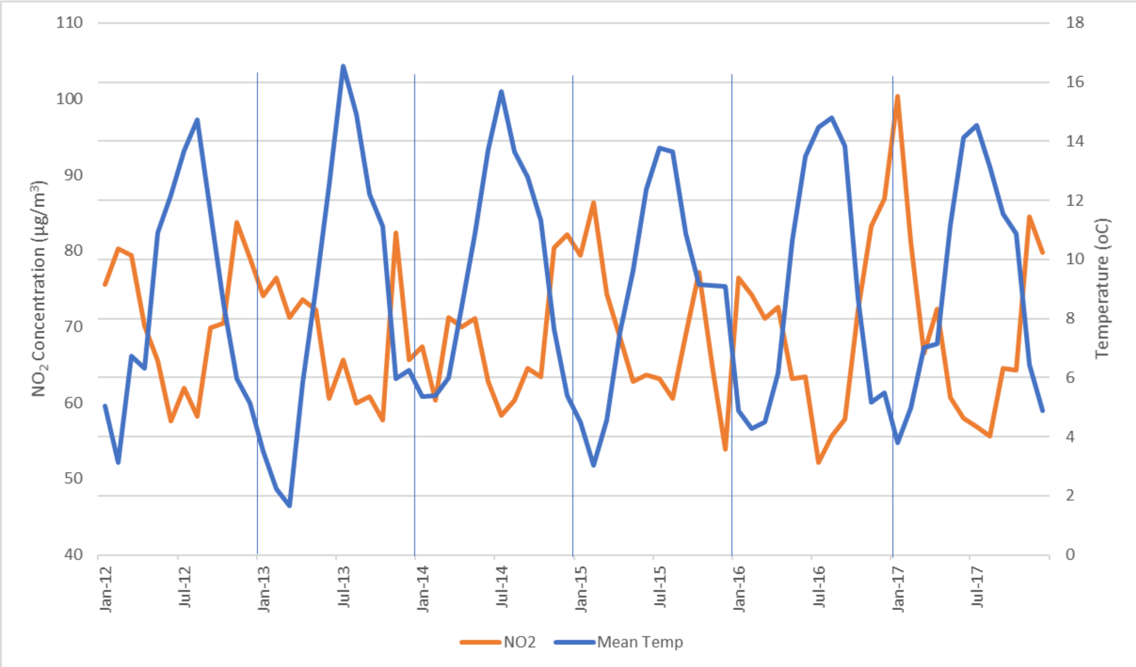

Figure 8: Average NO_2 concentrations and temperatures

2.4.14. These figures show that temperature is not necessarily the only meteorological driver. Figure 8 shows that temperatures during winter 2013/2014 are the highest winter temperatures, possibly contributing to the lower number of hourly exceedances in 2014, though the Crumlin junction roadworks were on-going at this time which also could be attributed to the lower concentrations as traffic was restricted. However, this is not mirrored for the winter period 2012/2013, where temperatures are lowest but concentrations are not significantly high, nor in 2016/2017, where temperatures are not unusually low but concentrations are the highest of all winter periods. Figure 9 demonstrates a lack of correlation between temperature and concentrations.

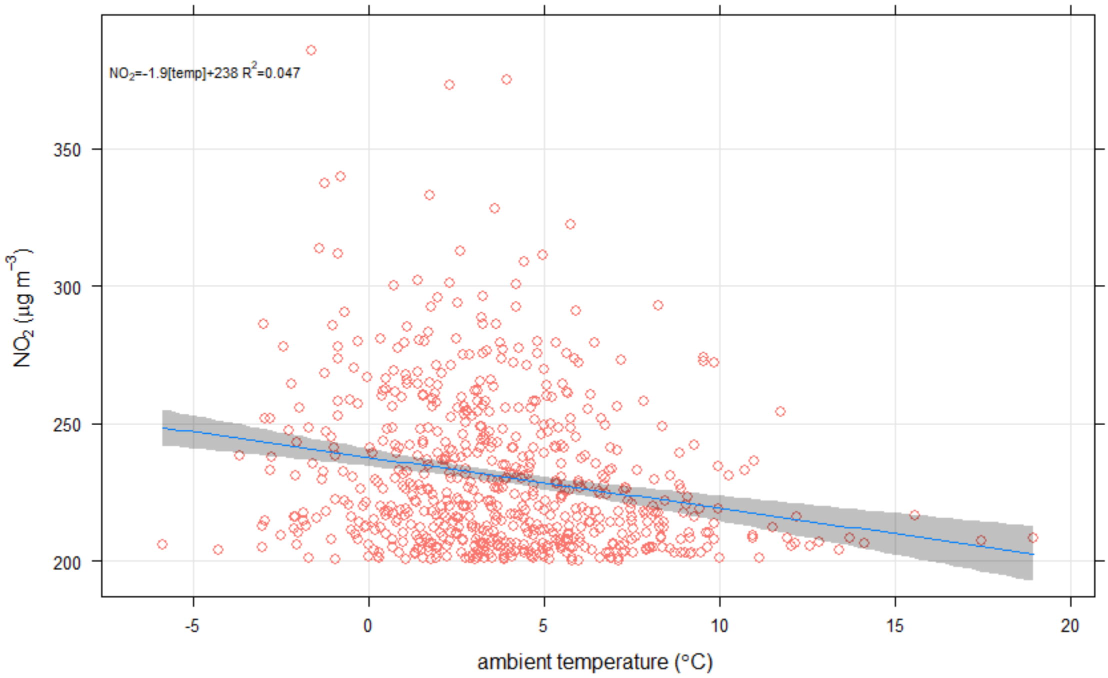

Figure 9: Scatterplot showing relationship between exceedances of the hourly objective and temperature

2.4.15. Figure 10 clearly shows the importance of low wind speeds and low temperatures in conjunction as drivers for higher concentrations.

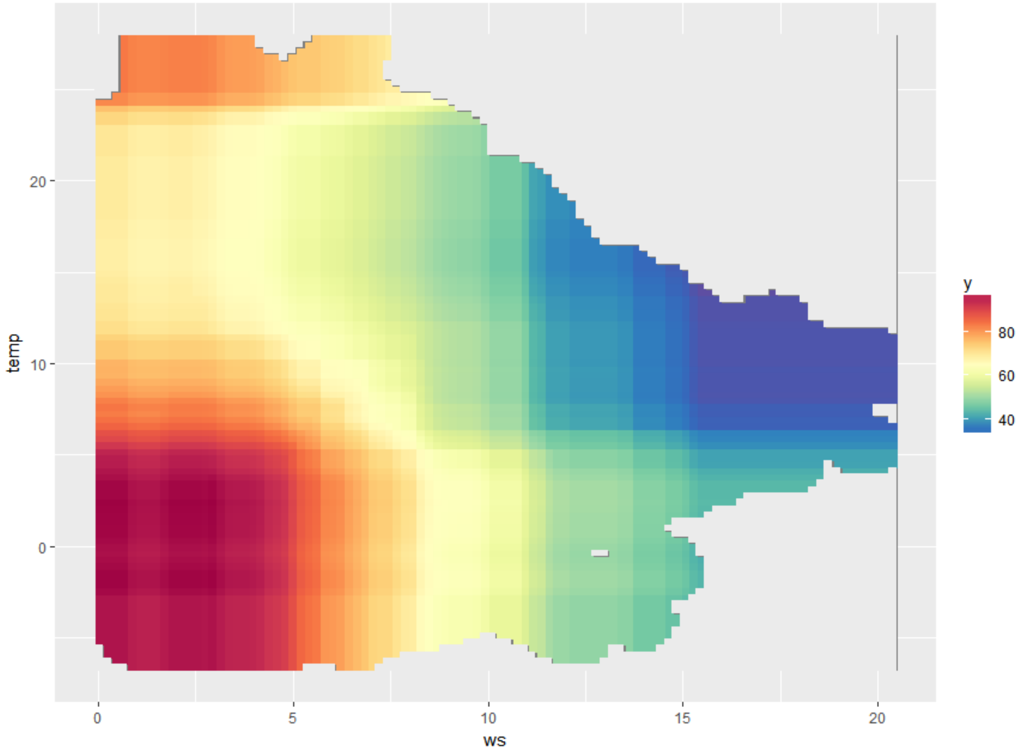

Figure 10: Average concentrations of NO_2 (y) by wind speed and temperature

2.4.16. Figure 11 investigates wind speeds by year. This suggests that wind speeds in 2013 and 2014 were on average higher than in 2016 and 2017. This could therefore explain the annual differences in hourly objective exceedances.

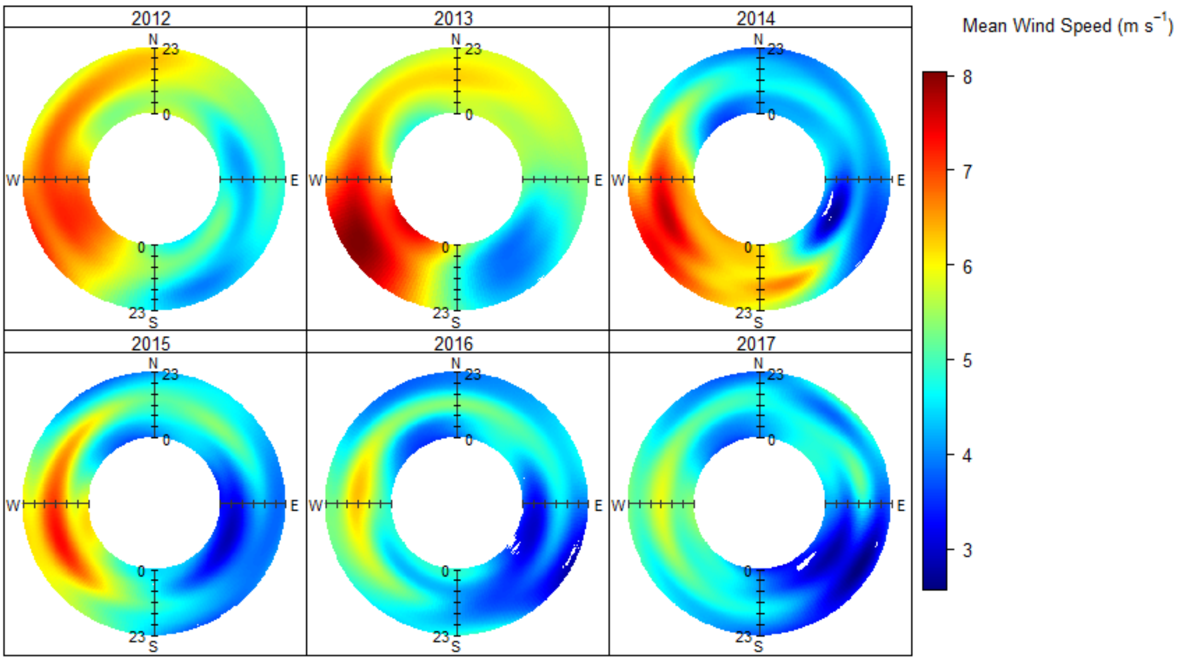

Figure 11: Polar annulus plot showing wind speed as a function of wind direction and time of day

2.4.17. In summary, the NO_2 exceedances are driven by vehicle emissions. Seasonal meteorology results in the highest exceedances (in terms of number and concentration) during the winter months. Data suggest that the concentrations are elevated during periods of low temperature and low wind speed i.e. a result of poor atmospheric dispersion. Further analysis to identify the impact of temperature inversions could be undertaken with further meteorology data analysis, although this is deemed unnecessary in the context of the findings of this analysis.

2.5. BASELINE INFORMATION

Further baseline information is contained within the WelTAG Stage One report for the following areas:

- Infrastructure and Local Facilities;
- Traffic Flows;
- Journey Time and Reliability;
- Personal Injury Collision Data;
- Public Transport;
- Origin and Destination Analysis;
- Economy;
- Demographics;
- Other Related Work; and
- Committed Developments.

2.6. OTHER SENSITIVE ENVIRONMENTAL AREAS

2.6.1. This section of the report identifies and determines the potential environmental constraints and opportunities within the vicinity of the scheme using aerial imagery and ordnance survey maps.

STATUTORY DESIGNATIONS

European Designated Sites

2.6.2. European Designated Sites (also known as Natura 2000 Sites) include any Special Protection Area (SPA), Special Area of Conservation (SAC), Sites of Community Importance (SCI's) and RAMSAR sites located within 2km of the A472 (measured from closest point) are listed below.

2.6.3. There are no SACs, SPA or Ramsar sites within 2km of the A472 Hafodyrynys Road.

SITES OF SPECIAL SCIENTIFIC INTEREST (SSSI)

2.6.4. There are no SSSIs within 2km of the A472 Hafodyrynys Road.

AREAS OF OUTSTANDING NATURAL BEAUTY (AONB)

2.6.5. There are no AONBs located within 2km of the A472 Hafodyrynys Road.

OTHER STATUTORY DESIGNATIONS

2.6.6. There are no other Statutory Designations (National Parks and Country Parks) located within 2km of the A472 Hafodyrynys Road.

NON-STATUTORY DESIGNATIONS

2.6.7. There are no Local Nature Reserves (LNR) and Natural Nature Reserves (NNR) within 2km of the A472 Hafodyrynys Road.

2.6.8. There are two Sites of Importance for Nature Conservation (SINC) comprising Llanerch Isaf Woodland which is located 200m north west, and Coed Goferau located adjacent to the A472.

2.6.9. There is one Visually Important Local Landscape site comprising Abercarn Valley which is located south of the A472.

SPECIAL LANDSCAPE AREAS

2.6.10. There are no Special Landscape Areas (SPA) located within 2km of the A472 Hafodyrynys Road.

AREAS OF POPULATION, COMMUNITY RESOURCES AND INFRASTRUCTURE

2.6.11. Sensitive human receptors (i.e. residential properties, hotels etc) and community resources (i.e. footpaths, cycleways etc) located within 1km of the A472 Hafodyrynys Road. These are presented in Table 2.

Receptor / Resource	Distance & Direction from A472
Residential properties on Hafodyrynys Road	Adjacent to A472
Llwynawen Farm	Adjacent to A472
Residential properties situated in Swffryd	100m north
Several pubs and cafes located on Main Street	100m west
Border Technology Park	150 south west
Bethel Baptist Church	30m north west
Crumlin Rugby Football Club	200m north west
Residential properties on Crown Street	145m south west
Cycle path	200m north east
Sofa Sofa	400m north west
Navigation Colliery	600m north west
Sofrydd Primary School	370m north
Enterprise Autos	550m south west
Crumlin High Level Primary School	600m south west

Table 2: Areas of Population, Community Resources And Infrastructure

SENSITIVE NOISE RECEPTORS

Noise Action Planning Priority Sites (NAPPA)

2.6.12. There is one Noise Action Planning Priority Area (NAPPA) area which is situated on Hafodyrynys Road and it mimics the footprint of the AQMA.

WATER ENVIRONMENT

2.6.13. Watercourses and permanent water bodies located within 1km of the A472 Hafodyrynys Road. These are presented in Table 3.

Main Water course / Water Body	Distance & Direction from A472
Unnamed drainage ditch	Adjacent to the A472
Ebbw River	45m south west
Nant Gawni	1km east

Table 3: Watercourses within 1km of A472 Hafodyrynys

CULTURAL HERITAGE, AND HISTORIC LANDSCAPE DESIGNATIONS

2.6.14. Listed Buildings, Scheduled Monuments, Historic Parks and Gardens and Conservation Areas within 1km of the A472 include:

LISTED BUILDINGS

2.6.15. There is one Listed Building comprising Bethel Church 30m north west. There is also a row of Listed Buildings as part of the Navigation Colliery located 600m north west.

SCHEDULED MONUMENTS

2.6.16. There are no Scheduled Monuments within 2km of the A472.

HISTORIC PARKS AND GARDENS

2.6.17. There are no Historic Parks and Gardens within 2km of the A472.

CONSERVATION AREAS

2.6.18. There are no Conservation Areas within 2km of the A472.

2.7. PROBLEM IDENTIFICATION

2.7.1. The A472 lies within the South Wales zone for the purpose of the assessment of compliance with the EU Air Quality Directive.

2.7.2. The national assessment of roadside NO_2 undertaken for the South Wales zone indicates that the annual limit value was exceeded in 2015 but it is likely to be achieved by 2026. More recent roadside monitoring data for 2017 suggests that the compliance date in this location is predicted to be 2029, as there has been no improvement in levels since 2015. The compliance date of the South Wales zone is, in current projections, determined by the compliance of the A472 adjacent to Woodside Terrace.

2.7.3. Elevated concentrations of NO_2 on this study corridor are due to a combination of high traffic volumes and periods of congestion associated with the eastbound AM peak for vehicles climbing the A472 towards Hafodyrynys village. CCBC are investigating whether there are any measures that can bring forward the projected compliance date.

2.8. OBJECTIVE OF THE STUDY

2.8.1. Whilst WelTAG provides a fixed framework for appraisal, the guidance acknowledges that the level of detail provided in the WelTAG report should be proportionate to the impacts under consideration.

2.8.2. As identified in the Stage One report, the objective of this study is to carry out an initial investigation and identify potential measures deliverable by CCBC which will assist in bringing forward reductions in NO_2 in the shortest possible time to ensure compliance with the Air Quality Framework Directive requirements along the A472. Therefore, the transport case will focus on air quality and reflect the key considerations in relation to the EU Air Quality Directive and bringing forward compliance with limit values.

2.8.3. The following key criteria were described in the Project Brief for the high-level appraisal of the potential measures:

- Effectiveness
- Timescales
- Feasibility

2.8.4. This has been interpreted for the purposes of this appraisal as meaning:

- **Effectiveness** – Is the measure likely to deliver reductions in roadside concentrations proportionate to the scale of the exceedance above the 40µg/m^3 legal limit
- **Timescales** – Can the measure be implemented within timescales that are meaningful (short enough) to have an impact on bringing forward the projected compliance date

- **Feasibility/Deliverability** – Can the measure be delivered in the location involved with the powers and resource available to the Local Authority

2.8.5. For the purpose of this appraisal, the phrase deliverability has been used, instead of feasibility to match more clearly the requirements of WelTAG for delivery.

2.8.6. In addition to the Air Quality Directive, the study also supports Caerphilly's Corporate Well-being Objectives, identified within the Council's Corporate Plan 2018-2023:

- Promote a modern, integrated and sustainable transport system that increases opportunity, promotes prosperity and minimises the adverse impacts on the environment
- Creating a county borough that supports a healthy lifestyle in accordance with the Sustainable Development Principle within the Well-being of Future Generations (Wales) Act 2015

2.8.7. It also contributes towards the strategic priorities of the Welsh Government, including that of the Well-being of Future Generations (Wales) Act 2015. As such, based on the Well-being of Future Generations Act and the recommendations contained within The National Institute for Health and Care Excellence (NICE) air quality guidelines[3] the following are considered as secondary criteria in the appraisal process so that health impacts can also be considered:

- Will the measure deliver an overall reduction in NO_2 emissions to air?
- Will the measure result in unintended consequences or other environmental impacts?
- Will the measure contribute to well-being?
- Will the measure impact equally across multiple vehicle classes and journey types?
- Will the measure have a positive impact on wider public health and inequalities?

2.8.8. It is possible that measures could be used in combination. Each individual measure need not bring forward compliance in itself but the improvement in NO_2 brought about by the measure should be proportionate to the scale of the exceedance of the limit value.

2.8.9. The Stage One appraisal focused on the three key criteria. The secondary criteria are considered in further detail during this Stage Two appraisal, and will likely be significant where two measures are mutually incompatible. In such cases, delivery against the secondary criteria could weigh in favour of a particular measure.

2.8.10. Information was collected on the legislative, policy and context of the area (see Section 2.1) and used within the WelTAG process to inform consideration of the implications of measures on the impact areas as reported in the Appraisal Summary Tables for each measure. The impacts are organised by the four areas of Sustainable Development – Environment, Economy, Social and Cultural.

2.8.11. More detailed consideration of how the goals and objectives of this study are integrated with other local policies and strategies, will be undertaken in WelTAG Stage Three, when further detail of the measures will be available.

2.8.12. While this appraisal is aimed at shortening the period of compliance against the required limit values, the measures when applied could themselves be helpful in the longer term by providing solutions which prevent environmental, social and health issues getting worse or even occurring. Collaboration and involvement of key stakeholders will need to be continued and expanded in later stages to ensure the appraisal, development and delivery of the measures considers the views of those affected and avoids unintended consequences.

2.9. THE PROCESS

2.9.1. This study has been undertaken following the WelTAG framework and with due consideration to the goals of the Well-being of Future Generations Act 2015.

[3] Air pollution: outdoor air quality and health, NICE guideline [NG70] Published date: June 2017

2.9.2. Stage One (Strategic Outline Case) identified the issues and objective, developed a long list of 30 possible measures, and recommended a short list of 10 measures to take forward to Stage Two (Outline Business Case).

2.10. SHORT LIST OF MEASURES

2.10.1. The WelTAG Stage One appraised the long list of 30 measures against the key criteria (Effectiveness, Timescales and Deliverability) for meeting the objective. The sifting of measures resulted in the short list of 10 measures for Stage Two (the Outline Business Case), based on their ability to bring forward the date of compliance with EU Limit Values on the A472. They are in Table 4 as follows.

Ref	Measure
01	Change Signal Timings at Crumlin Junction
02	Signalise the A472/B4471 Swyffryd Junction and introduce an eastbound queue detector
07	Reclassify National Speed Limit to 50mph on the A472 Hafodyrynys Road
11	Demolish Dwellings at Woodside Terrace and Re-align Road
13	Peak Hour HGV Bans
15	Emissions Barrier
20	Rear Access to Properties and Install NO_2 Filtration
26	Clean Air Zone / Low Emission Zone
27	Air Quality Public Awareness Campaign
28	Bypass

Table 4: Short List of Measures

2.10.2. The appraisal of this short list is documented in Section 3.

3. TRANSPORT CASE

3.1. METHODOLOGY

3.1.1. The approach to the Stage Two level of appraisal is intended to examine in greater detail the short list of measures for tackling the problem under consideration. The short list of measures has been appraised against the key criteria and secondary criteria for the objective and the three WelTAG areas.

3.1.2. Whilst the measures have already been appraised against the key criteria for the objective, this has been re-evaluated at Stage Two. It is recognised that in looking at measures in greater detail during Stage Two, the findings of Stage One may need updating as additional analysis can be used to support the WelTAG scoring of measures.

3.1.3. The aspects of well-being identified under WelTAG are:

- Economy
- Environment
- Social and Cultural

3.1.4. The measures that have been appraised against the WelTAG Aspect of Well-being are outlined in Table 5. Given that the measures are targeted at reducing NO_2 levels, it was not considered necessary to appraise against every impact area in detail. The areas which have been excluded from the appraisal have been done so on the basis of there being no notable impacts resulting from any of the measures. Equally, it has not been possible to appraise some of the impact areas due to the limitations of Stage Two, which are outlined in Section 4.4. It may be pertinent to re-introduce these impact areas at Stage Three.

Environment	Social and Cultural	Economy
Air Quality	Physical Activity	Journey time changes and Journey time reliability
Noise	Journey Quality	Capital Cost
Landscape	Accidents	Land
Townscape	Access to employment and services	
Historic Environment		
Biodiversity		
Water Environment		

Table 5: WelTAG Aspect of Well-Being (Impact Areas) that have been appraised

3.2. APPRAISAL OF WELTAG IMPACT AREAS

3.2.1. The following sections set out how each of the impact areas were appraised during Stage Two of the study. The appraisals undertaken adhere to the WelTAG 2017 guidance.

3.2.2. ENVIRONMENTAL APPRAISAL

AIR QUALITY

3.2.3. The GRAL/GRAMM modelling system (hereafter called 'GRAL') was used in this study. Dispersion modelling in complex terrain such as this is challenging and is especially so when low wind speeds arising from flows around buildings and other obstacles influence ambient air quality. Given the high NO_2 values measured at the Hafodyrynys AURN station (annual mean = 70 µg/m^3 in 2017) we believe that a more sophisticated micro-scale air quality modelling method is required than would normally be the case for such a small domain with relatively few road sources. This will ensure that in robustly capturing the baseline we set the conditions to be able to robustly model the effect of emissions reduction measures. Detailed information on the model can be found in the Air Quality Modelling Report found in Appendix A.

3.2.4. EMISSIONS MODELLING SYSTEM

Derivation of local emission factors

3.2.4 There has been much uncertainty in the use of national emission factors (known as COPERT factors) and how representative they are to real-world emissions. While the most recent set of emission factors take this into account to some degree, there remains large uncertainty as to how emissions behave in an environment such as the gradient at Woodside Terrace. To provide a robust study a field monitoring campaign using an OPUS instrument was undertaken and used to derive local emission factors to underpin the modelling and assessment of measures. Full details of this monitoring are provided in Appendix 1 and illustrative outputs are given below.

Illustrative outputs from the emissions model

3.2.5 Figure 12 below shows the difference in vehicle NOx emissions measured at Hafodyrynys compared to those derived using the national emission factors (COPERT). All vehicle categories were significantly underestimated by COPERT though the results are very specific to this case and cannot be assumed to hold elsewhere. Most vehicle emissions are 2 or more times greater in Hafodyrynys than national emission factors would have suggested.

3.2.6 Under each plot the linear relationship is provided between the pre and post OPUS emission estimates with the coefficient of determination for each.

3.2.7 The reasons for the divergence are not clear, though the effect of the gradient through the street canyon is likely to be the most important factor.

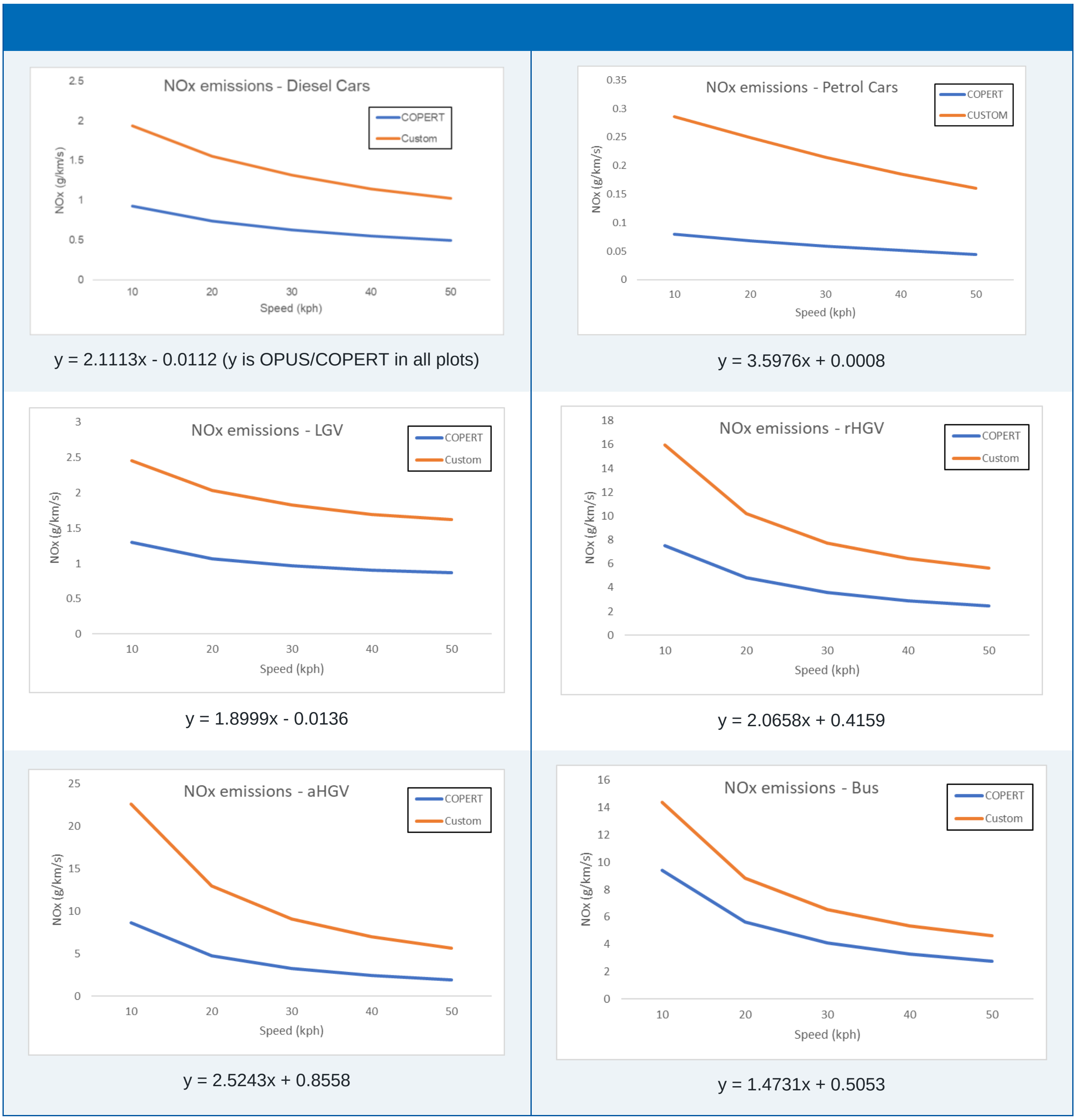

Figure 12: Comparison of modelled emission rates from COPERT 5 Vs OPUS

3.2.5. MODEL DOMAIN

3.2.8 Hafodyrynys is a village on the A472 road between Pontypool and Crumlin in Caerphilly county borough, south-east Wales. The area of interest for this study is immediately east of the junction of the A467 at Crumlin with the A472. The A472 is the principle road of interest in this study, the road traffic on which has been causing exceedances of NO_2 standards at housing a few hundred metres east of the junction.

3.2.6. TOPOGRAPHICAL CHARACTER

3.2.9 The dispersion situation at Hafodyrynys is complicated by both regional and local topography. The area is hilly with elevations varying sharply by a few hundred metres close to the site. The obvious street canyon topography in the street is compounded by the upward gradient of the road itself. Traffic climbs the gradient as it travels east from the junction, likely increasing their emissions, the impact of which are compounded by the canyon morphology.

3.2.10 Regional terrain is shown in Figure 13 and Figure 14 shows local topography. The road sits in a pronounced valley. Figure 15 also shows the orientation of the street gradient included in the air quality modelling. The microscale model domain is quite small but is sufficient to capture the main drivers for the NO_2 problem along Hafodyrynys Road.

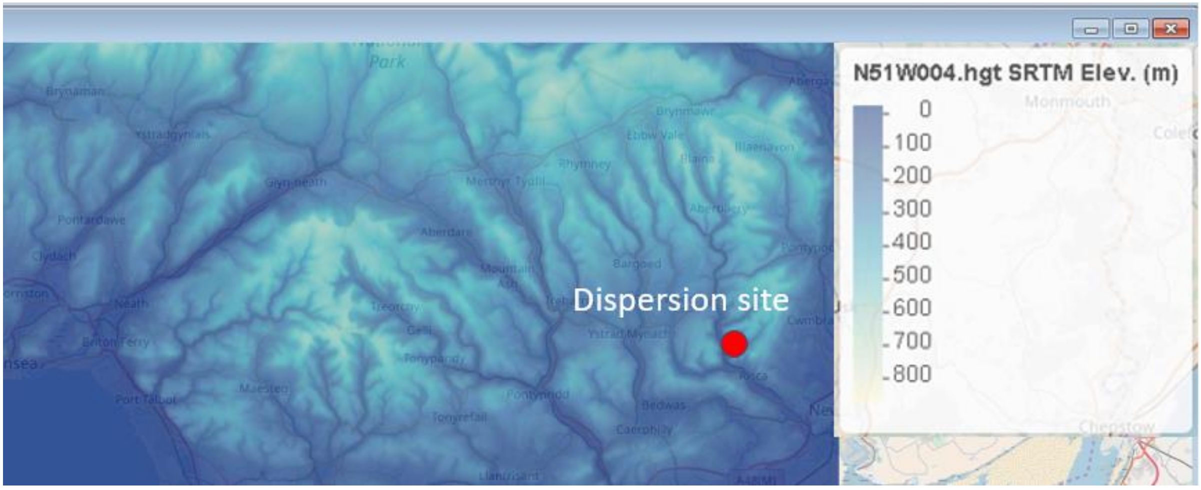

Figure 13: Terrain data used in the study

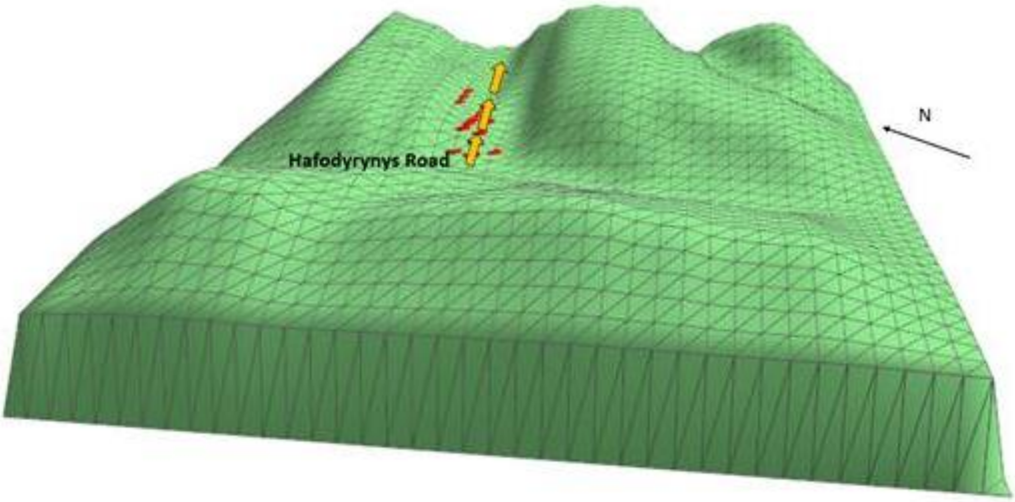

Figure 14: 3D mapping of the model domain (source: Google Earth)

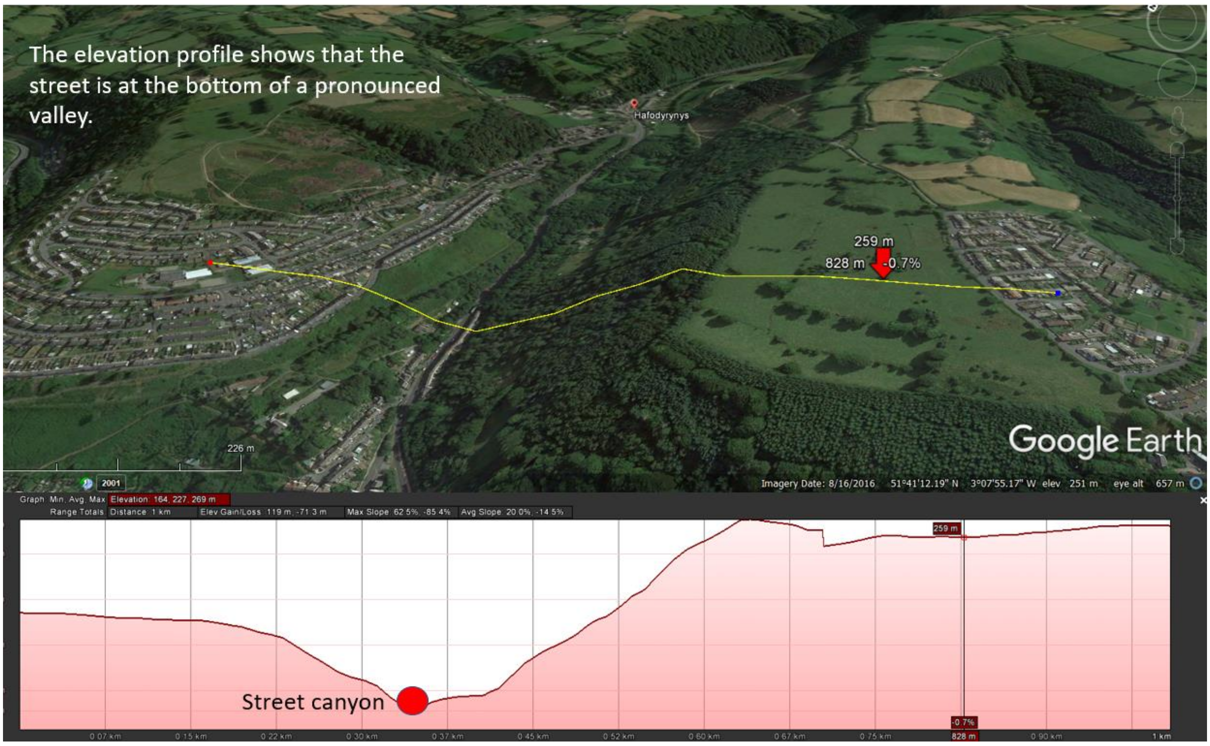

Figure 15: Elevation profile across the Hafodyrynys valley (source: Google Earth)

3.2.7. DOMAIN DESIGN

Nesting the domains

3.2.11 Two model domains have been set up on the GRAMM grid which was for an area 9km x 11km with a resolution of 50m. Terrain data was sourced[4] which influenced the weather model over this wider area. A second model domain, the GRAL was set up inside the GRAMM grid at a much higher resolution of 1.5m and included the Hafodyrynys Road for the micro-simulation model testing. The nested domains are shown in Figure 16 below.

[4] https://dds.cr.usgs.gov/srtm/version2_1/SRTM3/Eurasia/

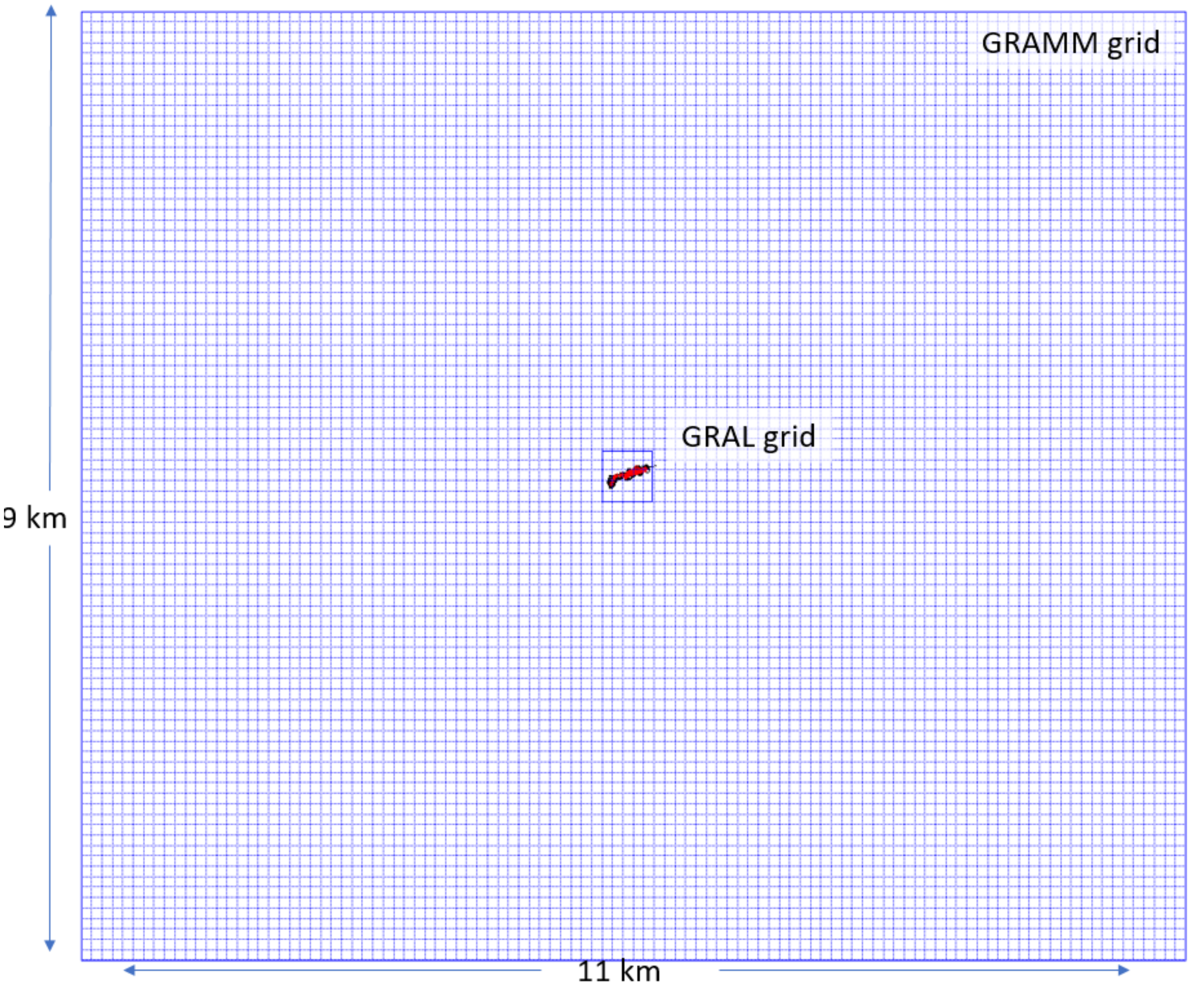

Figure 16: Domain representation in GRAMM

3.3. TRAFFIC CONDITIONS

3.2.12 The modelling for this report is based on quite simple traffic data. Later stages will use detailed traffic modelling, but this was not available to build this version of the dispersion model at this preliminary stage. The traffic situation is not overly complex- it only involves a single road so assumptions for the scenarios have been developed for this stage.

3.2.13 To model the emissions from road traffic we used an average speed on the link which accounts for both uphill and downhill components in the traffic. The average speed used was assumed constant through the day- though it is a weighted average which takes account of slower speeds in the peak periods and faster speeds in the off-peak hours.

3.2.14 The traffic conditions used are as follows:

1) Annual average daily traffic[5] (DfT)
2) Average speed (km/h)
3) Cars (%)
4) Rigid HGV (%)

[5] https://www.dft.gov.uk/traffic-counts/

5) Arctic HGV (%)
6) LGV (%)
7) Motorcycle (%)

3.4. AIR QUALITY MODELLING

3.4.1. GRAL DOMAIN

3.2.15 The domain used in the micro-scale model is shown in Figure 17. The domain is modelled at a horizontal resolution of 1.5m. The flow field model comprises 240 x 120 cells with 15 heights. The concentration model is set to calculate values at 1.5 m relative to ground level throughout the domain.

Figure 17: GRAL modelling domain

3.4.2. TOPOGRAPHY

3.2.16 The topography data used in GRAMM is too coarse to use in GRAL without causing major artefacts in the concentrations- GRAL interprets terrain as a series of ‘steps’, so if there are large changes in height in the steps, the micro-scale flow model will interpret these as blocks similar conceptually to buildings.

3.2.17 To avoid this, a micro-scale terrain model was created using data from Google Earth. We sampled the terrain across a grid of 200 points. A python program was developed to interpolate between the 200 values, yielding around 1 million points at an interval of about 0.1m. GRAL takes the terrain file and converts it to the same x, y resolution as the defined flow field.

3.4.3. METEOROLOGY

3.2.19 Measured weather data from Cardiff Airport were input to a weather model which took account of topography over a 11km x 9 km area centred on Hafodyrynys. An example of the winds produced by the flow-field model is shown in Figure 18 below. The example is for a westerly wind and we can observe the effects of obstacles and terrain in the data (the lines show wind direction and the darker grey areas show higher wind speeds). A pocket of stagnant air lies behind Woodside Terrace (white area), while faster wind speeds are at the edge of the modelling domain at distance from the buildings.

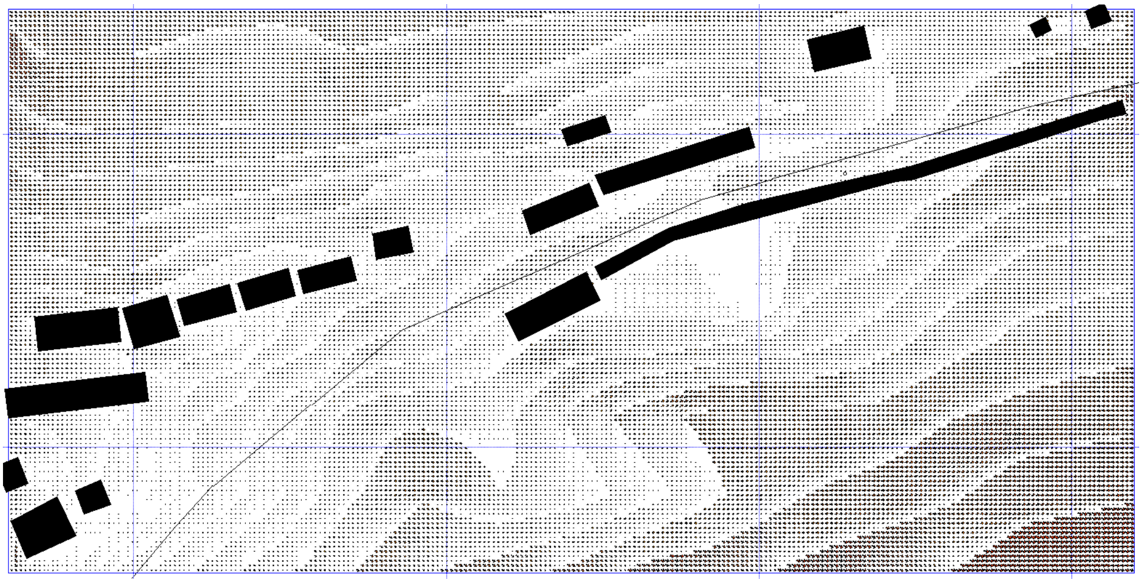

Figure 18: Wind field from GRAL- boundary conditions were westerly, 4ms

3.4.4. BACKGROUND NOx

3.2.20 Non-road background concentrations of NOx were obtained from the Defra UK-Air website. The component from road traffic was removed to avoid double counting. The background NOx climate in Hafodyrynys is quite low, with an average value at the model domain of around 9 µg/m^3. The low background value further reinforces the very dominant effect of local traffic on the NO_2 climate in the area.

3.4.5. EMISSIONS

3.2.21 Emissions of NOx were modelled as described previously. Conversion to NO_2 was done using an empirical relationship derived by running the Defra NOx to NO_2 calculator with regional outputs for Caerphilly.

3.4.6. CONVERSION TO NO2

3.2.22 The GRAL results require conversion with an empirically derived equation. A conversion function specific to the study was derived which used the default values for f-NO_2 in the Defra NOx to NO_2 calculator (0.28 in 2017 for ‘All UK Traffic’).

3.2.23 The background value was input into the Defra NOx to NO_2 calculator along with the diffusion tube results provided by CCBC to obtain a conversion curve that was applied to the modelled NOx concentrations. A 4th order polynomial expression was obtained which explains 99.999% of the variance in the relationship between total NOx and total NO_2. The expression is provided in Equation 1 below.

Equation 1

$$NO2 = -0.0000000041x^4 + 0.0000046117x^3 - 0.0019480281x^2 + 0.5073764794x + 3.2761150469$$

where *x* = total NOx

Where the impacts have been calculated as a range, the worst-case scenario is presented within the Appraisal Summary Tables (ASTs).

3.4.7. OTHER SENSITIVE ENVIRONMENTAL AREA

3.4.8. A qualitative appraisal has been undertaken for the following environmental areas:

- Noise
- Landscape

- Townscape
- Historic Environment
- Biodiversity
- Water Environment

3.4.9. SOCIAL AND CULTURAL APPRAISAL

Physical Activity

3.4.10. A qualitative appraisal has been undertaken in order to assess the amount of walking, cycling and other physical exercise which is undertaken as a result of the measure.

Journey Quality

3.4.11. A qualitative appraisal has been undertaken in order to assess the extent of impact of each of the measures on journey quality, taking into consideration the following aspects:

- Traveller care: aspects such as cleanliness, level of facilities, information and the general transport environment
- Travellers' views: the view and pleasantness of the external surroundings throughout the duration of the journeys
- Traveller stress: frustration, fear of accidents and route uncertainty

Accidents

3.4.12. A qualitative appraisal has been undertaken in order to assess the extent of potential anticipated change which occurs in the number and severity of injuries as a result of the measure.

Access to Employment and Services

3.4.13. A qualitative appraisal has been undertaken in order to assess how many jobs people can reach and the respective journey times, and the impact on journeys to key services such as health facilities and schools which occurs as a result of the measure.

3.4.14. Whilst the WelTAG 2017 guidance outlines access to employment and access to services as two separate appraisal areas, both areas have been combined within this assessment, as the appraisals will be proportionate to one another, with little to no difference in appraisal outcomes between the two considered likely to take place.

3.4.15. ECONOMIC APPRAISAL

Journey Time and Journey Time Reliability Changes

3.4.16. A qualitative appraisal has been undertaken in order to assess changes in journey times across all affected modes both for users and non-users of the measure. The appraisal also takes into account changes in the variation in journey times between times of day and between journeys made at the same time each day i.e. morning and evening peak periods.

3.4.17. Whilst the WelTAG 2017 guidance outlines journey time and journey time reliability changes as two separate appraisal areas, both areas have been combined within this assessment, as the appraisals are proportionate to one another, with little to no difference in appraisal outcomes between the two considered likely to take place.

Capital Costs

3.4.18. The measures have been costed within the following cost bands:

- Low – up to £500k
- Medium – £500k – £2m
- High – £2m+

3.4.19. Cost banding has been used to denote the costs of each measure in order to differentiate between more cost effective measures which could be implemented within a shorter timeframe, and those which will require more funds and longer lead-in periods. The banding takes into account the capital costs of each measure and does not take account of revenue costs.

Land

3.4.20. A qualitative appraisal has been undertaken to assess the extent to which the measure will potentially reduce the amount of agricultural land and open up development sites.

3.4.21. VALUE FOR MONEY ASSESSMENT

3.4.22. The value for money assessment categorises measures within banded ranges. Categorisation has been determined based on the banding of capital costs and broad benefits which have been weighted as far as possible in favour of the objective. Whilst all benefits have been taken into account, the final value for money score has taken into the impact on air quality as the primary consideration. Value for money will be presented in line with anticipated Benefit to Cost ratios as per the following:

- Poor: BCR of 0 – 1
- Fair: BCR of 1 – 2
- Good: BCR of 2+

3.4.23. OTHER ISSUES

3.4.24. Further potential issues with each measure have been explored and considered accordingly in the instance that they have not been covered under any of the other appraisal areas. These include:

Overall Acceptability

3.4.25. A qualitative appraisal has been undertaken in order to assess the receptivity of the public, local authorities and key stakeholders, both groups and individuals to the measure. The appraisal has been undertaken on a measure by measure basis.

Technical, Operational and Financial Feasibility

3.4.26. Where appropriate a qualitative appraisal has been undertaken in order to assess measures on the following criteria:

- Technical: The extent to which the measure is technically feasible within the specified budget and timeframe
- Operational: The extent to which the measure is operationally feasible within the specified budget and timeframe
- Financial: The extent to which the measure is financially feasible

Deliverability and Risk

3.4.27. At this stage, it is difficult to identify issues regarding deliverability and risk given the high-level nature of the measure's development. Where possible, this has been identified as qualitative statements though should be reassessed at WelTAG Stage Three when the measures are developed further.

3.5. APPRAISAL AGAINST OBJECTIVES

3.5.1. The Stage One procedure involved undertaking the appraisal of the long list of measures, with each measure assessed against the WelTAG criteria, and then considered within the context of the study objective; namely, the extent to which each measure would be successful in bringing forward reductions in NO_2 in the shortest possible time to ensure compliance with the air quality framework directive requirements within the A472 study corridor.

3.5.2. The Stage Two appraisal essentially comprised a re-undertaking of this process. This was necessary, as it elicited different results in cases where additional evidence had been produced or sourced, allowing appraisals to be undertaken in greater detail and with a greater degree of certainty, with the potential for differing appraisal outcomes in comparison to Stage One.

3.5.3. KEY CRITERIA

Effectiveness – Is the measure likely to deliver reductions in roadside concentrations proportionate to the scale of the exceedance above the 40µg/m^3 legal limit

3.5.4. This has been updated in lieu of more detailed assessment work at Stage Two.

Timescales – Can the measure be implemented within timescales that are meaningful (short enough) to have an impact on bringing forward the projected compliance date

3.5.5. This has been updated in lieu of more detailed assessment work at Stage Two.

Deliverability – Can the measure be delivered in the location involved with the powers available to the Local Authority

3.5.6. This has been updated in lieu of more detailed assessment work at Stage Two.

3.5.7. SECONDARY CRITERIA

Will the measure deliver an overall reduction in NO_2 emissions to air?

3.5.8. This is a qualitative appraisal based on the likelihood of overall reduction to NO_2 resulting from the measure. This will enable the differentiation of measures which simply redistribute the impacts rather than seeking to reduce overall NO_2 emissions to air.

Will the measure result in unintended consequences or other environmental impacts?

3.5.9. This is a qualitative appraisal that considers whether there will be any other adverse environment impacts resulting from the measures. This will summarise the findings of the appraisal against the Environmental Impact Areas.

Will the measure contribute to well-being?

3.5.10. This will be a qualitative appraisal which considers the objectives of the Well-being of Future Generations (Wales) Act 2015.

3.6. STAGE TWO APPRAISAL

3.6.1. For Stage Two of the study, the appraisal outcomes have been summarised solely within the Appraisal Summary Table (AST) in order to avoid unnecessary duplication of summaries and appraisal outcomes within the report. The appraisals have been undertaken on a measure by measure basis, and the appraisal outcomes have been derived based upon the assessments undertaken in accordance with the WelTAG 2017 guidance. The AST provides a breakdown of the impact of each measure on each of the WelTAG appraisal areas. The scoring has been undertaken using the WelTAG 7-point scale where applicable.

3.6.2. BASELINE RESULTS

Model Validation

3.6.3. Agreement between the modelled values and the observed values was very good. The road NOx component was underpredicted by about 5% and overall NO_2 was underpredicted by <1% with a root mean square value of 5 µg/m3 - this is a good result given the very high NO_2 concentrations which have been measured at Woodside Terrace. Nevertheless, the model was adjusted to account for this underprediction following the government guidance[6].The model validation data and plots for road NOx and total NO_2 are provided in Table 6, Figure 19 and Figure 20 below.

[6] LAQM Technical Guidance 2016

Table 6: Model validation data for annual mean NO_2

Site	Measured NO_2 ($\mu g/m^3$)	Modelled NO_2 ($\mu g/m^3$)	Error ($\mu g/m^3$)
CCBC48	42.0	50.6	+8.6
CCBC60	35.0	36.9	+1.9
CCBC83	59.0	63.0	+4.0
CCBC79	59.0	53.5	-5.5
Auto site	70.0	64.3	-5.7
		RMSE	*5.1*

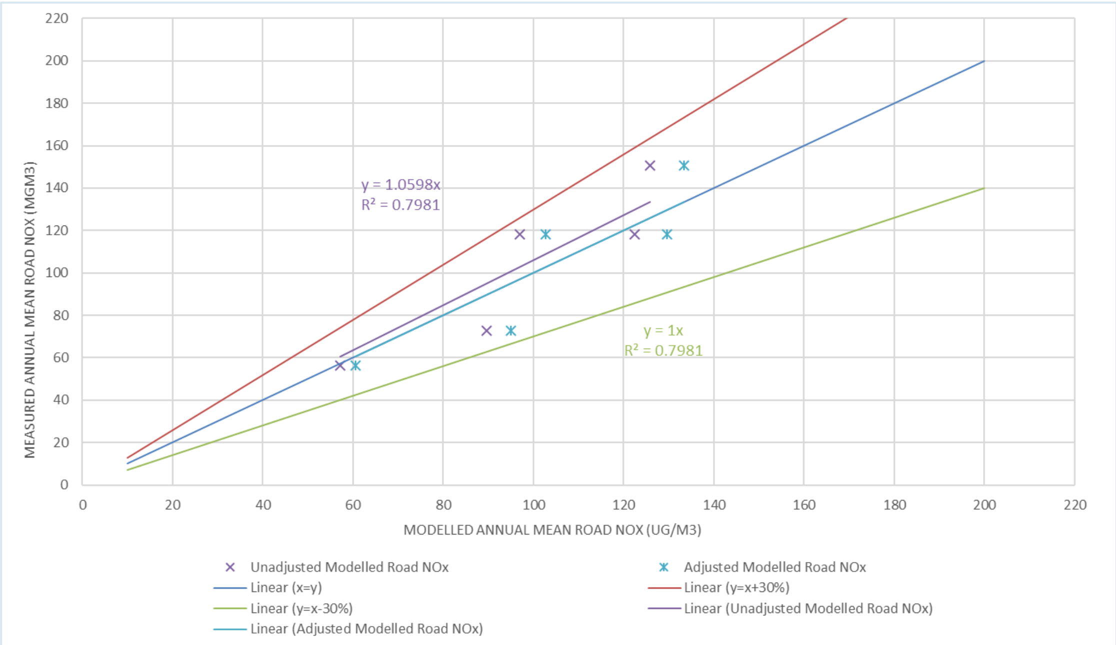

Figure 19: Model validation plot for road NOx component

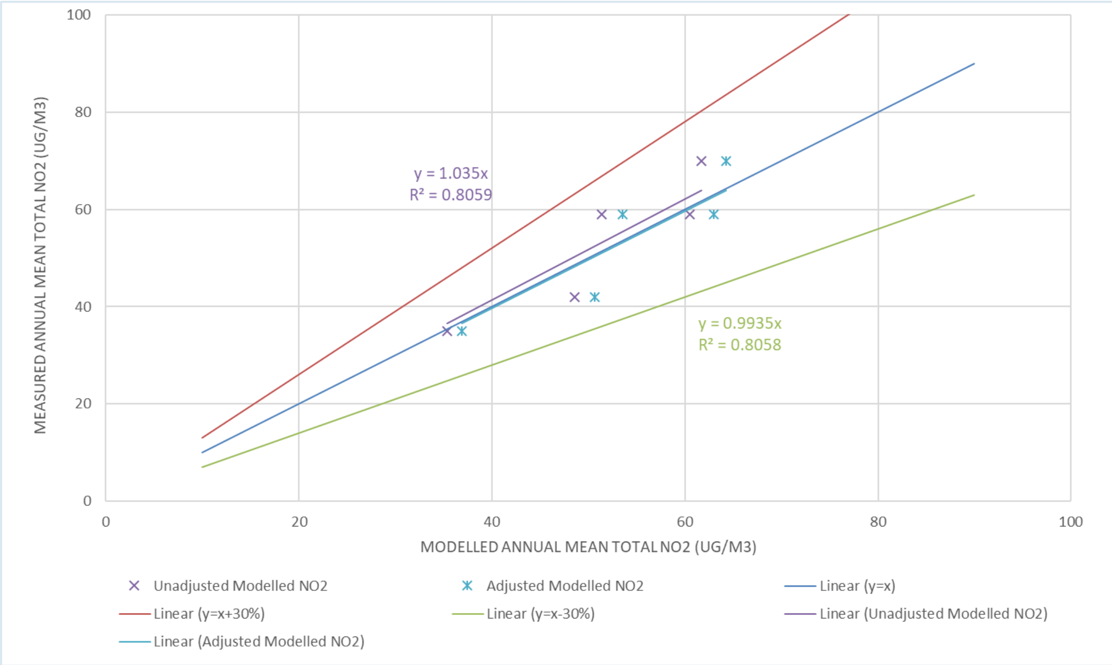

Figure 20: Model validation plot for total NO_2 component

Receptor locations to aid comparison of scenarios

3.6.4. As the modelled concentrations vary significantly along and across Woodside Terrace, a number of locations have been identified to aid comparison of modelled annual average concentrations with and without the selected measures. These receptors are shown below in Figure 21 and include the automatic monitoring site (Auto_site); four diffusion tube monitoring sites (CCBC48, 60, 83 and 79); and two locations at the building façade (façade 1 & 2).

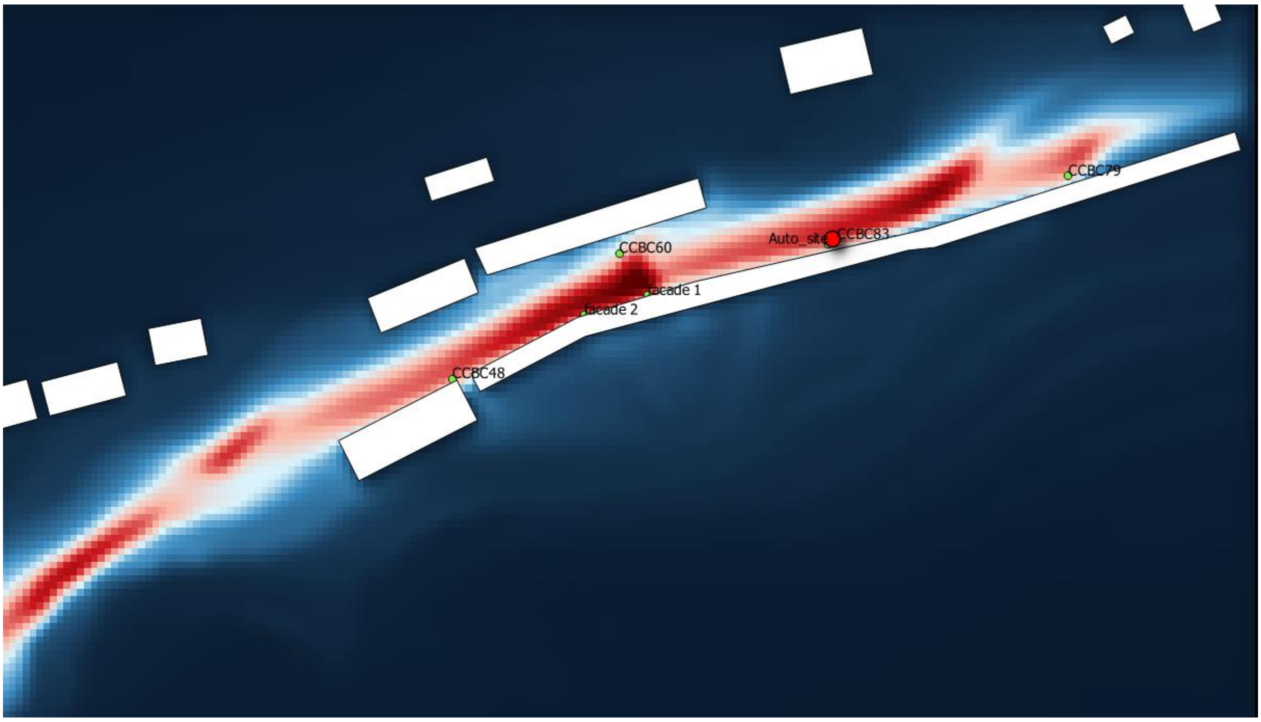

Figure 21: Receptors where annual average concentrations of NO_2 are compared with and without the potential measures

Visualisation of NO_2 concentration- baseline conditions

3.6.5. Figure 22 shows the modelled NO_2 climate along Woodside Terrace in 2017. As we can see there are areas of significant exceedance of the NO_2 annual mean limit value through the street.

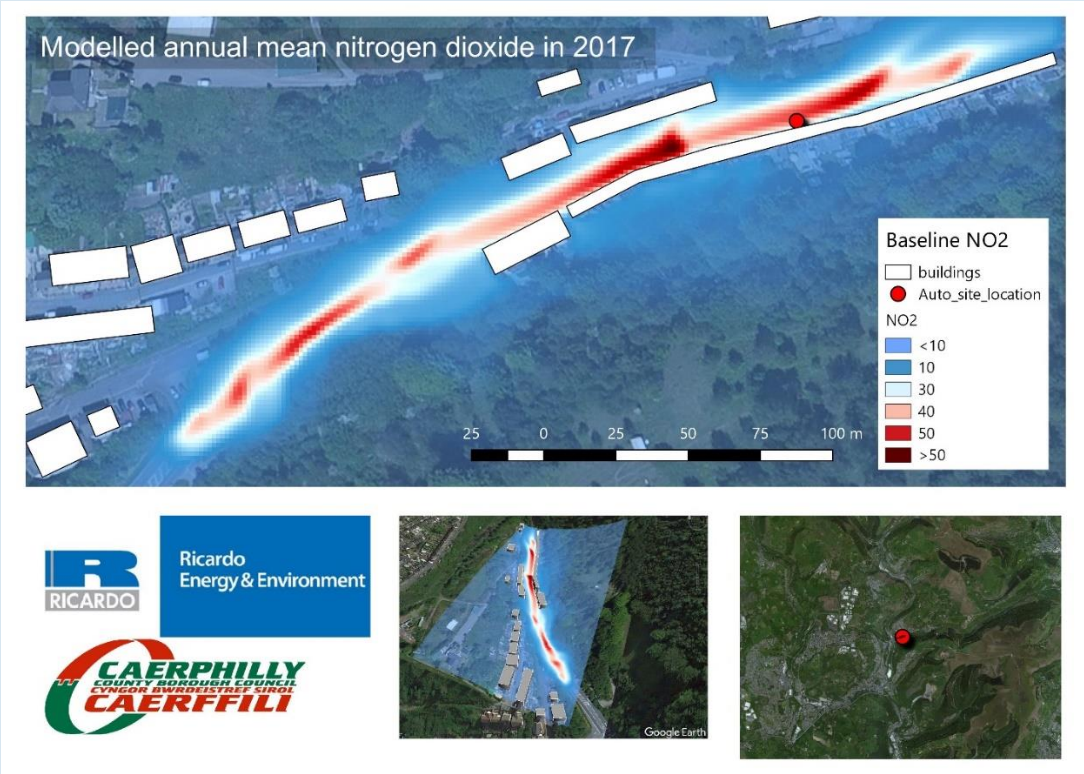

Figure 22: Visualisation of modelled concentrations of NO_2 for 2017

3.6.6. Concentrations vary significantly along and across Woodside Terrace, although it should be noted that the above are preliminary modelled results and fuller analysis will be undertaken as part of the Stage 3 study which will rely on more robust traffic input data. The concentrations follow a "wavy" style presentation which is expected in a street canyon where there is complex turbulence and air pockets where the shearing of the wind creates forces that produce eddies.

3.6.7. Annual average modelled concentrations at the selected receptor locations are given in Table 7 below.

Table 7: Model data for annual mean NO_2 at selected receptor locations

Site	Modelled NO_2 ($\mu g\ m^{-3}$)
CCBC48	57.9
CCBC60	36.9
CCBC83	68.9
CCBC79	53.6
Auto Site	64.3
Façade 1	86.7
Façade 2	96.2

3.6.8. SCENARIO RESULTS

3.6.9. For each emission reduction scenario, both modelled NO_2 concentrations and a NO_2 reduction percentage plot are provided. Some of the NO_2 changes are quite subtle and are better illustrated with difference plots than the absolute NO_2 concentrations. As is shown, Scenarios 1 and 13 offer only small reductions of a few percent NO_2, whereas Scenarios 26 and 28 offer dramatic reductions in NO_2 concentrations.

3.6.10. SCENARIO 1

CHANGE SIGNAL TIMINGS AT CRUMLIN JUNCTION

Scenario 1 consists of an increase in average speed to reflect changes to traffic signals. The Council's traffic consultants, WSP, advised that the scenario could deliver an uplift in average speed from 23mph to 34mph in the peak periods. To build this into the modelling a new weighted average speed for the whole day was derived- which in this case is essentially 34mph, which was observed during May in 2018 on the corridor. The modelled NO_2 concentration for scenario 1 is presented in Figure 23 below.

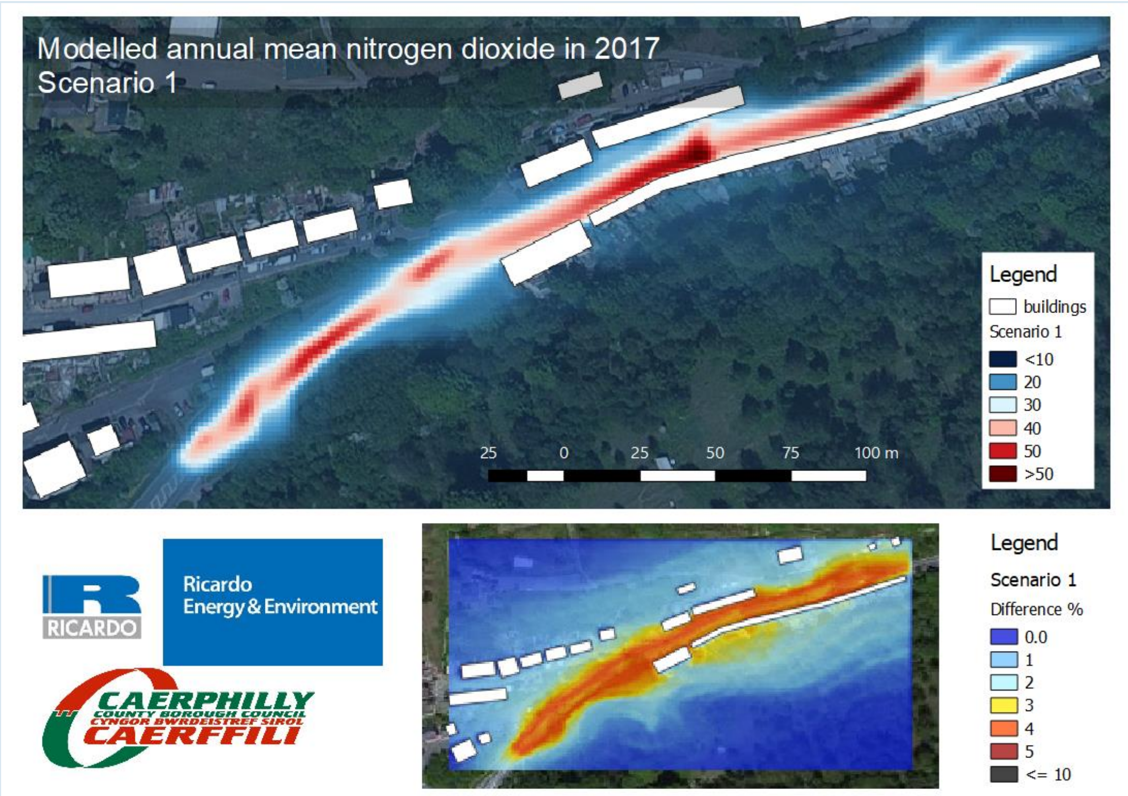

Figure 23: Visualisation of modelled concentrations of NO_2 for 2017- Scenario 1

3.6.11. Retiming the Crumlin junction signals is intended to hold peak hour traffic back at the junction at the bottom of the hill to allow free flow traffic conditions going up the hill. Prior to the improvements at Crumlin Junction in 2015, traffic did not queue up the hill at Woodside Terrace. There was no change in overall volume (AADT).

3.6.12. Predicted concentrations of NO_2 from this measure are lower compared to the baseline in all receptor locations. However, these are only minor reductions compared to the level needed to achieve compliance with the limit value of 40 µg m^{-3}. The results for each receptor have been displayed in Table 8.

Table 8: Model data for annual mean NO_2 at selected receptor locations

Site	Modelled NO_2 (µg m^{-3})	
	Baseline (no measure)	Scenario 1
CCBC48	57.9	55.1
CCBC60	36.9	35.1
CCBC83	68.9	65.6
CCBC79	53.6	51.0
Auto Site	64.3	61.2
Façade 1	86.7	82.5
Façade 2	96.2	91.5

3.6.13. SCENARIO 2

3.6.14. SIGNALISE THE A472/B4471 AS A PRIORITY JUNCTION AND INTRODUCE AN EASTBOUND QUEUE DETECTOR

3.6.15. While the overall impact on speed in this measure is similar to that in Scenario 1 above, the means of achieving this impact differs. Signalising this junction should prevent drivers on the A472 stopping to let traffic merge from the B4471 and therefore improve traffic flow up the hill during the morning peak hour. This will not impact the eastbound direction during the other peaks. Equally, the option will have no effect on the westbound direction. No change in overall volume (AADT).

3.6.16. As the impact on average speed is similar to that in Scenario 1, the impact on the predicted NO_2 concentrations will be equally similar.

3.6.17. SCENARIO 11

3.6.18. DEMOLISH DWELLINGS AT WOODSIDE TERRACE AND RE-ALIGN ROAD

3.6.19. This preliminary assessment considered the impact of removal of the majority of the terraced residential dwellings on Woodside Terrace, but retained the three dwellings downhill from the bus stop which are separated from the main row of terraces. The dwellings proposed for removal, should this option be progressed, are shown in Figure 24. Should this scenario prove to be effective then a number of sensitivities tests will be undertaken as part of the next detailed Stage Three including the removal of all dwellings on this side of the road.

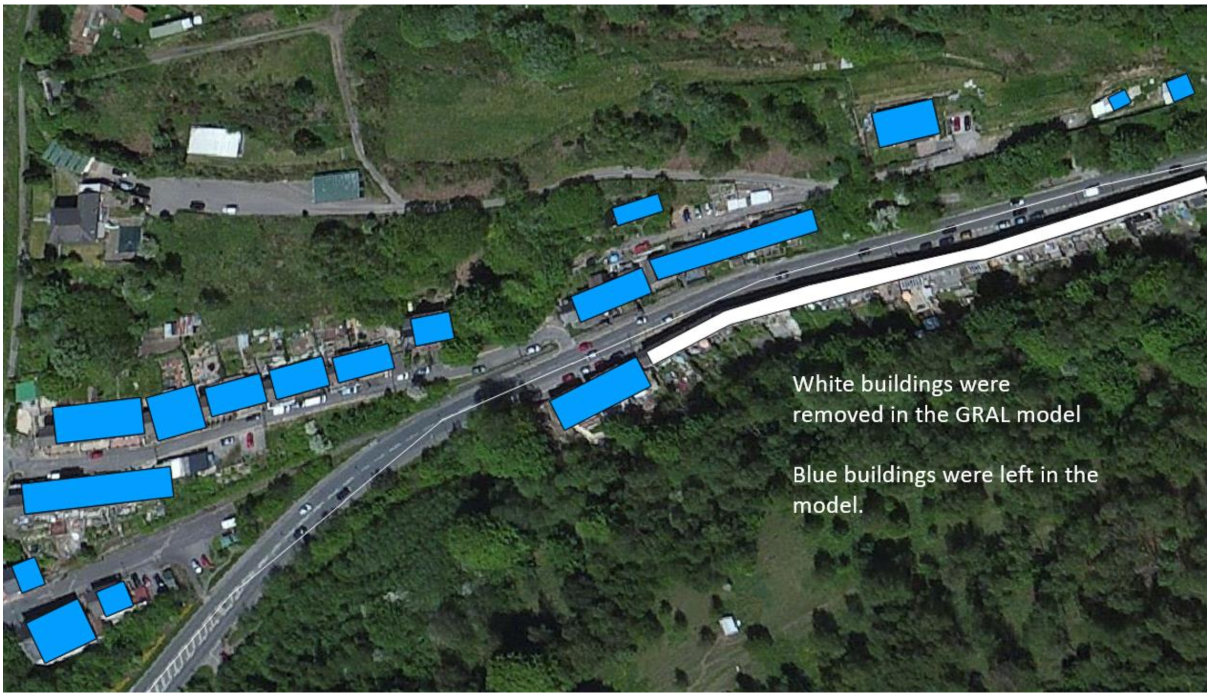

Figure 24: Visualisation of Scenario 11

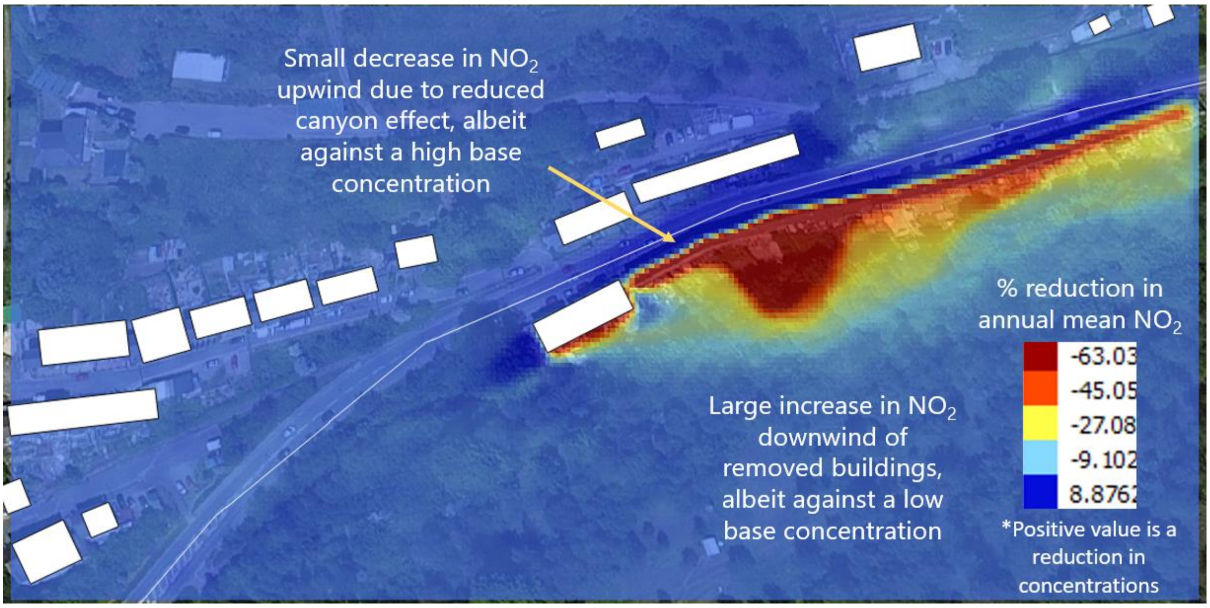

Figure 25: Visualisation of difference in modelled concentrations of NO_2 for 2017- Scenario 11

3.6.20. Predicted NO_2 concentrations show significant reductions at diffusion tube locations, (a complete list of results is displayed in Table 9). CCBC60 (close to residential dwelling to the northside of the road and also at location CCBC79 close to the top of the hill. However, at other locations concentrations remain over the limit value, particularly at the 3 dwellings retained in this scenario on the south of the road. With the removal of all residential dwellings on the southside, exposure is removed in the areas with retained high concentration levels. Concentrations of NO_2 at the properties to the north of Woodside Terrace show a reduction by about 8% with the removal of the terraces. This preliminary model indicates that the removal of all residential properties on the southside of the road should be considered further in the next detailed Stage Three work programme.

Table 9: Model data for annual mean NO_2 at selected receptor locations

Site	Modelled NO_2 (µg m^{-3})	
	Baseline (no measure)	Scenario 11
CCBC48	57.9	58.2
CCBC60	36.9	29.2
CCBC83	68.9	59.0
CCBC79	53.6	34.4
Auto Site	64.3	54.3
Façade 1	86.7	68.5
Façade 2	96.2	55.5

3.6.21. SCENARIO 13

3.6.22. PEAK HOUR HGV BANS

3.6.23. This scenario assumes a peak hour bans in place between 0700-1000 and 1600-1900 for articulated and rigid HGVs. Automatic Traffic Count data from surveys undertaken in May 2018 indicates that peak hour HGVs account for approximately 35% of total daily HGVs. It is assumed that half of these (17.5% of the daily total) find alternative routes or result in businesses to relocate, whilst half of the HGVs would remain on the corridor though be displaced to off peak times.

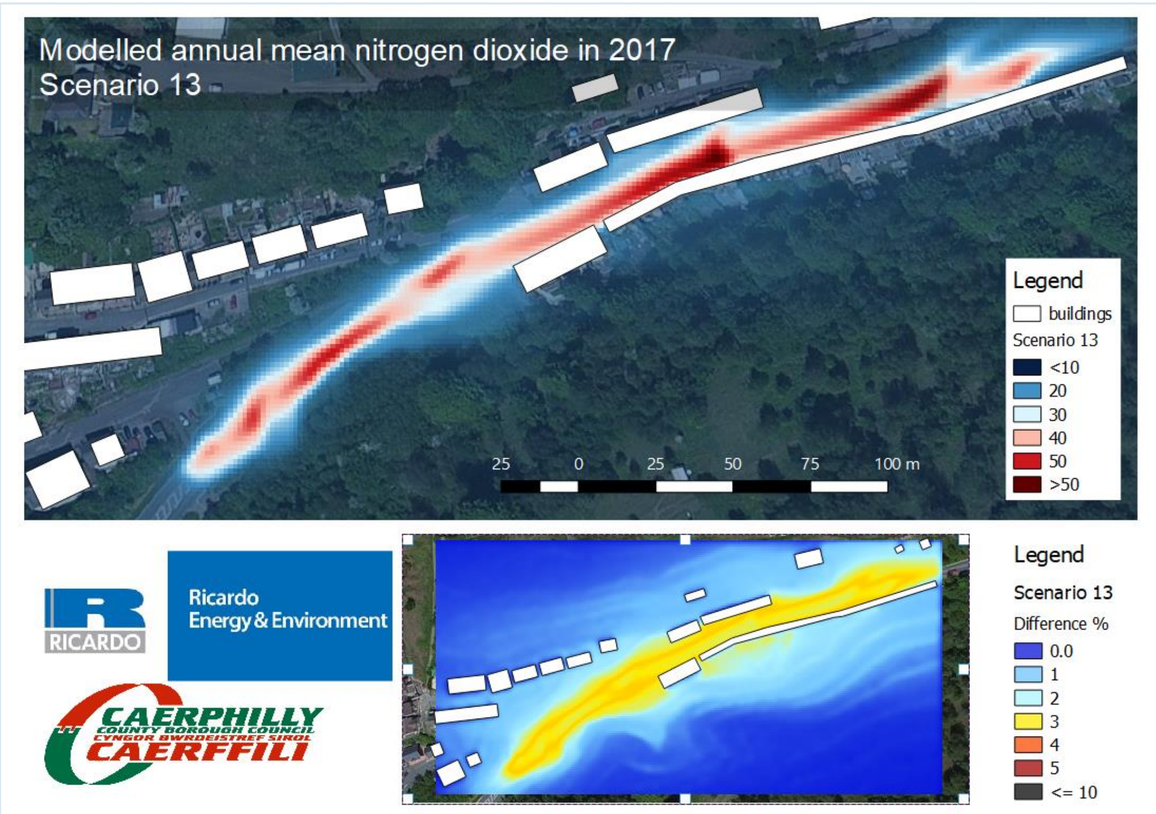

Figure 26: Visualisation of modelled concentrations of NO_2 for 2017- Scenario 13

3.6.24. Predicted concentrations from this measure only show a minimal reduction and concentrations remain very elevated compared to the limit value of 40 µg m^{-3}. The results of from each receptor are displayed in Table 10 below.

Table 10: Model data for annual mean NO_2 at selected receptor locations

Site	Modelled NO_2 (µg m^{-3})	
	Baseline (no measure)	Scenario 13
CCBC48	57.9	55.7
CCBC60	36.9	35.5
CCBC83	68.9	66.3
CCBC79	53.6	51.6
Auto Site	64.3	61.9
Façade 1	86.7	83.4
Façade 2	96.2	92.5

3.6.25. SCENARIO 15

3.6.26. EMISSIONS BARRIER

3.6.27. Model the impact of barriers erected similar to noise barriers. This barrier was assumed to be 4m in height and located in front of the terraced houses (Figure 27). Should this preliminary assessment indicate this measure could be effective in reducing exposure to the pollution levels, further sensitivity tests will be undertaken in the more detailed Stage Three work programme. This would include detailed barrier design with access routes from the roadside to the frontage of the houses.

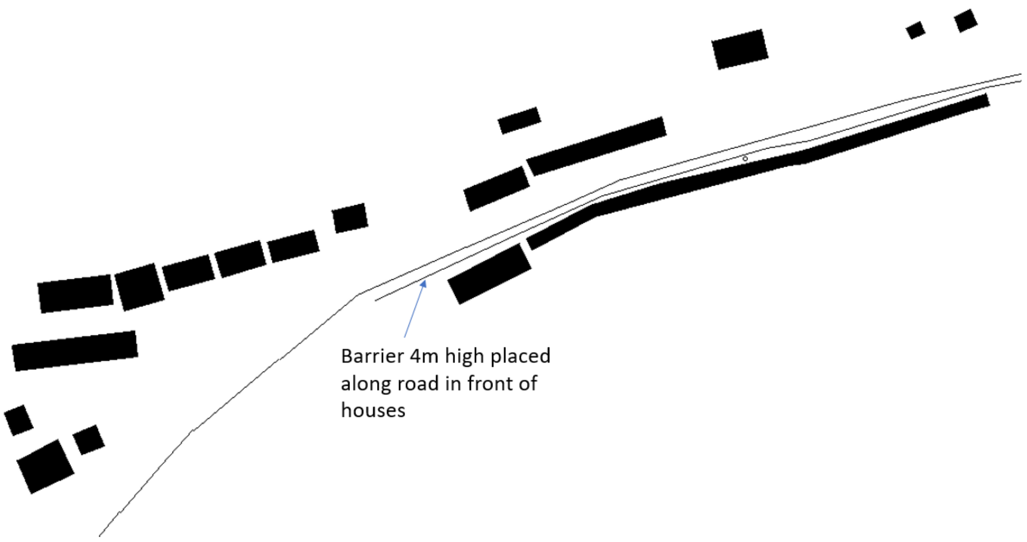

Figure 27: Visualisation of Scenario 15

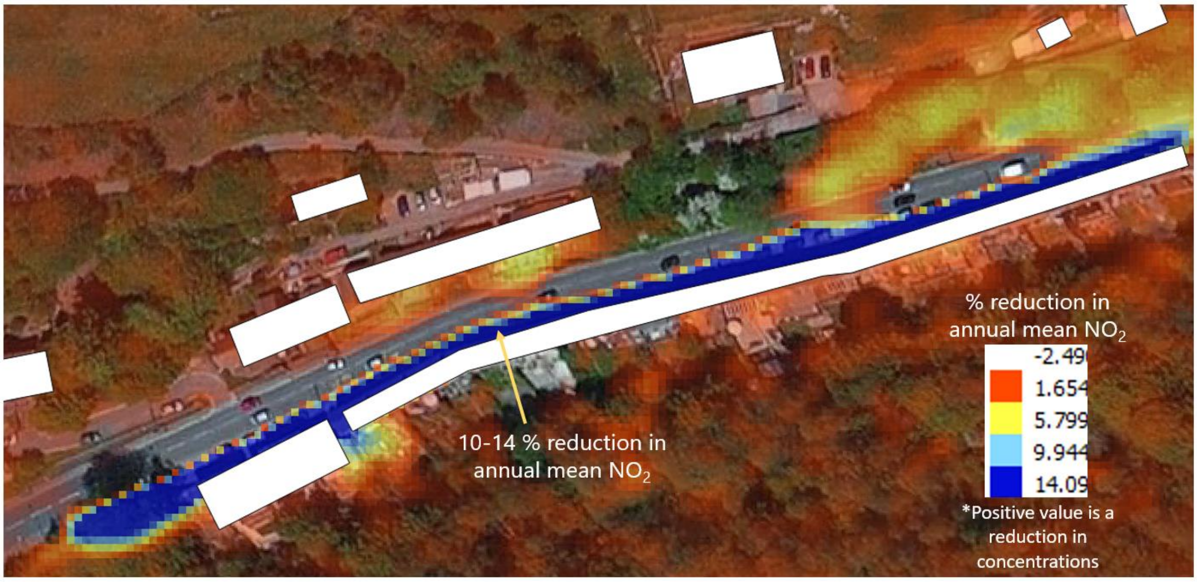

Figure 28: Visualisation of difference in modelled concentrations of NO_2 for 2017- Scenario 15

3.6.28. Results indicate a significant reduction (10-14%) in annual average NO_2 concentrations to the rear of the barrier (at the façade of the houses), this is displayed in Figure 28.

3.6.29. Preliminary results indicate that this would bring the area closer to compliance with the limit value but concentrations still remain over 40 µg m^{-3}. Dispersion of emissions is inhibited but as this measure does not result in lower emissions, then concentrations on the roadside of the barrier are likely to be further elevated, and levels behind the barrier whilst lower, they remain in exceedance as the emissions rise over the barrier with the road vehicle turbulence.

3.6.30. SCENARIO 26

3.6.31. CLEAN AIR ZONE / LOW EMISSION ZONE

3.6.32. This scenario assumes that the area is declared a "Clean Air Zone" aligned to the Welsh Government's framework on Clean Air Zones. For this scenario, it has been assumed that all vehicles are either Euro 6/VI diesel and Euro 4 petrol 24/7 and no changes to flows or speeds were made. At this preliminary stage should this measure appear effective further detailed design should be considered at the Stage Three study regarding how the measure could be implemented and enforced and the wider economic and social impacts.

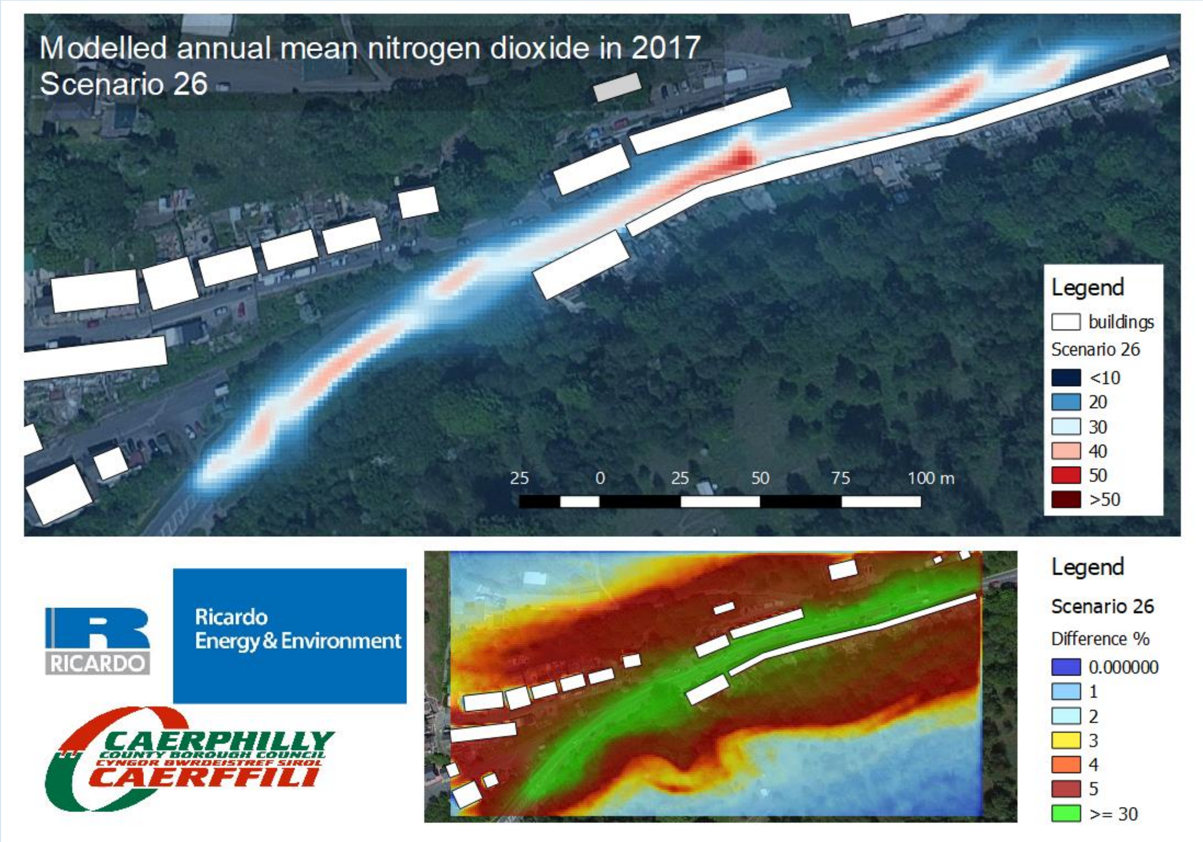

Figure 29: Visualisation of difference in modelled concentrations of NO_2 for 2017- Scenario 26

3.6.33. Predicted concentrations in Figure 29 show significant reductions with the measure (Table 11). However, this preliminary modelling at two locations on the building façade show high concentrations with the measure in place. This is most likely due to the elevated real-world emissions given the steep gradient, even from the most recent vehicles.

Table 11: Model data for annual mean NO_2 at selected receptor locations

Site	Modelled NO_2 (µg m^{-3})	
	Baseline (no measure)	Scenario 26
CCBC48	57.9	40.9
CCBC60	36.9	26.3
CCBC83	68.9	48.8
CCBC79	53.6	37.9
Auto Site	64.3	45.5
Façade 1	86.7	61.2
Façade 2	96.2	67.8

3.6.34. SCENARIO 28

3.6.35. BYPASS

3.6.36. This measure is based on the evidence that the total daily trip rate for a resident dwelling in this location is 4.370 trips per dwelling per day. Assuming all through traffic is removed from Woodside Terrace and the only remaining traffic is for the 50 or so properties on or near Woodside Terrace the AADT would be approximately (50*4.370) 218 vehicles in a 'with bypass scenario'.

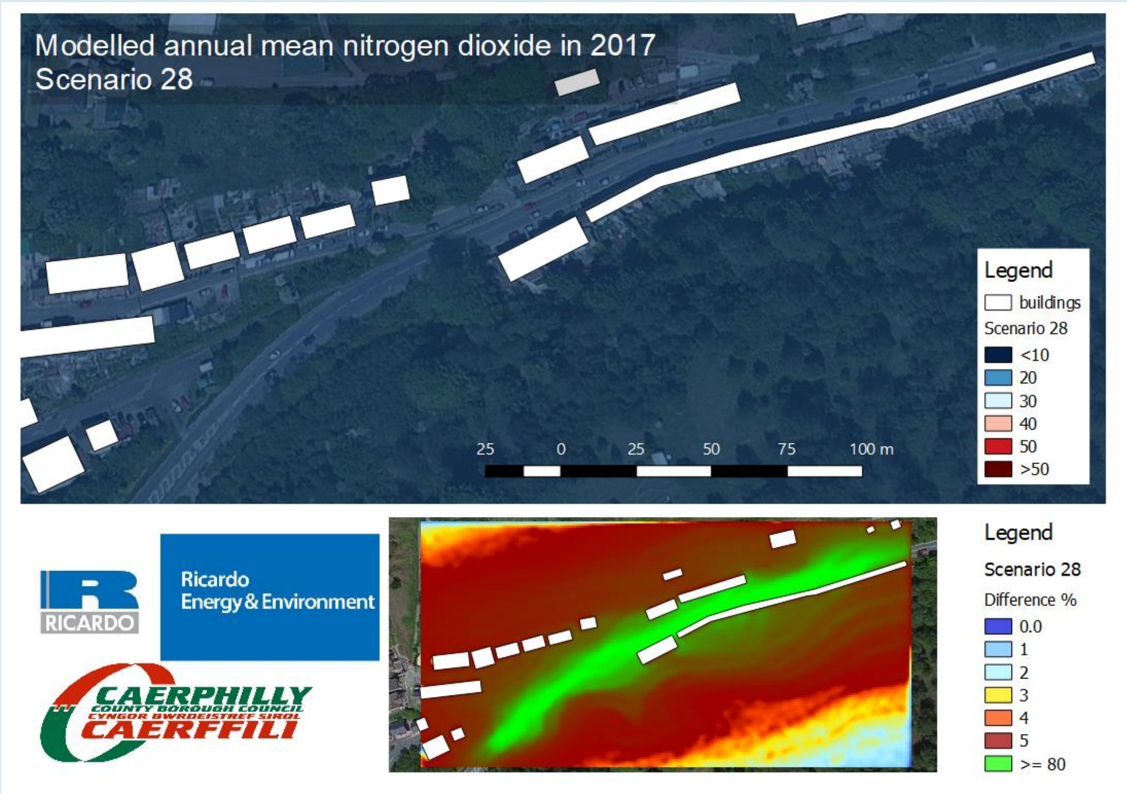

Figure 30: Visualisation of difference in modelled concentrations of NO_2 for 2017- Scenario 28

3.6.37. As expected, this scenario brings substantial reduction in NO_2 concentrations(). However, the timescales to design, plan and construct a bypass are lengthy.

Site	Modelled NO_2 (µg m^{-3})	
	Baseline (no measure)	Scenario 28
CCBC48	57.9	7.9
CCBC60	36.9	7.6
CCBC83	68.9	8.2
CCBC79	53.6	7.9
Auto Site	64.3	8.1
Façade 1	86.7	8.5
Façade 2	96.2	8.7

3.7. APPRAISAL SUMMARY TABLES

3.7.1. The full impacts of the measures have been considered and are detailed in the Appraisal Summary Tables (ASTs) overleaf.

3.7.2. The outcome of the Stage Two appraisal is summarised in Table 12.

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Appraisal Summary Table

Option No. / Theme | **1**

Name of scheme:	Change Signal Timings at Crumlin Junction
Location:	Crumlin Junction
Effectiveness:	Low
Timescale:	Up to 5 months
Feasibility:	Yes. Road network is managed by CCBC Highways Operations Department.

Objective		Summary of key impacts	Assessment – Qualitative
Environment	Air Quality	Predicted concentrations of NO2 from this measure are lower compared to the baseline in all receptor locations, due to the slightly higher average speeds related to the decreasing congestion in peak hours. However, these are only minor averaging about 3 µg m-3 compared to the level needed to achieve compliance with the limit value of 40 µg m-3. This measure could be combined with other to form a package of measures to achieve compliance.	Slight Beneficial (+)
	Noise	There is one NAPPA located along the A472 Hafod Yr Ynys Road within the study area, and several sensitive residential dwellings adjacent to the A472. By slowing the volume of traffic travelling west at a given time this could generate a slight decrease to the levels of noise on the A472.	Slight Beneficial (+)
	Landscape	The site is not situated within 1km or within proximity of any designated landscape areas. The scheme is unlikely to generate significant impacts upon the landscape.	Neutral (0)
	Historic Environment	There are no Conservation Areas, Historic Parks and Gardens or Scheduled monuments within 1km of the site. There is one listed structure set just north west of the A472 and several locally important assets, however, the scheme is unlikely to affect the historic environment.	Neutral (0)
	Biodiversity	There are no statutory designated sites within 2km of the site. There is one SINC located 200m north west. With limited vegetation clearance required, the scheme is unlikely to affect biodiversity.	Neutral (0)
	Water Environment	The River Ebbw is located 45m south west, and an unnamed drainage ditch also flows adjacent to the A472, however, no significant impacts are anticipated to occur to the water environment.	Neutral (0)
	Townscape	There are no Conservation Areas located within 1km of the site. Several listed buildings are located within 1km of the route corridor, however, no impact upon townscape features are anticipated to occur as a result of the scheme.	Neutral (0)
Economy	Journey Time Changes	Minor journey time improvements envisaged. However, this could be offset by the queuing traffic at the A467.	Neutral (0)
	Capital Costs	Low (up to £500k)	Low (up to £500k)
	Land	It is anticipated that this option can be accommodated within the verge of current road system. This is not anticipated to have any requirements for additional land.	Neutral (0)
S&C	Journey Quality	Changing signal timings, is not envisaged to have an impact on the journey quality and, therefore, is considered to be neutral.	Neutral (0)
	Physical Activity	Signals' timing modifications should not impact physical activity along the study route. Therefore, it is considered that the impact should be neutral.	Neutral (0)
	Accidents	The signal timing's change is not expected to impact on accidents along the study route. Therefore, it is considered that the impact should be neutral.	Neutral (0)
	Access	Changes to signal timing's are not expected to impact on access to services, employment, or healthcare along the study route. Therefore, it is considered that the impact should be neutral.	Neutral (0)
VfM	Value for Money	It is anticipated that the Benefit to Cost ratio for this option would be within the range of 1 to 2	Fair - Expected BCR between 1 and 2.
Other Issues	Acceptability	Given the nature of the proposals, this measure is unlikely to be opposed by any groups or individuals.	
	Technical, Operational & Financial Feasibility	None identified at this stage. To be re-evaluated at Stage 3 when detailed scheme drawings and cost estimates are available.	
	Deliverability & Risk	Changing signal timings at Crumlin junction is likely to result in increased queues and levels of NO2 elsewhere. To be re-evaluated at Stage 3 when detailed scheme drawings and cost estimates are available.	
Secondary Criteria of the Objective	Will the intervention deliver an overall reduction in NO2 emissions to air	Yes. It is considered that this measure should have minimal impact on overall reduction in NO2	
	Will the intervention result in unintended consequences or other environmental impacts	No. There are no adverse consequences to other environmental impacts.	
	Will the intervention impact equally across multiple vehicle classes and journey types	Yes. This scheme should have an equal impact on all vehicle classes and journey types.	
	Will the intervention have a positive impact on wider public health and inequalities	Yes. It is considered that this measure should marginally improve the wider public health.	

Date Produced - 13/09/2018

Appraisal Summary Table

Option No. / Theme | **2**

Name of scheme:	Signalise the A472/B4471 as a Priority Junction and Introduce an Eastbound Queue Detector
Location:	A472/B4471 Priority Junction
Effectiveness:	Low
Timescale:	18-24 months
Feasibility:	Yes. Road network is managed by CCBC Highways Operations Department.

Objective		Summary of key impacts	Assessment Qualitative
Environment	Air Quality	Predicted concentrations of NO2 from this measure are lower compared to the baseline in all receptor locations, due to the slightly higher average speeds related to the decreasing congestion in peak hours. However, these are only minor averaging about 3 µg m-3 compared to the level needed to achieve compliance with the limit value of 40 µg m-3. This measure could be combined with other to form a package of measures to achieve compliance.	Slight Beneficial (+)
	Noise	There is one NAPPA located along the A472 Hafod Yr Ynys Road within the study area, and several sensitive residential dwellings adjacent to the A472. By reducing the time of queuing congested traffic travelling east on the A472 may generate a slight decrease to the levels of noise on the A472.	Slight Beneficial (+)
	Landscape	The site is not situated within 1km or within proximity of any designated landscape areas. The scheme is unlikely to generate significant impacts upon the landscape.	Neutral (0)
	Historic Environment	There are no Conservation Areas, Historic Parks and Gardens or Scheduled monuments within 1km of the site. There is one listed structure set just north west of the A472 and several locally important assets however, the scheme is unlikely to affect the historic environment.	Neutral (0)
	Biodiversity	There are no statutory designated sites within 2km of the site. There is one SINC located 200m north west. With limited vegetation clearance required, the scheme is unlikely to affect biodiversity.	Neutral (0)
	Water Environment	The River Ebbw is located 45m south west, and an unnamed drainage ditch also flows adjacent to the A472, however, no significant impacts are anticipated to occur to the water environment.	Neutral (0)
	Townscape	There are no Conservation Areas located within 1km of the site. Several listed buildings are located within 1km of the route corridor, however, no impact upon townscape features are anticipated to occur as a result of the scheme.	Neutral (0)
Economy	Journey Time Changes	Slight journey times improvements at the A472/B4471 junction from controlling the flow of the main line.	Slight Beneficial (+)
	Capital Costs	Medium (£500k - £2m)	Medium (£500k - £2m)
	Land	It is anticipated that this option can be accommodated within the verge of current road system. This is not anticipated to have any requirements for additional land.	Neutral (0)
S&C	Journey Quality	Installing a new signalling at the A472/B4471 junction, is not envisaged to have an impact on the journey quality and, therefore, is considered to be neutral.	Neutral (0)
	Physical Activity	Installing the new signalling at the A472/B4471 junction should not impact physical activity along the study route. Therefore, it is considered that the impact should be neutral.	Neutral (0)
	Accidents	It is envisaged that signalising the A472/B4471 junction should be slightly beneficial on the number and severity of recorded accidents, due to the safer approach to the junction	Slight Beneficial (+)
	Access	Signalising the A472/B4471 junction is expected to slightly benefit the access to services, employment, or healthcare along the study route. Therefore, it is considered that the impact should be slightly beneficial.	Slight Beneficial (+)
VfM	Value for Money	It is anticipated that the Benefit to Cost ratio for this option would be within the range of 1 to 2	Fair - Expected BCR between 1 and 2.
Other Issues	Acceptability	Given the nature of the proposals, this measure is unlikely to be opposed by any groups or individuals.	
	Technical, Operational & Financial Feasibility	None identified at this stage. To be re-evaluated at Stage 3 when detailed scheme drawings and cost estimates are available.	
	Deliverability & Risk	None identified at this stage. To be re-evaluated at Stage 3 when detailed scheme drawings and cost estimates are available.	
Secondary Criteria of the Objective	Will the intervention deliver an overall reduction in NO2 emissions to air	Yes. It is considered that this measure should have minimal impact on overall reduction in NO2	
	Will the intervention result in unintended consequences or other environmental impacts	No. There are no adverse consequences to other environmental impacts.	
	Will the intervention impact equally across multiple vehicle classes and journey types	Yes. This scheme should have an equal impact on all vehicle classes and journey types.	
	Will the intervention have a positive impact on wider public health and inequalities	Yes. It is considered that this measure should marginally improve the wider public health.	

Date Produced - 13/09/2018

Appraisal Summary Table

Option No. / Theme | **3**

Name of scheme:	Reclassify National Speed Limit to 50mph on the A472 Hafodyrynys Road
Location:	A472
Effectiveness:	Ineffective
Timescale:	Up to 5 months
Feasibility:	Yes. Road network is managed by CCBC Highways Operations Department and would need to be enforced by the police.

Objective		Summary of key impacts	Assessment – Qualitative
Environment	Air Quality	As only a small number of vehicles were above 50 mph this measure will make no significant difference to average speeds and therefore will have no impact on the concentrations of NO2	Neutral (0)
	Noise	There is one NAPPA located along the A472 Hafod Yr Ynys Road within the study area, and several sensitive residential dwellings adjacent to the A472. By reducing the speed of traffic travelling west this could generate a slight decrease to the levels of noise between the A472 and receptors	Slight Beneficial (+)
	Landscape	The site is not situated within 1km or within proximity of any designated landscape areas. The scheme is unlikely to generate significant impacts upon the landscape.	Neutral (0)
	Historic Environment	There are no Conservation Areas, Historic Parks and Gardens or Scheduled monuments within 1km of the site. There is one listed structure set just north west of the A472 and several locally important assets, however, the scheme is unlikely to affect the historic environment.	Neutral (0)
	Biodiversity	There are no statutory designated sites within 2km of the site. There is one SINC located 200m north west. With limited vegetation clearance required, the scheme is unlikely to affect biodiversity.	Neutral (0)
	Water Environment	The River Ebbw is located 45m south west, and an unnamed drainage ditch also flows adjacent to the A472, however, no significant impacts are anticipated to occur to the water environment.	Neutral (0)
	Townscape	There are no Conservation Areas located within 1km of the site. Several listed buildings are located within 1km of the route corridor, however, no impact upon townscape features are anticipated to occur as a result of the scheme.	Neutral (0)
Economy	Journey Time Changes	The journey times may decrease for some drivers as an effect of the lower maximum speed enforced along the A472 road.	Slight Adverse (-)
	Capital Costs	Low (up to £500k)	Low (up to £500k)
	Land	It is anticipated that this option can be accommodated within the verge of current road system. This is not anticipated to have any requirements for additional land.	Neutral (0)
S&C	Journey Quality	Limiting the maximum permitted speed is not envisaged to have a significant impact on the journey quality and, therefore, is considered to be neutral.	Neutral (0)
	Physical Activity	Modifications to the existing speed limit should not impact physical activity along the study route. Therefore, it is considered that the impact should be neutral.	Neutral (0)
	Accidents	It is envisaged that enforcing and/or reducing the speed limit should be slightly beneficial on the number and severity of recorded accidents.	Slight Beneficial (+)
	Access	Reclassifying the existing speed on the A472 Hafodyrynys Road, is not expected to impact on access to services, employment, or healthcare along the study route. Therefore, it is considered that the impact should be neutral.	Neutral (0)
VfM	Value for Money	It is anticipated that the Benefit to Cost ratio for this option would be within the range of 1 to 2	Fair - Expected BCR between 1 and 2.
Other Issues	Acceptability	Given the nature of the proposals, this measure is anticipated to be opposed by some groups or individuals.	
	Technical, Operational & Financial Feasibility	None identified at this stage though measure ruled out on effectiveness.	
	Deliverability & Risk	None identified at this stage. To be re-evaluated at Stage 3 when detailed scheme drawings and cost estimates are available.	
Secondary Criteria of the Objective	Will the intervention deliver an overall reduction in NO2 emissions to air	No. This measure will make no significant difference to average speeds and therefore will have no impact on the NO2 emissions.	
	Will the intervention result in unintended consequences or other environmental impacts	No. There are no adverse consequences to other environmental impacts.	
	Will the intervention impact equally across multiple vehicle classes and journey types	Yes. This scheme should have an equal impact on all vehicle classes and journey types.	
	Will the intervention have a positive impact on wider public health and inequalities	No. Reclassifying National Speed Limit should have a neutral impact on wider public health and inequalities.	

Date Produced - 13/09/2018

Appraisal Summary Table

Option No. / Theme | **4**

Name of scheme:	Demolish Dwellings at Woodside Terrace and Re-align Road
Location:	A472
Effectiveness:	High
Timescale:	2-3 years
Feasibility:	Yes. Subject to the CCBC's ability to enforce the Compulsory Purchase Order.

	Objective	Summary of key impacts	Assessment Qualitative
Environment	Air Quality	Predicted NO2 concentrations show significant reductions at diffusion tube locations, (a complete list of results is displayed in Table 5). CCBC60 (close to residential dwelling to the northside of the road and also at location CCBC79 close to the top of the hill. However, at other locations concentrations remain over the limit value, particularly at the 3 dwellings retained in this scenario on the south of the road where concentrations increase with the removal of the other dwellings. This is likely to be due to the increased turbulence which pushes the emissions further back from the kerbside. With the removal of all residential dwellings on the southside, exposure is removed in the areas with retained high concentration levels. Concentrations of NO2 at the properties to the north of Woodside Terrace show a reduction by about 8% with the removal of the terraces. This preliminary model indicates that the removal of all residential properties on the southside of the road should be considered further in the next detailed Stage 3 work programme.	Large Beneficial (+++)
Environment	Noise	By demolishing the residential dwellings on Woodside Terrace removes the impacts on those receptors, but is not improving the noise climate for the other receptors in that area. There is a missed opportunity for reducing noise levels for elevated properties on Gladstone Road. Potential impacts during the demolition of the properties on sensitive receptors will be temporary.	Neutral (0)
Environment	Landscape	The option would allow the A472 road corridor to remain within the steep sided valley enclosure of Cym y Glyn and Hafodyrynys. As such the effect on landscape character would be limited to the immediate valley setting, while the wider landscape character beyond the valley would not significantly alter. The valley slope and plateau landscape to the immediate south of the A472 is a locally designated Visually Important Local Landscape (VILL, Caerphilly Council), with the forested areas noted as being of a high visual and sensory value for rarity in a regional context. There would be some loss of roadside woodland cover associated with the route, although this loss would not significantly influence the appearance of the valley landscape in relation to the road. The loss of residential dwellings would represent an erosion of the cultural character associated with linear and residential settlement pattern along the valley towards Crumlin.	Slight Adverse (-)
Environment	Historic Environment	There are no Conservation Areas, Historic Parks and Gardens or Scheduled monuments within 1km of the site. There is one listed structure set just north west of the A472 and several locally important assets, however, the scheme is unlikely to affect the historic environment.	Neutral (0)
Environment	Biodiversity	There are no statutory designated sites within 2km of the site. There is one SINC located 200m north west and Coed Goferau SINC located adjacent to the A472. The demolition works could pose a short term and temporary impact to ecology and biodiversity through waste removal, noise, light and dust pollution as well as limited vegetation removal although with the inclusion of appropriate mitigation this is not likely to pose any long term or permanent impact to ecology or biodiversity. Buildings could potentially support roosting bats. Surveys would be required to assess suitability and determine if any roosts were present. Should any bat roosts be present, a licence would be required from NRW to permit demolition. Mitigation would also be required, which could include provision of replacement roosts.	Slight Adverse (-)
Environment	Water Environment	The River Ebbw is located 45m south west, and an unnamed drainage ditch also flows adjacent to the A472. The alignment of the ditch will need to be maintained. The demolition works could pose a short term and temporary impact to water quality in the ditch that could be conveyed to the River Ebbw downstream, although with the inclusion of appropriate mitigation this is not likely to pose any long term or permanent impact to water quality within the ditch or River Ebbw.	Neutral (0)
Environment	Townscape	There are no Conservation Areas located within 1km of the site. Several listed buildings are located within 1km of the route corridor, however, no impact upon townscape features are anticipated to occur as a result of the scheme	Neutral (0)
Economy	Journey Time Changes	Demolishing the dwellings along the A472 road should not affect the journey times.	Neutral (0)
Economy	Capital Costs	High (£2m+)	High (£2m+)
Economy	Land	It is anticipated that demolishing the dwellings may result in a transgression to the existing land/road system.	Slight Adverse (-)
S&C	Journey Quality	Demolishing the dwellings along the A472 road is not envisaged to have an impact on the journey quality and, therefore, is considered to be neutral.	Neutral (0)
S&C	Physical Activity	Demolishing the Woodside Terrace dwellings should not impact physical activity along the study route. Therefore, it is considered that the impact should be neutral.	Neutral (0)
S&C	Accidents	Demolishing the existing Woodside Terrace dwellings is not expected to impact on accidents along the study route. Therefore, it is considered that the impact should be neutral.	Neutral (0)
S&C	Access	Demolishing the existing Woodside Terrace dwellings will result in displacing the current residents. This, in turn, will impact on their trips to services, employment, and healthcare. The impact is considered to be slightly adverse.	Slight Adverse (-)
VfM	Value for Money	It is anticipated that the Benefit to Cost ratio for this option would be within the range of 0 to 1	Poor - Expected BCR between 0 and 1
Other Issues	Acceptability	Given the nature of the proposals, this measure is anticipated to be opposed by the Woodside Terrace's residents.	
Other Issues	Technical, Operational & Financial Feasibility	None identified at this stage. To be re-evaluated at Stage 3 when detailed scheme drawings and cost estimates are available.	
Other Issues	Deliverability & Risk	The deliverability is subject to the Caerphilly Council's ability to enforce the Compulsory Purchase Order.	
Secondary Criteria of the Objective	Will the intervention deliver an overall reduction in NO2 emissions to air	No. This measure will not reduce the emissions from the vehicles. It will, however, take away the canyon effect and pollution concentrations decrease significantly on the northern side of the road.	
Secondary Criteria of the Objective	Will the intervention result in unintended consequences or other environmental impacts	Yes. There are slight adverse consequences to the landscape and biodiversity.	
Secondary Criteria of the Objective	Will the intervention impact equally across multiple vehicle classes and journey types	Yes. This scheme should have an equal impact on all vehicle classes and journey types.	
Secondary Criteria of the Objective	Will the intervention have a positive impact on wider public health and inequalities	Yes. The residents will no longer be exposed to the high NO2 concentration. However, some social inequalities are envisaged due to the displacing the residents.	

Date Produced - 13/09/2018

Appraisal Summary Table

Option No. / Theme | **5**

Name of scheme:	Peak Hour HGV Bans
Location:	A472
Effectiveness:	Low
Timescale:	Up to 5 months
Feasibility:	Yes. Road network is managed by CCBC Highways Operations Department and would need to be enforced by the police.

Objective		Summary of key impacts	Assessment Qualitative
Environment	Air Quality	This measure assumes a peak hour ban in place between 0700-1000 and 1600-1900 for articulated and rigid HGV when about 35% HGV movements occur. As emissions from HGVs are typically higher compared to peak hour, HGV movements will find an alternative route, therefore will add to pollution levels elsewhere. In Hafodyrynys predicted concentrations from this measure only show a minimal reduction (about 2 µg m-3) and concentrations remain very elevated compared to the limit value of 40 µg m-3. This measure could be combined with other to form a package of measures to achieve compliance.	Slight Beneficial (+)
	Noise	There is one NAPPA located along the A472 Hafod Yr Ynys Road within the study area, and several sensitive residential dwellings adjacent to the A472. By reducing the number of HGVs using the A472 this could generate a slight decrease to the levels of noise on the A472.	Slight Beneficial (+)
	Landscape	The site is not situated within 1km or within proximity of any designated landscape areas. The scheme is unlikely to generate significant impacts upon the landscape.	Neutral (0)
	Historic Environment	There are no Conservation Areas, Historic Parks and Gardens or Scheduled monuments within 1km of the site. There is one listed structure set just north west of the A472 and several locally important assets, however, the scheme is unlikely to affect the historic environment.	Neutral (0)
	Biodiversity	There are no statutory designated sites within 2km of the site. There is one SINC located 200m north west. With limited vegetation clearance required, the scheme is unlikely to affect biodiversity.	Neutral (0)
	Water Environment	The River Ebbw is located 45m south west, and an unnamed drainage ditch also flows adjacent to the A472, however, no significant impacts are anticipated to occur to the water environment.	Neutral (0)
	Townscape	There are no Conservation Areas located within 1km of the site. Several listed buildings are located within 1km of the route corridor, however, no impact upon townscape features are anticipated to occur as a result of the scheme.	Neutral (0)
Economy	Journey Time Changes	Removing the HGVs from the road during the peak times may slightly improve journey times.	Slight Beneficial (+)
	Capital Costs	Low (up to £500k)	Low (up to £500k)
	Land	It is anticipated that this option can be accommodated within the verge of current road system. This is not anticipated to have any requirements for additional land.	Neutral (0)
S&C	Journey Quality	HGV peak hour ban could result in slightly lower numbers of these vehicles along the route under the study This, however, is not envisaged to have a significant impact on the journey quality and, therefore, is considered to be neutral.	Neutral (0)
	Physical Activity	The peak hours HGV ban, may be slightly beneficial for the physical activity. However, considering low number of the HGVs alone the study route, it is considered that the impact should be neutral.	Neutral (0)
	Accidents	Banning the HGVs at peak hours is not expected to impact on accidents along the study route. Therefore, i is considered that the impact should be neutral.	Neutral (0)
	Access	Banning the HGVs during peak hours will impact on their trips to the local service and employment hubs. This, in turn, will affect these places' operational ability. The impact is considered to be moderately adverse.	Moderate Adverse (--)
VfM	Value for Money	It is anticipated that the Benefit to Cost ratio for this option would be within the range of 1 to 2	Fair - Expected BCR between 1 and 2.
Other Issues	Acceptability	Given the nature of the proposals, this measure is anticipated to be opposed by the local businesses and service providers.	
	Technical, Operational & Financial Feasibility	None identified at this stage. To be re-evaluated at Stage 3 when detailed scheme drawings and cost estimates are available.	
	Deliverability & Risk	Whilst it may decrease levels during the peak hours, it may also encourage HGVs to travel earlier or later in to the night and impact on noise at other times. The options could also cause displacement effects	
Secondary Criteria of the Objective	Will the intervention deliver an overall reduction in NO2 emissions to air	Yes. It is considered that this measure should have a positive impact on overall reduction in NO2	
	Will the intervention result in unintended consequences or other environmental impacts	No. There are no adverse consequences to other environmental impacts.	
	Will the intervention impact equally across multiple vehicle classes and journey types	No. HGVs will be targeted	
	Will the intervention have a positive impact on wider public health and inequalities	Yes. It is considered that this measure should marginally improve the wider public health.	

Date Produced - 13/09/2018

Appraisal Summary Table

Option No. / Theme | **6**

Name of scheme:	Emissions Barrier
Location:	A472
Effectiveness:	High
Timescale:	18-24 months
Feasibility:	No - Physical constraints mean that it is not possible to construct an emissions barrier and maintain the footway

	Objective	Summary of key impacts	Assessment Qualitative
Environment	Air Quality	Preliminary results indicate that this would bring the area closer to compliance with the limit value, but concentrations still remain over 40 µg m-3. Dispersion of emissions is inhibited but as this measure does not result in lower emissions, then concentrations on the roadside of the barrier are likely to be further elevated, and levels behind the barrier whilst lower, they remain in exceedance as the emissions rise over the barrier with the road vehicle turbulence.	Large Beneficial (+++)
	Noise	There is one NAPPA located along the A472 Hafod Yr Ynys Road within the study area, and several sensitive residential dwellings adjacent to the A472. This scheme is unlikely to have any impacts on noise.	Neutral (0)
	Landscape	The site is not situated within 1km or within proximity of any designated landscape areas. The barrier may have a visual impact on the area during construction and operation and intervene with natural views, however it is situated within the existing transportation corridor and therefore the impact is likely to be reduced as a result.	Slight Adverse (-)
	Historic Environment	There are no Conservation Areas, Historic Parks and Gardens or Scheduled monuments within 1km of the site. There is one listed structure set just north west of the A472 and several locally important assets, however, the scheme is unlikely to affect the historic environment.	Neutral (0)
	Biodiversity	There are no statutory designated sites within 2km of the site. There is one SINC located 200m north west. This intervention could have slight impact upon the local ecology on the carriageway soft estate due to the removal of vegetation required.	Slight Adverse (-)
	Water Environment	The River Ebbw is located 45m south west, and an unnamed drainage ditch also flows adjacent to the A472, however, no significant impacts are anticipated to occur to the water environment.	Neutral (0)
	Townscape	There are no Conservation Areas located within 1km of the site. Several listed buildings are located within 1km of the route corridor, however, no impact upon townscape features are anticipated to occur as a result of the scheme.	Neutral (0)
Economy	Journey Time Changes	It is not envisaged that installing the barriers will affect the journey times.	Neutral (0)
	Capital Costs	Medium (£500k - £2m)	Medium (£500k - £2m)
	Land	It is anticipated that this option can be accommodated within the verge of current road system. This is not anticipated to have any requirements for additional land.	Neutral (0)
S&C	Journey Quality	Introducing the emissions barriers along the western stretch of the road under study, is envisaged to have a slight adverse impact on the travellers views, such as pleasantness of the journey.	Slight Adverse (-)
	Physical Activity	Installing the emissions barriers is likely to have an adverse impact on physical activity along the study route due to the removal of the footway. Therefore, it is considered that the impact should be slight adverse.	Slight Adverse (-)
	Accidents	Installing the emissions barriers is not expected to impact on accidents along the study route in a day-to-day operation. There may be, however, occasional impact on the safety of the broken-down vehicles, to which access will be limited due to the barriers. It is, however, considered that the impact should be neutral.	Neutral (0)
	Access	Installing the emissions barriers is not expected to impact on access to services, employment, or healthcare along the study route. Therefore, it is considered that the impact should be neutral.	Neutral (0)
VfM	Value for Money	It is anticipated that the Benefit to Cost ratio for this option would be within the range of 0 to 1	Poor - Expected BCR between 0 and 1
Other Issues	Acceptability	Given the nature of the proposals, this measure is anticipated to be opposed by the Woodside Terrace's residents, who might be impacted by the reduction in parking spaces. Also, the emissions barriers will likely reduce the amount of natural light reaching the properties.	
	Technical, Operational & Financial Feasibility	Due to physical constraints along the corridor this measure has been ruled out on feasibility.	
	Deliverability & Risk	The deliverability is subject to the design assessment and potential issues identification.	
Secondary Criteria of the Objective	Will the intervention deliver an overall reduction in NO2 emissions to air	No. This measure will not reduce the emissions from the vehicles. It will, however, remove the exposure.	
	Will the intervention result in unintended consequences or other environmental impacts	Yes. There are slight adverse consequences to the landscape and biodiversity.	
	Will the intervention impact equally across multiple vehicle classes and journey types	Yes. This scheme should have an equal impact on all vehicle classes and journey types.	
	Will the intervention have a positive impact on wider public health and inequalities	Yes. It is considered that this measure should marginally improve the wider public health.	

Date Produced - 13/09/2018

Appraisal Summary Table

Option No. / Theme 7

Name of scheme:	Rear Access to Properties and Install NO2 Filtration
Location:	A472
Effectiveness:	Medium
Timescale:	18-24 months
Feasibility:	No - Physical constraints mean that it is not possible to provide safe and convenient rear access to

Objective		Summary of key impacts	Assessment Qualitative
Environment	Air Quality	This measure involves the construction of an access route to the rear of properties on the southside of Woodside Terrace. The footpath along the road would remain enabling access to residents' car parking. As, there is no change in emissions then the modelled NO2 concentrations are the same as the baseline (with no measures). The hourly limit value remains in exceedance where exposure along the footpath.	Moderate Beneficial (++)
	Noise	There is one NAPPA located along the A472 Hafod Yr Ynys Road within the study area, and several sensitive residential dwellings adjacent to the A472. This scheme is unlikely to have any impacts on noise.	Neutral (0)
	Landscape	The site is not situated within 1km or within proximity of any designated landscape areas. The scheme is unlikely to generate significant impacts upon the landscape.	Neutral (0)
	Historic Environment	There are no Conservation Areas, Historic Parks and Gardens or Scheduled monuments within 1km of the site. There is one listed structure set just north west of the A472 and several locally important assets, however, the scheme is unlikely to affect the historic environment.	Neutral (0)
	Biodiversity	There are no statutory designated sites within 2km of the site. There is one SINC located 200m north west. With limited vegetation clearance required, the scheme is unlikely to affect biodiversity.	Neutral (0)
	Water Environment	The River Ebbw is located 45m south west, and an unnamed drainage ditch also flows adjacent to the A472, however, no significant impacts are anticipated to occur to the water environment.	Neutral (0)
	Townscape	There are no Conservation Areas located within 1km of the site. Several listed buildings are located within 1km of the route corridor, however, no impact upon townscape features are anticipated to occur as a result of the scheme.	Neutral (0)
Economy	Journey Time Changes	It is not envisaged that the modification to properties will affect the journey times.	Neutral (0)
	Capital Costs	Medium (£500k - £2m)	Medium (£500k - £2m)
	Land	Modifications to the access to the properties may not be accommodated within existing boundaries. It is anticipated that additional land acquisition should be required.	Slight Adverse (-)
S&C	Journey Quality	Introducing the modifications to the existing properties, is not envisaged to have an impact on the journey quality and, therefore, is considered to be neutral.	Neutral (0)
	Physical Activity	Modification to the existing Woodside Dwellings should not impact physical activity along the study route. Therefore, it is considered that the impact should be neutral.	Neutral (0)
	Accidents	It is envisaged that due to the change in the dwellings' access layout, and therefore removing the existing parking spaces along the A472 route, should be slightly beneficial on the number and severity of recorded accidents.	Slight Beneficial (+)
	Access	Modifications to the Woodside Terrace's properties are not expected to impact on access to services, employment, or healthcare along the study route. Therefore, it is considered that the impact should be neutral.	Neutral (0)
VfM	Value for Money	It is anticipated that the Benefit to Cost ratio for this option would be within the range of 0 to 1	Poor - Expected BCR between 0 and 1
Other Issues	Acceptability	Given the nature of the proposals, this measure is anticipated to be opposed by the Woodside Terrace's residents. It is likely that access to the properties by emergency services would become more difficult.	
	Technical, Operational & Financial Feasibility	Measure has been ruled out on feasibility	
	Deliverability & Risk	The deliverability is subject to design and comply with the buildings regulations. It is likely that the engineering requirements associated with the measureand its topography would be complicated and costly.	
Secondary Criteria of the Objective	Will the intervention deliver an overall reduction in NO2 emissions to air	No. This measure should not result in a reduction of NO2 emissions	
	Will the intervention result in unintended consequences or other environmental impacts	No. There are no adverse consequences to other environmental impacts.	
	Will the intervention impact equally across multiple vehicle classes and journey types	Yes. This scheme should have an equal impact on all vehicle classes and journey types.	
	Will the intervention have a positive impact on wider public health and inequalities	Yes. It is considered that this measure should marginally improve the wider public health.	

Date Produced - 13/09/2018

Appraisal Summary Table **Option No. / Theme** 8

Name of scheme:	Clean Air Zone/Low Emission Zone
Location:	A472
Effectiveness:	Medium
Timescale:	3 years
Feasibility:	Yes. Road network is managed by CCBC Highways Operations Department.

Objective		Summary of key impacts	Assessment Qualitative
Environment	Air Quality	This measure could result in significant reductions in concentrations. However, exceptionally high concentrations at the building façade of Woodside Terrace still remain. This measure could be combined with other to form a package of measures to achieve compliance.	Moderate Beneficial (++)
	Noise	There is one NAPPA located along the A472 Hafod Yr Ynys Road within the study area, and several sensitive residential dwellings adjacent to the A472. Limiting the number of non-compliant vehicles travelling along the A472 may have an impact on noise levels. Newer vehicles are also likely to produce less noise however, the ratio of newer cars to older cars is unlikely to produce a significant benefit.	Neutral (0)
	Landscape	The site is not situated within 1km or within proximity of any designated landscape areas. The scheme is unlikely to generate significant impacts upon the landscape.	Neutral (0)
	Historic Environment	There are no Conservation Areas, Historic Parks and Gardens or Scheduled monuments within 1km of the site. There is one listed structure set just north west of the A472 and several locally important assets, however, the scheme is unlikely to affect the historic environment.	Neutral (0)
	Biodiversity	There are no statutory designated sites within 2km of the site. There is one SINC located 200m north west. With limited vegetation clearance required, the scheme is unlikely to affect biodiversity.	Neutral (0)
	Water Environment	The River Ebbw is located 45m south west, and an unnamed drainage ditch also flows adjacent to the A472, however, no significant impacts are anticipated to occur to the water environment.	Neutral (0)
	Townscape	There are no Conservation Areas located within 1km of the site. Several listed buildings are located within 1km of the route corridor, however, no impact upon townscape features are anticipated to occur as a result of the scheme.	Neutral (0)
Economy	Journey Time Changes	There are some journey times improvements envisaged for the A472 road users. However, this is likely to be offset by the increase in distance travelled by the drivers, who's vehicles will not comply with this enforcement.	Neutral (0)
	Capital Costs	High (£2m+)	High (£2m+)
	Land	It is anticipated that this option can be accommodated within the verge of current road system. This is not anticipated to have any requirements for additional land.	Neutral (0)
S&C	Journey Quality	Introducing the Clean Air Zone/Low Emission Zone may result in lower numbers of the HGVs on the A472 road. This however, is not envisaged to have a significant impact on the journey quality and, therefore, is considered to be neutral.	Neutral (0)
	Physical Activity	Introducing the Clean Air Zone/Low Emission Zone should not impact physical activity along the study route. Therefore, it is considered that the impact should be neutral.	Neutral (0)
	Accidents	Introducing the Clean Air Zone/Low Emission Zone is not expected to impact on accidents along the study route. Therefore, it is considered that the impact should be neutral.	Neutral (0)
	Access	Introducing the Clean Air Zone/Low Emission Zone, will reduce the residents' access to the local services, employment and healthcare. The impact is considered to be largely adverse.	Large Adverse (---)
VfM	Value for Money	It is anticipated that the Benefit to Cost ratio for this option would be within the range of 0 to 1	Poor - Expected BCR between 0 and 1
Other Issues	Acceptability	Given the nature of the proposals, this measure is anticipated to be opposed by the local businesses and general public. The road users are likely to be financially penalised either by the introduced charges or the requirement to buy a newer vehicle.	
	Technical, Operational & Financial Feasibility	None identified at this stage. To be re-evaluated at Stage 3 when detailed scheme drawings and cost estimates are available.	
	Deliverability & Risk	The deliverability and risk is subject to the ongoing operation and infrastructure requirements issues.	
Secondary Criteria of the Objective	Will the intervention deliver an overall reduction in NO2 emissions to air	Yes. There may potentially be an overall reduction to NO2, although it is likely that there may be localised increases in NO2 elsewhere, due to the Clean Air Zone/Low Emission Zone avoidance.	
	Will the intervention result in unintended consequences or other environmental impacts	No. There are no adverse consequences to other environmental impacts.	
	Will the intervention impact equally across multiple vehicle classes and journey types	No. Older vehicles will be targeted.	
	Will the intervention have a positive impact on wider public health and inequalities	No. Although there may be a positive impact on the residents' health, the significant social inequalities are envisaged due to the vehicles' emissions restriction.	

Date Produced - 13/09/2018

Appraisal Summary Table

Option No. / Theme | **9**

Name of scheme:	Air Quality Area
Location:	A472
Effectiveness:	Ineffective
Timescale:	Up to 5 months
Feasibility:	Yes. Road network is managed by CCBC Highways Operations Department.

Objective		Summary of key impacts	Assessment Qualitative
Environment	Air Quality	Behaviour change measure with no quantified impact on NO2 concentrations in Hafodyrynys. This measure is an important complementary measure and likely to be beneficial to support key measures.	Neutral (0)
	Noise	There is one NAPPA located along the A472 Hafod Yr Ynys Road in the study area, and several sensitive residential dwellings adjacent to the A472. This scheme is unlikely to have any impacts on noise.	Neutral (0)
	Landscape	The site is not situated within 1km or within proximity of any designated landscape areas. The scheme is unlikely to generate significant impacts upon the landscape.	Neutral (0)
	Historic Environment	There are no Conservation Areas, Historic Parks and Gardens or Scheduled monuments within 1km of the site. There is one listed structure set just north west of the A472 and several locally important assets, however, the scheme is unlikely to affect the historic environment.	Neutral (0)
	Biodiversity	There are no statutory designated sites within 2km of the site. There is one SINC located 200m north west. With limited vegetation clearance required, the scheme is unlikely to affect biodiversity.	Neutral (0)
	Water Environment	The River Ebbw is located 45m south west, and an unnamed drainage ditch also flows adjacent to the A472, however, no significant impacts are anticipated to occur to the water environment.	Neutral (0)
	Townscape	There are no Conservation Areas located within 1km of the site. Several listed buildings are located within 1km of the route corridor, however, no impact upon townscape features are anticipated to occur as a result of the scheme.	Neutral (0)
Economy	Journey Time Changes	It is not envisaged that implementing the Air Quality Area will affect the journey times.	Neutral (0)
	Capital Costs	Low (up to £500k)	Low (up to £500k)
	Land	It is anticipated that this option can be accommodated within the verge of current road system. This is not anticipated to have any requirements for additional land.	Neutral (0)
S&C	Journey Quality	The Air Quality Area is a soft behavioural measure. It is not envisaged to have an impact on the journey quality and, therefore, is considered to be neutral.	Neutral (0)
	Physical Activity	Introducing the Air Quality Area should not impact physical activity along the study route. Therefore, it is considered that the impact should be neutral.	Neutral (0)
	Accidents	Introducing the Air Quality Area is not expected to impact on accidents along the study route. Therefore, it is considered that the impact should be neutral.	Neutral (0)
	Access	Introducing the Air Quality Area is not expected to impact on access to services, employment, or healthcare along the study route. Therefore, it is considered that the impact should be neutral.	Neutral (0)
VfM	Value for Money	It is anticipated that the Benefit to Cost ratio for this option would be within the range of 1 to 2	Fair - Expected BCR between 1 and 2.
Other Issues	Acceptability	Given the nature of the proposals, this measure is unlikely to be opposed by any groups or individuals.	
	Technical, Operational & Financial Feasibility	None identified at this stage. To be re-evaluated at Stage 3 when detailed scheme drawings and cost estimates are available.	
	Deliverability & Risk	None identified at this stage. To be re-evaluated at Stage 3 when detailed scheme drawings and cost estimates are available.	
Secondary Criteria of the Objective	Will the intervention deliver an overall reduction in NO2 emissions to air	At this stage, there is no way of quantifying what reductions this measure may, or may not have.	
	Will the intervention result in unintended consequences or other environmental impacts	No. There are no adverse consequences to other environmental impacts.	
	Will the intervention impact equally across multiple vehicle classes and journey types	Yes. This scheme should have an equal impact on all vehicle classes and journey types.	
	Will the intervention have a positive impact on wider public health and inequalities	No. The Air Quality Area's introduction should have a neutral impact on wider public health and inequalities.	

Date Produced - 13/09/2018

Appraisal Summary Table

Option No. / Theme | **10**

Name of scheme:	Bypass
Location:	Adjacent to the A472
Effectiveness:	High
Timescale:	7+ years until opening and potential for increased impacts during construction
Feasibility:	Yes. Road network is managed by CCBC Highways Operations Department. Subject to the additional land acquisition.

Objective		Summary of key impacts	Assessment Qualitative
Environment	Air Quality	This measure brings substantial reduction in NO2 concentrations to below background levels. Concentrations would be around 8 µg m-3 from the current level of 70 µg m-3. However, the timescales to design, plan and construct a bypass are lengthy.	Large Beneficial (+++)
	Noise	There is one NAPPA located along the A472 Hafod Yr Ynys Road in the study area,. It is anticipated that the proposed bypass will have a reduction of noise for residents close to the A472 and there will be a relative reduction in noise levels in the NAPPA as the volume of traffic is redistributed. However, there is a potential for an increase of noise impacts south of the alignment for the residents situated on Old Pant Road. Potential impacts during construction and operation are also anticipated on biodiversity receptors.	Slight Beneficial (+)
	Landscape	The re-alignment of the A472 from Craig Gwent, across the plateau farmland of Pen-y-caeau and towards Crumlin would divert the route away from the steep valley enclosure of the existing road corridor. The new route alignment, in contrast would be elevated on the plateau setting and visually exposed to the surrounding hills and plateaus. This is a locally designated Visually Important Local Landscape (VILL, Caerphilly Council), with the forested areas noted as being of a high visual and sensory value for rarity in a regional context. The alignment would materially affect this landscape setting, and would represent a new built element which would require the loss of existing and mature woodland cover. There would be a severance of the established agricultural land pattern, with the amenity value of the landscape further influenced by the route corridor where it would interrupt the existing network of footpaths that link adjacent urban valleys with this upland landscape.	Large Adverse (---)
	Historic Environment	There are no Conservation Areas, Historic Parks and Gardens or Scheduled monuments within 1km of the site. There is one listed structure set just north west of the A472 and several locally important assets, however, scheme is unlikely to affect these assets. The bypass route passes through an area of historically locally important quarrying, and close to the site of an industrial period building and pool.	Slight Adverse (-)
	Biodiversity	There are no statutory designated sites within 2km of the site. There is one SINC located 200m north west and Coed Goferau SINC located adjacent to the A472. Large amounts of vegetation removal of a permanent nature is required, and likely to include within the Coed Goferau SINC therefore, significant impacts could occur on ecology and biodiversity in the local area and likely to directly impact upon the condition and functioning of the Coed Goferau SINC. The scale of impact means assessment of effects on statutory designated sites more than 2km away could be needed.	Large Adverse (---)
	Water Environment	The River Ebbw is located 45m south west, and an unnamed drainage ditch also flows adjacent to the A472 and conveys runoff to the River Ebbw. Water quality and conveyance of these features are unlikely to be affected by the proposed bypass. The bypass will, however, cross the alignment of the drainage ditch that starts at Hafodyrynys and flows east adjacent to the A472. The works could pose a short term and temporary impact to water quality in the ditch, although with the inclusion of appropriate mitigation this is not likely to pose any long term or permanent impact to water quality within the ditch or downstream receptors. The alignment of the ditch will need be maintained via an appropriately sized culvert or similar, although this is not predicted to pose any impact to flow conveyance.	Neutral (0)
	Townscape	There are no Conservation Areas located within 1km of the site. Several listed buildings are located within 1km of the route corridor, however no impact upon townscape features are anticipated to occur as a result of the scheme.	Neutral (0)
Economy	Journey Time Changes	There are significant journey time improvement envisaged as an effect of building a bypass to divert traffic from the A472.	Large Beneficial (+++)
	Capital Costs	High (£2m+)	High (£2m+)
	Land	It is anticipated that new bypass should require a large land acquisition.	Large Adverse (---)
S&C	Journey Quality	Building a new road bypassing the existing dwellings, is envisaged to have a significant impact on the journey quality, especially if the existing A472 road alongside the Woodside Terrace will be allowing the bus and local residents traffic only. This measure is therefore considered as moderately beneficial.	Moderate Beneficial (++)
	Physical Activity	Building a bypass road with its amenities may encourage cycling and other activities, and therefore, have a positive impact on the physical activity.	Slight Beneficial (+)
	Accidents	It is envisaged that introducing a new road, bypassing the existing Woodside Terrace dwellings should be slightly beneficial on the number and severity of recorded accidents.	Moderate Beneficial (++)
	Access	Building a bypass will result in the improved traffic flow and effectively will impact on the commuters' and residents' trips to services, employment, and healthcare. The impact is considered to be slightly beneficial.	Slight Beneficial (+)
VfM	Value for Money	It is anticipated that the Benefit to Cost ratio for this option would be within the range of 1 to 2	Fair - Expected BCR between 1 and 2.
Other Issues	Acceptability	Given the nature of the proposals, this measure is anticipated to be opposed by the environmental action groups.	
	Technical, Operational & Financial Feasibility	Potential long leading time for this option due to requirements for detailed design and full assessments of this option. This measure has been ruled out on timescales.	
	Deliverability & Risk	The deliverability is subject to the design assessment and potential issues identification.	
Secondary Criteria of the Objective	Will the intervention deliver an overall reduction in NO2 emissions to air	Yes. It is considered that this measure should result in overall NO2 reduction at Hafodyrynys due to the improved traffic flows.	
	Will the intervention result in unintended consequences or other environmental impacts	Yes. There are large adverse consequences to the landscape and biodiversity and slight adverse consequence to the historic environment. It would also likely lead to increased concentrations elsewhere along the new bypass route and a bypass could encourage more traffic to use this area.	
	Will the intervention impact equally across multiple vehicle classes and journey types	Yes. This scheme should have an equal impact on all vehicle classes and journey types.	
	Will the intervention have a positive impact on wider public health and inequalities	Yes. The residents will no longer be exposed to the high NO2 concentration due to the trips rerouting.	

Table 12: Summary of WelTAG Stage Two Appraisals

		Key Criteria			Environment							Social and Cultural				Economy			
Measure /Ref	Shortlisted Measure	**Effectiveness**	**Timescales**	**Fesibility**	**Air Quality**	**Noise**	**Landscape**	**Historic Environment**	**Biodiversity**	**Water Environment**	**Townscape**	**Physical Activity**	**Journey Quality**	**Accidents**	**Access to Services**	**Journey time / reliability**	**Land**	**Capital Costs**	**Implementation Timeframe**
01	Change Signal Timings at Crumlin Junction	Low	Y	Y	+1	+1	0	0	0	0	0	0	0	0	0	0	0	Low (up to £500k)	Up to 5 months
02	Signalise the A472/B4471 Swyffryd Junction and introduce an eastbound queue detector	Low	Y	Y	+1	+1	0	0	0	0	0	0	0	+1	+1	+1	0	Medium (£500k - £2m)	18-24 months
07	Reclassify National Speed Limit to 50mph on the A472 Hafodyrynys Road	Ineffective	Y	Y	0	+1	0	0	0	0	0	0	0	+1	0	-1	0	Low (up to £500k)	Up to 5 months
11	Demolish Dwellings at Woodside Terrace and Re-align Road	High	Y	Y	+3	0	-1	0	-1	0	0	0	0	0	-1	0	-1	High (£2m+)	2-3 years
13	Peak Hour HGV Bans	Low	Y	Y	+1	+1	0	0	0	0	0	0	0	0	-2	+1	0	Low (up to £500k)	Up to 5 months
15	Emissions Barrier	High	Y	N	+3	0	-1	0	-1	0	0	-1	-1	0	0	0	0	Medium (£500k - £2m)	18-24 months
20	Rear Access to Properties and Install NO_2 Filtration	Medium	Y	N	+2	0	0	0	0	0	0	0	0	+1	0	0	-1	Medium (£500k - £2m)	18-24 months
26	Clean Air Zone / Low Emission Zone	Medium	Y	Y	+2	0	0	0	0	0	0	0	0	0	-3	0	0	High (£2m+)	3 years
27	Air Quality Public Awareness Campaign	Ineffective	Y	Y	0	0	0	0	0	0	0	0	0	0	0	0	0	Low (up to £500k)	Up to 5 months
28	Bypass	High	N	Y	+3	+1	-3	-1	-3	0	0	+1	+2	+2	+1	+3	-3	High (£2m+)	7+ years

Key

+3 = Large Beneficial +2 = Moderate Beneficial +1 = Slight Beneficial 0 = Neutral -1 = Slight Adverse -2 = Moderate Adverse -3 = Large Adverse

3.8. APPRAISAL OUTCOME

3.8.1. The full impacts of the measures have been considered in the appraisal summary tables.

3.8.2. This Stage Two has reappraised measures against the Key Criteria of the objective in lieu of further refinement of measures and more detailed appraisal. Consequently, the following measures have been identified as failing against one or more of the criteria:

Measure 07: Reclassify National Speed Limit to 50mph on the A472 Hafodyrynys Road **[Fails on effectiveness]**

Measure 15: Emissions barriers **[Fails on feasibility]**

Measure 20: Rear access to properties and install NO_2 filtration **[Fails on feasibility]**

Measure 28: Bypass **[Fails on timescales]**

3.8.3. The following measures will be taken forward for further assessment at WelTAG Stage Three:

Measure 01: Change Signal Timings at Crumlin Junction

Measure 02: Signalise the A472/B4471 Swyffryd Junction and introduce an eastbound queue detector

Measure 11: Demolish Dwellings at Woodside Terrace and Re-align Road

Measure 13: Peak Hour HGV Bans

Measure 26: Clean Air Zone / Low Emission Zone

Measure 27: Air Quality Public Awareness Campaign –The appraisal has identified that this measure does not have tangible benefits with respect to air quality. However, this measure has the potential to provide passive benefits as a complementary measure. This would further public awareness of the air quality problems and mitigate the acceptability of the other proposals. On this basis, this measure will progress to WelTAG Stage Three.

4. MANAGEMENT CASE

4.1. OVERVIEW

4.1.1. The Management Case 'covers the delivery arrangements for the project and proposed management during its life time'. The WelTAG guidance states that in the Stage Two report the Management Case needs to 'set out which organisation and groups within that organisation will sit on the Review Group that meets at the end of each WelTAG stage'.

4.2. PROJECT PLANNING – GOVERNANCE, ORGANISATIONAL STRUCTURE

4.2.1. KEY PROJECT PARTIES & ROLES

Caerphilly County Borough Council (CCBC)

4.2.2. Ultimate client commissioning the study and overseeing delivery.

Welsh Government (WG)

4.2.3. Directing CCBC in the delivery of this study.

RICARDO / WSP

4.2.4. Project Consultants, delivering the study.

4.2.5. REVIEW GROUP

4.2.6. A Review Group has been set up to guide the WelTAG process and have met regularly to discuss the project. This group will take on the role of the Review Group and its members are as follows:

- Caerphilly County Borough Council
- Welsh Government
- Third party consultants (Ricardo / WSP at Stage One and Two)

4.3. COMMUNICATIONS & STAKEHOLDER MANAGEMENT PLAN

4.3.1. Key stakeholders for the current stage of the study are:

Caerphilly County Borough Council (CCBC)

4.3.2. The study team will consult with CCBC staff who currently manage and operate the network to capture views on current processes, issues and potential measures. Consultation will be carried out informally throughout the study. These also form the Review Group and their comments have been incorporated into the Report.

Other Third Party Stakeholders

4.3.3. Third party stakeholders were not consulted to support the development of the study. Third party consultation will be carried out in a later stage of the WelTAG process.

The Public

4.3.4. Public consultation was not carried out during this stage of the study, however it will form part of a later stage. Residents within the study area are being communicated to via letter updates, meetings and drop in sessions throughout the process.

4.4. KEY CONSIDERATIONS FOR WELTAG STAGE THREE

4.4.1. This section highlights the key requirements for Stage Three, particularly with respect to the elements which have not been undertaken at Stage Two.

4.4.2. The WelTAG Stage Three assessment should include:

- Preliminary scheme drawings
- Preliminary costs estimates
- Assessment of Technical, Operational and Financial Feasibility, and Deliverability and Risk
- Qualitative Value for Money assessment
- Detailed modelling of impacts – both traffic modelling and emissions/dispersion modelling.

4.5. MEASURE IMPLEMENTATION

4.5.1. There are a number of routes available to facilitate the implementation of preferred measures identified in Stage Two. All measures which have been identified and appraised at Stage Two are deliverable by the Local Authority in principle. However, some measures require partnership working, i.e. banning HGVs at peak times. Whilst the Council can make the traffic order and erect signage, the enforcement of such an order would be the responsibility of the Police. The Council has no control over Police priorities and resources and as such these measures could become very difficult to implement.

4.5.2. Given the uncertainties surrounding some aspects of the Stage Two appraisal, it is recognised that it is important to use an adaptive approach to implementation of measures, whereby the impact of measures is monitored and adjusted based upon emerging evidence.

4.5.3. By adopting a flexible approach to implementation and integrating robust measurement and evaluation of the performance of these measures to meet the objective, measures can be adjusted based on an improving evidence base. As such, it has been identified that it may be beneficial to take forward the measures below as 'measure packages' as opposed to standalone measures. Similarly, consideration should be given as to whether there is merit in packaging the measures which have been identified as ineffective during the Stage Two appraisal, should it be proven that the preferred measures are not as effective as this study has determined on the basis of the information available.

4.5.4. The implementation timeframes assumed for this report are considered to be an optimistic, best case scenario, and in reality, some measures may take longer to implement.

4.6. IMPLEMENTATION TIMEFRAME

4.6.1. SHORT TERM MEASURES

4.6.2. It is recognised that many of the measures identified within this assessment have the potential for immediate implementation, with potential benefits to the reduction of NO_2. Immediate measures include the low cost, short timeframe measures, and other low to medium costs measures that could be implemented in a trial basis and then considered for longer term use. For the A472 these include:

- **Measure 01**: Change Signal Timings at Crumlin Junction
- **Measure 27**: Air Quality Public Awareness Campaign

4.6.3. By implementing measures on a trial basis, on-site monitoring can be utilised to evidence the effectiveness of these measures before applying them permanently. The results of monitoring could also be used to inform the WelTAG Stage Three appraisal process.

4.6.4. MEDIUM TERM MEASURES

Whilst some measures are relatively straight forward to implement in infrastructure terms, further consultation and analysis needs to be undertaken prior to implementation. This includes:

- **Measure 13**: Peak Hour HGV Bans

4.6.5. Prior to implementing peak hour HGV bans, consideration would need to be given to enforcement of this measure and this may involve consultation with the police. Similarly, local business should be consulted to identify the acceptability of the proposals and further understand the likely impacts as the potential loss of business and subsequent loss of jobs would have significant adverse impacts on the local economy.

4.6.6. LONG TERM MEASURES

4.6.7. Other measures have been identified as meeting the objective, whilst ensuring acceptable impacts against the other appraisal areas. These may be implemented on a permanent basis though would be required to undergo Stage Three (Business Case) appraisal. These are:

- **Measure 02**: Signalise the A472/B4471 Swyffryd Junction and introduce an eastbound queue detector
- **Measure 11:** Demolish Dwellings at Woodside Terrace
- **Measure 26:** Clean Air Zone / Low Emission Zone

5. FINANCIAL CASE

5.1. OVERVIEW

5.1.1. The financial case 'presents information on whether an option (measure) is affordable in the first place and long term financial viability. It covers both capital and annual revenue requirements over the life cycle of the project and the implications of these for the balance sheet, income and expenditure accounts of public sector organisations.'

5.2. ASSESSMENT

5.2.1. The WelTAG Stage Two report represents an Outline Business Case and the details to inform the financial case are of a preliminary nature at this stage. No lifetime costs have been calculated at this stage. The Stage Two appraisals have been undertaken in line with broad capital cost estimates and should be refined at Stage Three. Lifetime costs and the anticipated scheme life of measures have been identified as broad cost bands at Stage Two for the short list of measures.

5.3. AFFORDABILITY

5.3.1. Capital scheme costs have been considered as broad costs bands. It is considered that any of the measures identified in the Low (up to £500k) and Medium (£500k – £2m) are affordable within the information available to inform the study, though the measures identified with High costs will need the affordability re-evaluated when detailed designs are available at Stage Three.

6. COMMERCIAL CASE

6.1. OVERVIEW

6.1.1. The commercial case covers 'whether it is going to prove possible to procure the scheme and then to continue with it in the future'.

6.2. ASSESSMENT

6.2.1. It is not considered possible at this stage to determine the commercial case of each measure, given the preliminary information available.

7. SUMMARY AND NEXT STEPS

7.1. OVERVIEW

7.1.1. The European Union Ambient Air Quality Directive (2008/50/EC) sets legally binding limits for concentrations of certain air pollutants in outdoor air, termed 'limit values'. The Directive requires that Member States report annually on air quality within zones designated under the Directive and, where the concentration of pollutants in air exceeds limit values, to develop air quality plans that set out measures in order to attain the limit values.

7.1.2. The A472 lies within the South Wales zone for the purpose of the assessment of compliance with the EU Air Quality Directive. The national assessment of roadside NO_2 undertaken for the South Wales zone indicates that the annual limit value was exceeded in 2015 and it is likely to be compliant by 2026. However, more recent monitoring of NO_2 in Hafodyrynys in 2017 were higher than that estimated in the national assessment and consequently compliance is not predicted until 2029 without further mitigation.

7.1.3. The compliance date of the South Wales zone (2029 without additional measures) is, in current projections, determined by the compliance of the A472 adjacent to Woodside Terrace.

7.1.4. This report has presented the Stage Two: Outline Business Case of the WelTAG process for reducing the levels of NO_2 on the A472 carriageway network in South Wales. Elevated concentrations of NO_2 on this study corridor are due to a combination of high traffic volumes and periods of congestion for eastbound flows climbing the A472 towards Hafodyrynys village during the AM peak.

7.1.5. The appraisal of measures has been undertaken in accordance with the Welsh Government's WelTAG [2017] guidance. A short list of measures has been appraised against the key criteria and secondary criteria for the objective and the three WelTAG impact areas.

7.2. PREFERRED MEASURES

SHORT TERM MEASURES

7.2.1. It is recognised that many of the measures identified within this assessment have the potential for immediate implementation, with potential benefits to the reduction of NO_2. Immediate measures include the low cost, short timeframe measures, and other low to medium costs measures that could be implemented in a temporary, and then permanent basis. For the A472 these include:

- **Measure 1**: Change Signal Timings at Crumlin Junction
- **Measure 27**: Air Quality Public Awareness Campaign

7.2.2. Given the uncertainties surrounding some aspects of the Stage Two appraisal, it is recognised that it is important to use an adaptive approach to implementation of measures, whereby the impact of measures is monitored and adjusted based upon emerging evidence.

7.2.3. By implementing measures on a temporary basis, on-site monitoring can be utilised to evidence the effectiveness of these measures. This could be used to inform the WelTAG Stage Three appraisal process. This could include trials of measures which have been identified as ineffective during the Stage Two appraisal to provide a robust evidence base. However, it is believed that the preferred measures should be prioritised based on their effectiveness.

MEDIUM TERM MEASURES

Whilst some measures are relatively straight forward to implement in infrastructure terms, further consultation and analysis needs to be undertaken prior to implementation. This includes:

- **Measure 13**: Peak Hour HGV Bans

7.2.4. Prior to implementing peak hour HGV bans, consideration would need to be given to enforcement of this measure and this may involve consultation with the police. Similarly, local business should be consulted to identify the acceptability of the proposals and further understand the likely impacts as the potential loss of business and subsequent loss of jobs would have significant adverse impacts on the local economy.

LONG TERM MEASURES

7.2.5. Other measures have been identified as meeting the objective, with acceptable impacts against the other appraisal areas. These may be implemented on a permanent basis though would be required to undergo Stage Three (Business Case) appraisal. These are:

- **Measure 2**: Signalise the A472/B4471 Swyffryd Junction and introduce an eastbound queue detector
- **Measure 11:** Demolish Dwellings at Woodside Terrace and Re-align Road
- **Measure 26:** Clean Air Zone / Low Emission Zone

7.2.6. The Stage Three assessment will further explore the effectiveness of these measures, this will identify which measures should be taken forward in the event that measures are mutually exclusive.

7.3. NEXT STEPS

7.3.1. This study has taken appraisal of measures through WelTAG Stage Two. The Stage Two appraisals have been undertaken at a high level in acknowledgement of the uncertainties of a number of the network management measures. It is recognised that it is important to use an adaptive approach to implementation of measures, whereby the impact of measures is monitored and adjusted based upon emerging evidence. This study has identified measures that are likely to bring forward the date of compliance with EU Limit Values, pending confirmation of future assessments and monitoring results.

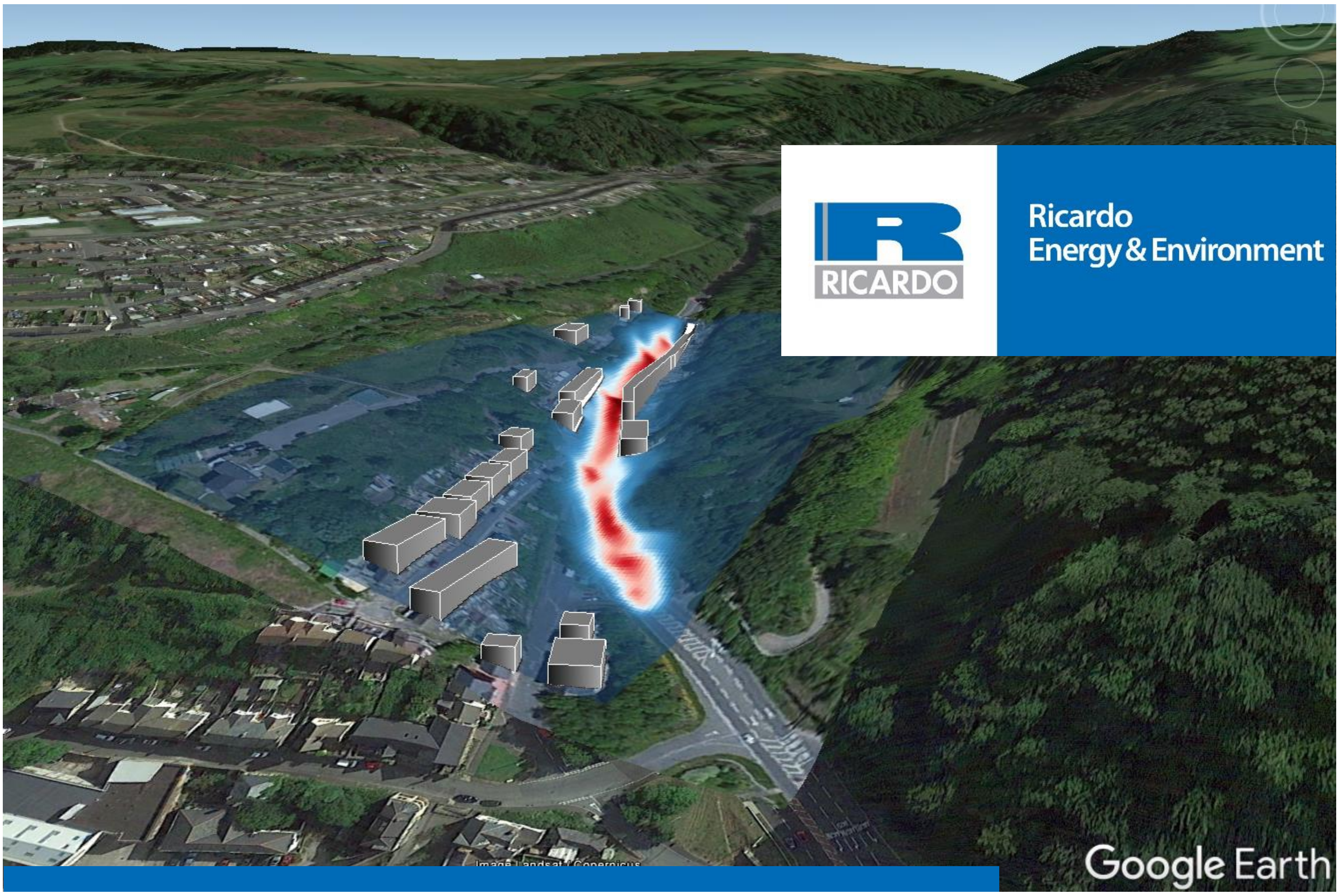
7.3.2. The WelTAG Stage Three assessment will need to include elements of the Stage Two appraisal which have not been undertaken at this time. The WelTAG 2017 guidance embeds the Well-being of Future Generations (Wales) Act 2015, to ensure that the measures are developed using the sustainable development principle and maximise their contribution to the well-being of future generations.

7.3.3. The Stage Three will need to address the elements of Stage Two which have not yet been undertaken for the reasons identified herein, these include:

- Qualitative analysis of impacts against WelTAG impact areas where appropriate. This should include all relevant traffic and air quality modelling and outline quantifiable benefits in order to determine a Present Value of Benefits (PVB) for each measure assessed;
- Detailed scheme drawings;
- Detailed costs estimates;
- Assessment of Technical, Operational and Financial Feasibility, and Deliverability and Risk;
- Quantitative Value for Money assessment.

Appendix A

AIR QUALITY TECHNICAL REPORT



Air quality modelling: Hafod-yr-Ynys

Simulation of baseline and scenario conditions for Stage 2 of WelTAG

Report for Caerphilly County Borough Council

ED 11355 | Issue Number 2 | Date 21/09/2018

Customer:

Caerphilly County Borough Council

Customer reference:

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Executive summary

This report is the air quality technical annex to a Stage 2 WelTAG assessment to consider the feasibility of measures to reduce annual average nitrogen dioxide (NO_2) concentrations to achieve compliance with the limit value (according to the Air Quality Directive 2008/50/EC) in as short a time as possible. Caerphilly County Borough Council has been directed by the Welsh Government to undertake such an assessment. This is focussed on the road link in Hafod-yr-Ynys where air quality monitoring shows significantly elevated concentrations and compliance is not expected until 2029 without any intervention.

This assessment follows on from an initial Stage 1 assessment which concluded that 10 potential measures should be considered further to reduce concentrations of NO_2 as indicated below.

Scenario number and description of potential measure to improve air quality
1 - Change Signal Timings at Crumlin Junction
2 - Signalise the A472/B4471 as a Priority Junction and introduce an eastbound queue detector
7 - Reclassify National Speed Limit to 50mph on the A472 Hafod-yr-Ynys Road
11 - Demolish Dwellings at Woodside Terrace and Re-align Road
13 - Peak Hour HGV Bans
15 - Emissions Barrier
20 - Rear Access to Properties and Install NO_2 Filtration
26 - Clean Air Zone / Low Emission Zone
27 - Public awareness raising campaign
28 - Bypass

This report sets out a preliminary quantified assessment of the potential impact of these measures. More robust detailed traffic modelling and air quality modelling will be undertaken at the next Stage 3 assessment to consider the most effective measures identified here. The Stage 3 work programme will also consider more detailed design of measures along with their wider economic and social impacts.

The air quality impact of Scenario 2 in the table above was not quantified as this would have the same impact as Scenario 1 but with a different implementation mechanism. Also, Scenario 27 was not quantified as this measure focusses on raising awareness of air quality, its sources of emission and impact on human health. While this measure will complement any of the others outlined above, it is difficult to quantify the behaviour response by such measures.

The study found that dramatic reductions in NO_2 were predicted with the construction of a bypass, however it is recognised that the timescale to construct this is very long and this measure is unlikely to bring compliance with the limit value in as "short a time as possible".

Potential high reductions in personal exposure to NO_2 could be achieved by the construction of a barrier to the frontage of the residential dwellings. However, this measure does not reduce emissions and further detailed analysis is recommended regarding the potential design of any barriers.

Similarly, the removal of the terraced residential properties would remove the personal exposure but not reduce the emissions. However, the more open topography does aid dispersion of the pollution. Perhaps surprisingly, the introduction of a "Clean Air Zone" so that only the cleanest (Euro 6 diesel and Euro 4 petrol) vehicles are allowed free access to the road, did not achieve compliance on immediate implementation. This can be attributed to the elevated emissions as a result of the gradient and the complex topography giving rise to very high predicted concentrations at the building façade.

Changes in speed as a result of traffic management measures via traffic light alterations delivered only quite marginal improvements in NO_2 concentrations.

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Appendices

1 Introduction

1.1 Introducing the air quality modelling study

1.1.1 Scope

Caerphilly County Borough Council, like many other urban areas, has elevated levels of Nitrogen Dioxide (NO_2) due mainly to road transport emissions. As such the Council (CCBC) has designated two Air Quality Management Areas (AQMA) across the Borough where concentrations of NO_2 breach Government, health-based air quality objectives and has undertaken reviews of current and predicted levels in the future, including assessments of measures to reduce pollution levels.

At the national level the EU has commenced infraction proceedings against the UK Government and Devolved Administrations for their failure to meet the EU Limit Value for NO_2. In 2015, the Supreme Court ordered the Government to consult on new air pollution plans that had to be submitted to the European Commission no later than 31 December 2015. As such DEFRA released plans on behalf of the Welsh Government[1] to improve air quality, specifically tackling NO_2, in December 2015. These Plans were successfully challenged in the High Court by Client Earth in 2016, and a subsequent set of Plans were published in July 2017. The 2017 Plans identified two areas in Wales where the EU Limit Value for NO_2 are not expected to be met by 2021. The Welsh Government has subsequently issued a legal Direction under the Environment Act 1995 to both Cardiff and Caerphilly Councils to undertake a feasibility study for Nitrogen Dioxide Compliance. For Caerphilly, this requirement is focussed on the Hafod-yr-Ynys AQMA.

1.1.2 Aims and objectives

This is the air quality technical report to accompany the WelTAG Stage 2 report which sets out the second stage in the delivery of this required Feasibility Study which is “The Initial Plan” on behalf of Caerphilly County Borough Council. The aim of this “Initial Plan” is to set out the case for change and identifying, exploring, analysing and developing options for measures which the local authority will implement to deliver compliance in the shortest possible time, with indicative costs for those options.

The assessment methods employed to consider many options within this stage has relied on indicative traffic data and conservative assumptions. At the next stage of assessment more detailed traffic data will be employed to further inform decision making regarding the most cost-effective options to improve air quality.

1.2 Air quality data analysis

The automatic monitoring site at Woodside Terrace was installed on the 29th November 2011 (Figure 1). This section undertakes an analysis of data measured during the period 1st January 2012 to 31st December 2017. All years had data capture of 93% or greater, providing valid data for all years considered. No meteorological data are collected at the site however modelled wind direction and wind speed data are derived for the site[2].

[1] https://www.gov.uk/government/publications/air-quality-in-the-uk-plan-to-reduce-nitrogen-dioxide-emissions
[2] https://airquality.gov.wales/maps-data/openair-introduction

Figure 1: Hafod-yr-ynys air quality monitoring site (green box)

Figure 2 shows the trend in exceedances of the annual and hourly NO_2 objectives. Since monitoring began the site has been out of compliance with both Objectives every year. The annual mean concentration has remained relatively static, fluctuating just 3 µg/m³ over the period. In contrast the number of hourly exceedances has fluctuated quite significantly, with the highest number of exceedances in 2012 (137) and 2017 (132) and the lowest in 2014 (75) when the roadworks was on-going and traffic flows impeded.

Figure 2. Trends in exceedances of the two NO_2 Objectives.

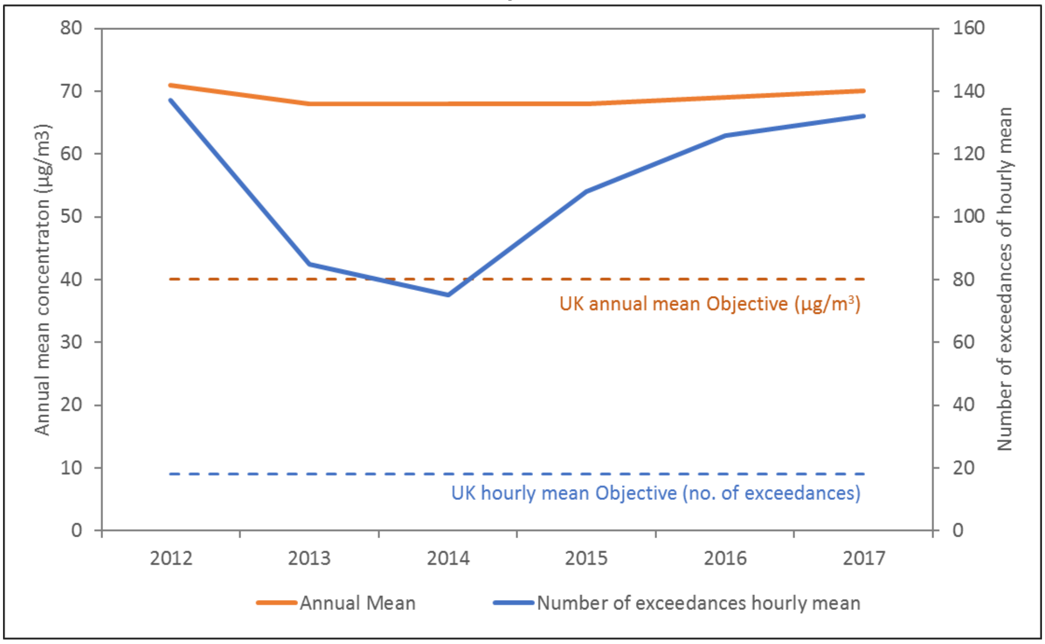


Figure 2 shows the temporal trends in concentrations for hours of the day, days of the week, and months of the year. This analysis clearly shows the influence of traffic on concentrations with the highest concentrations recorded during rush hour on weekday mornings between 6 am and 7am and the second highest during afternoon rush hour around 5 pm. Also of interest is the strong seasonal influence with winter months having significantly higher concentrations than the summer months.

Figure 3 shows the range in maximum hourly concentrations for 2017. The highest exceedances occurred during January and February, again highlighting the seasonal trends evident in Figure 4.

Figure 3. Temporal variation in NO_2 concentrations – average of all years.

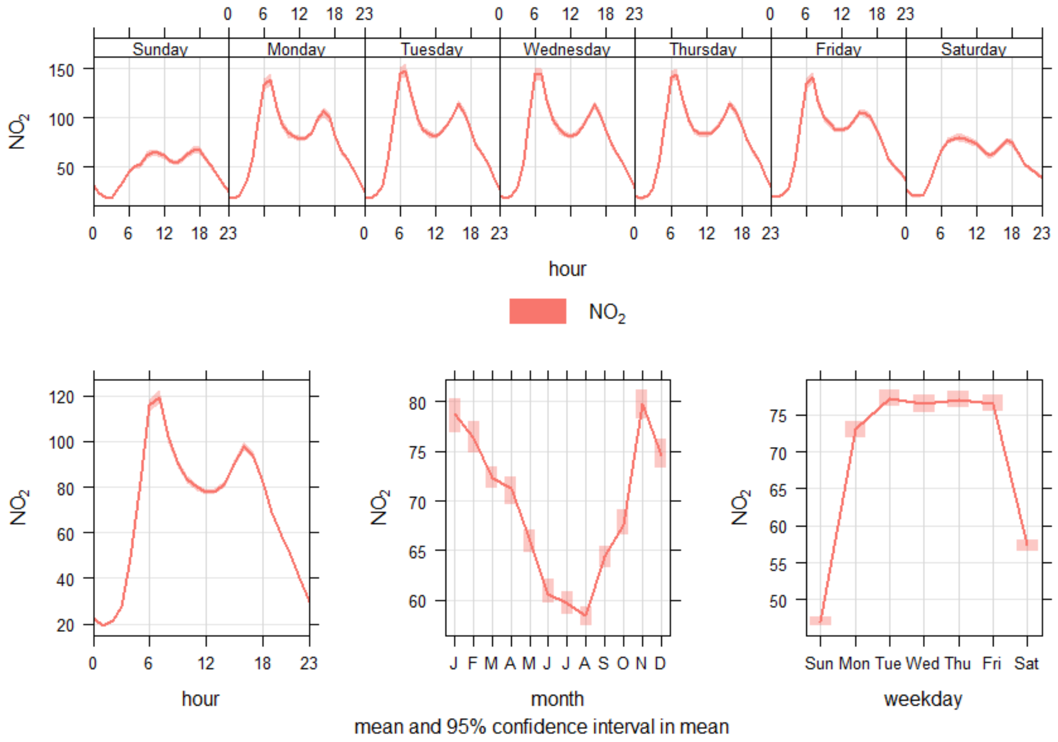


Figure 4. Calendar plot of maximum hourly concentrations, 2017.

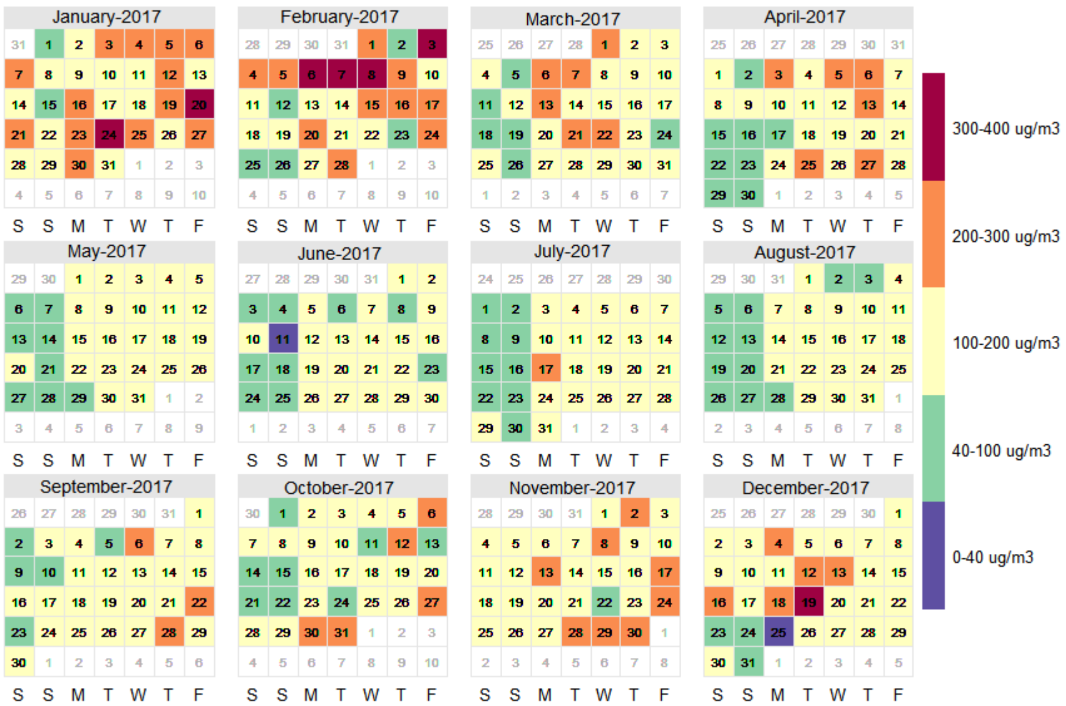
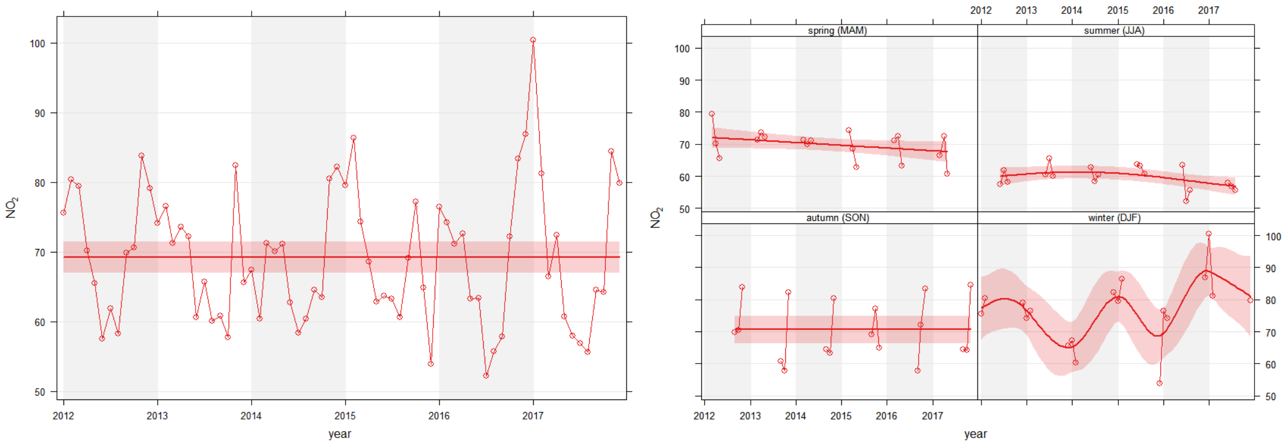


Figure 5 presents the trends in monthly mean concentrations for all years (left) and by season (right). The trends for spring, summer and autumn are fairly level and consistent but the concentration trends during winter vary greatly year on year. This suggests it is the winter conditions that are influencing the change in hourly exceedances as seen in Figure 5.

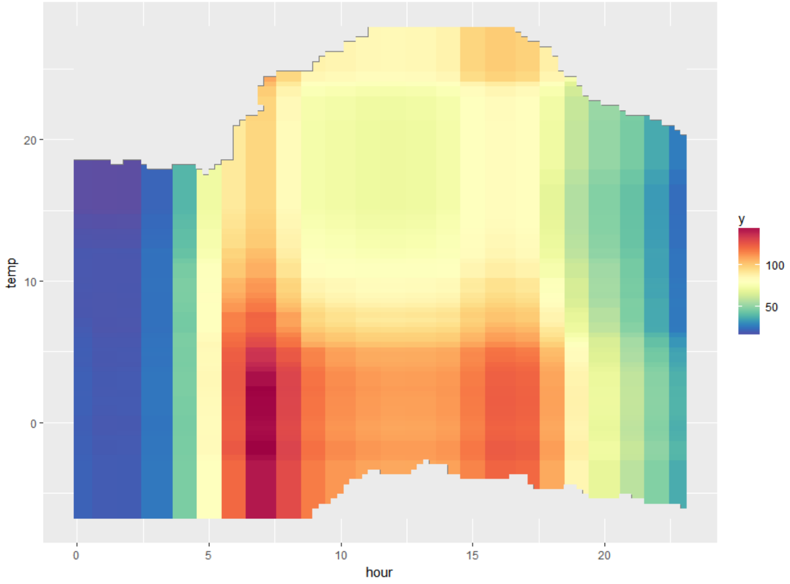
Figure 5. Trends in monthly mean NO_2 concentrations for all data and by season.



The key influencing factor for exceedances of the objectives is clearly seasonal. The drivers for this are likely a combination of meteorology (low temperatures, temperature inversions, wind speeds) and seasonal emissions sources (cold starts, domestic heating). To investigate further some additional analyses were undertaken.

Firstly, the data were analysed to investigate emissions sources which are contributing to the high concentrations during the winter months. Figure 3 demonstrates the strong influence of traffic at the site but is there evidence of other sources? For example, if domestic heating were a significant source it would be expected that high concentrations would be seen outside of peak rush hour periods during colder temperatures. Figure 6 shows average concentrations as a function of hour of the day and temperature. This clearly shows the highest concentrations occur during the morning peak rush hour approximately around 7am to 8am at lower average temperatures (below 10 ºC). This is likely a result of a combination of cold weather delaying engine/catalyst warm-up and lower pollutant dispersion at low temperatures. Some degree of elevated average concentrations occurs throughout the day until the end of evening peak rush hour. There is little evidence of a signature from domestic sources, which would be expected to produce higher concentrations extended into the evening hours.

Figure 6. Plot showing average concentrations of NO_2 (y) by hour of the day and temperature.



The other issue to investigate is the fluctuation in hourly exceedances from year to year. This could be driven by fluctuation in emissions and/or meteorology. To analyse emissions fluctuations, it would be necessary to have traffic count data for each year by month which is not currently available. To investigate the meteorological impact the effect of temperature and wind speed on concentrations is analysed.

Figure 7 shows average monthly temperature and NO_2 concentrations and Figure 8 shows a scatterplot of all concentrations greater than 200 µg/m^3 versus temperature. These figures show that temperature is not necessarily the only meteorology driver.
Figure 7 shows that temperatures during winter 2013/2014 are the highest winter temperatures possibly contributing to the lower number of hourly exceedances in 2014, though the Crumlin junction roadworks were on-going at this time which also could be attributed to the lower concentrations as traffic was restricted. However, this is not mirrored for the winter period 2012/2013, where temperatures are lowest but concentrations are not significantly high, nor in 2016/2017 where temperatures are not unusually low but concentrations are the highest of all winter periods. Figure 8 demonstrates a lack of correlation between temperature and concentrations.

Figure 7. Average NO_2 concentrations and temperatures.

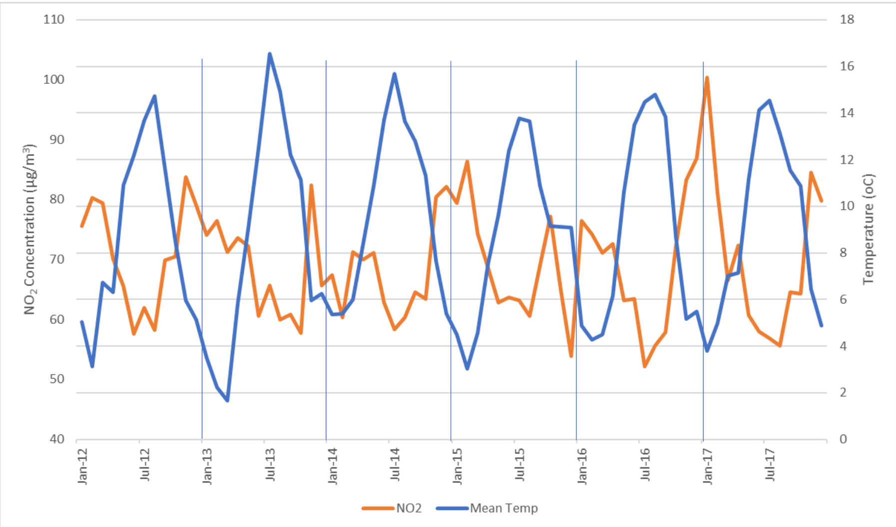


Figure 8. Scatterplot showing relationship between exceedances of the hourly objective and temperature.

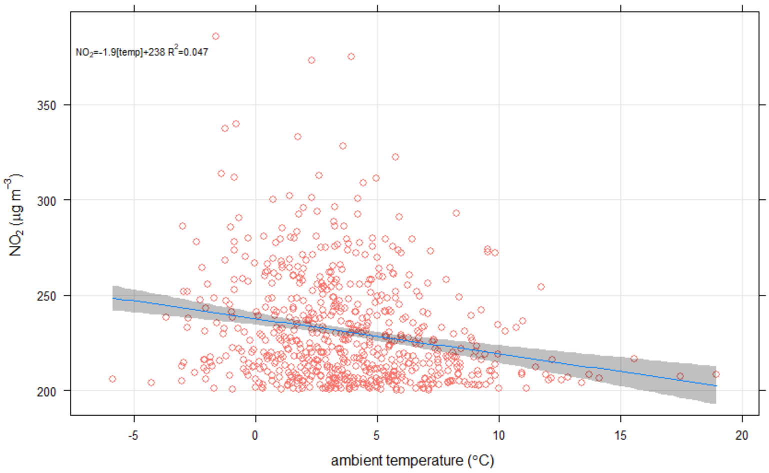


Figure9 clearly shows the importance of low wind speeds and low temperatures in conjunction as drivers for higher concentrations. Figure 10 investigates wind speeds by year. This suggests that wind speeds in 2013 and 2014 were on average higher than in 2016 and 2017. This could therefore explain the annual differences in hourly objective exceedances although the Crumlin junction roadworks were underway during this period which restricted traffic flows.

Figure 9. Average concentrations of NO_2 (y) by wind speed and temperature.

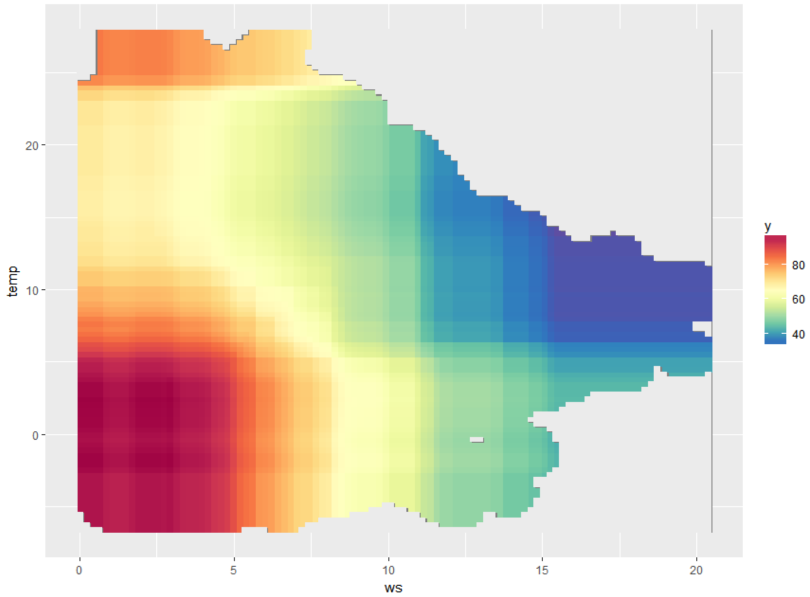
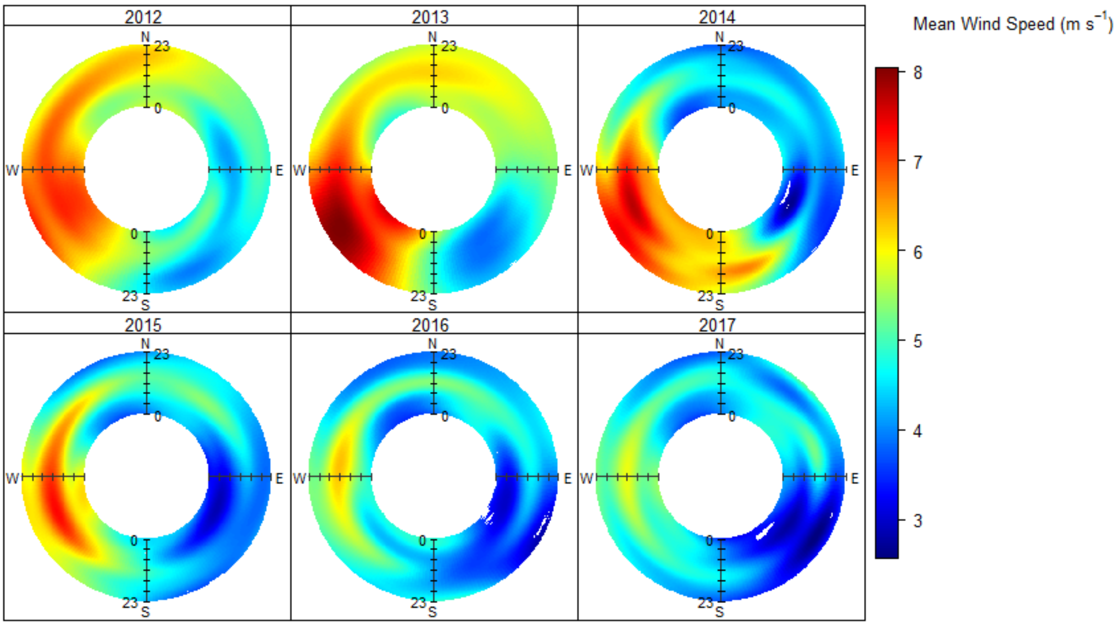


Figure 10. Polar annulus plot showing wind speed as a function of wind direction and time of day



In summary the NO_2 exceedances are driven by vehicle emissions. Seasonal meteorology results in the highest exceedances (in terms of number and concentration) during the winter months. Data suggest that the concentrations are elevated during periods of low temperature and low wind speed i.e. a result of poor atmospheric dispersion. Further analysis to identify the impact of temperature inversions could be undertaken with further meteorology data analysis but this is deemed unnecessary in the context of the findings of this analysis.

1.3 Measures to improve air quality

1.3.1 Existing measures within the Air Quality Action Plan

The AQMA at Hafod-yr-ynys (Figure 12) was the focus of a study on an Air Quality Action Plan in 2017 undertaken by the Council[3]. The study showed that road transport was the major contributor to NOx emissions (Figure 13) and that a 60% reduction in road transport emissions for NOx were required to meet the Limit Value in Woodside Terrace. Some options were modelled in detail and these included:

a. Local traffic management – removal of parking bays, bus stop relocation and prohibition of right turn access onto Gladstone Road.
b. Gating traffic at the top of the hill
c. Future (new) by-pass constructed to divert traffic to the south of the AQMA, connecting the A472 to A467.

However, all of these options did not bring the situation into compliance in Air Quality Directive terms (i.e. exceedance at the monitor still occurred) but did bring the situation into compliance in accordance with LAQM (i.e. no exceedance at the residential property façade) with the assumed design of the options. It should be clearly noted, however, that traffic micro-simulation modelling was not available

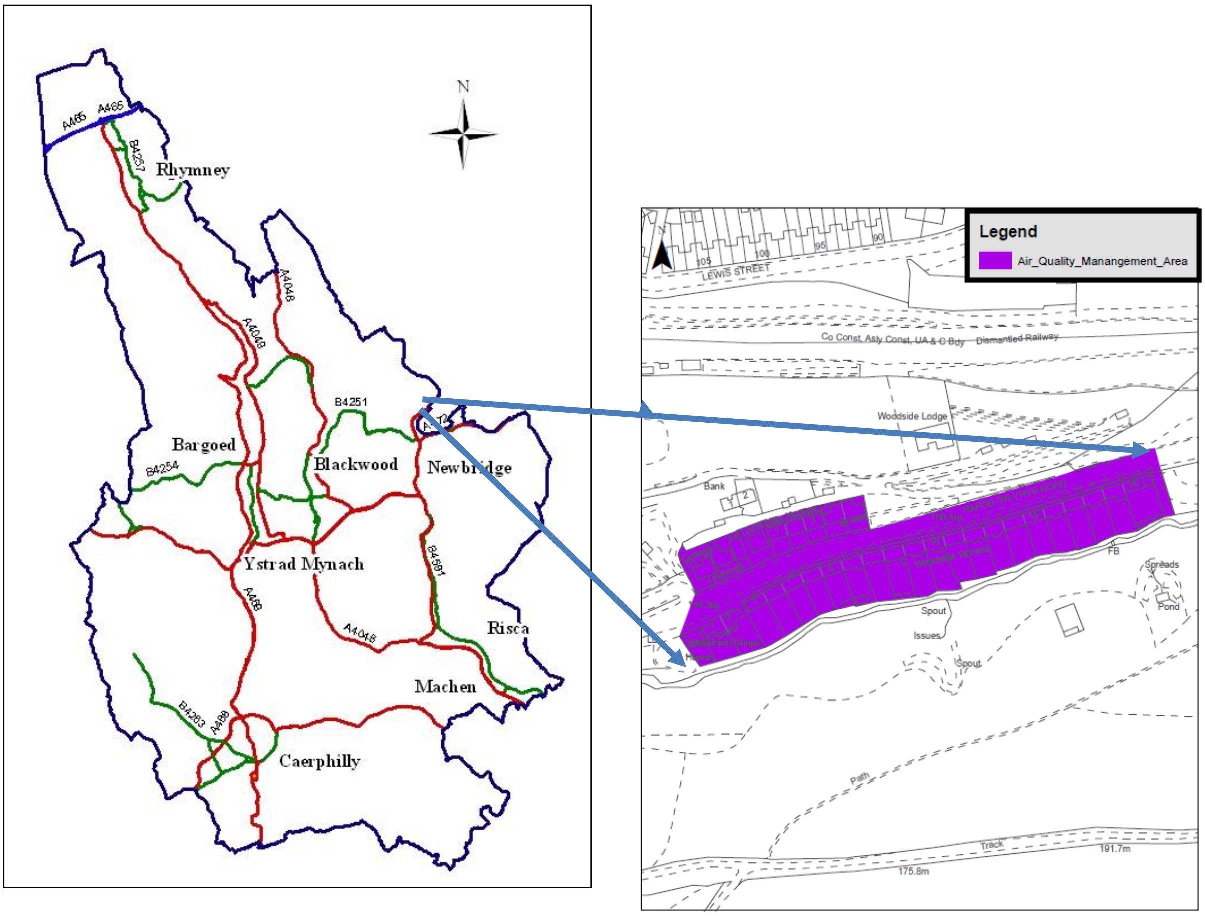
[3] Air Quality Action Plan, 2017, http://www.caerphilly.gov.uk/involved/Consultations/Hafodyrynys-air-quality-consultation

to support the assessment of these options, and neither was there a comprehensive review of the design possibilities of these options and their alternatives.

The AQAP recommended that more detailed traffic and air quality monitoring should be undertaken.

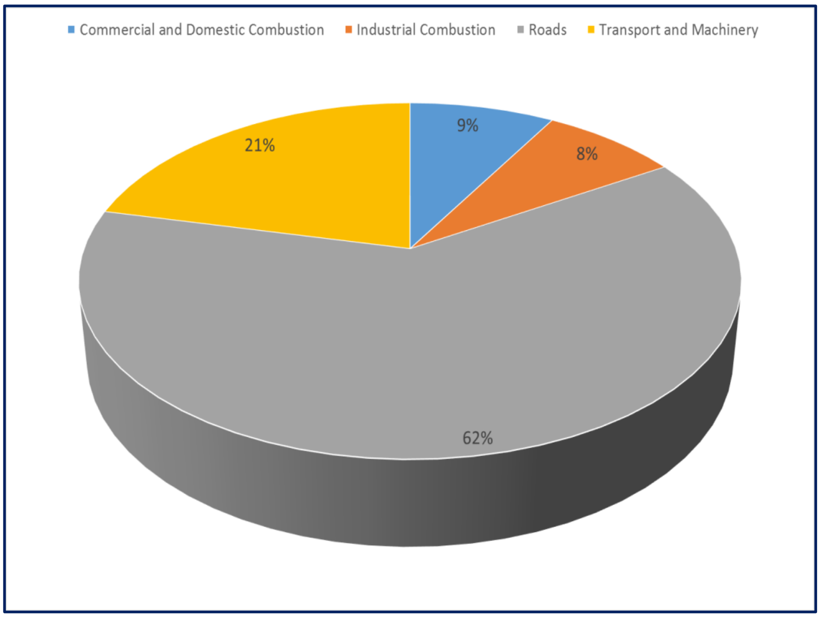
An extensive junction improvement at A472/A467 at the bottom of the hill from the monitor was completed in 2015 with limited impact on air quality measurements.

Figure 12: Main roads and towns in Caerphilly County Borough Council and AQMA in Hafod-yr-Ynys



Hafod-yr-ynys Air Quality Management Area

Figure 13: Road transport NOx emissions source apportionment for the background in Hafod-yr-Ynys



1.3.2 Potential Future Measures to improve air quality

The Council considered a full range of measures with stakeholders in a workshop held at the Council offices in July 2018. These were reported in the WelTAG Stage 1 report which concluded the following measures for further evaluation in this Stage 2 report. Scenario numbers referred to those presented in the Stage 1 report. The modelling assumptions were based on traffic count data collected during April and May 2018 and expert judgement. Detailed micro-simulation traffic modelling will be available for the Stage 3 assessment which will provided more refined evidence for the assessment to underpin the final plan.

Table 1: Description of potential measures derived from WelTAG Stage 1 report along with modelling assumptions used in this screening study.

Scenario number and description of potential measure to improve air quality	Assumptions used in this screening assessment
1 - Change Signal Timings at Crumlin Junction	The purpose of retiming the Crumlin junction signals would be to hold peak hour traffic back at the junction at the bottom of the hill to allow free flow traffic conditions going up the hill. Prior to the junction improvements at Crumlin Junction in 2015, traffic did not queue up the hill at Woodside Terrace. The traffic survey data collected in May 2018 indicates that the average speed of traffic in the eastbound direction is c.23mph at Woodside Terrace during the morning peak and c.34mph under free flow conditions in the evening peak. It is assumed that congestion relief would see eastbound speeds increase from average 23mph to 34mph in the morning peak. No change in speeds would be observed in the eastbound direction in the inter-peak, evening peak or weekend peak. It is assumed that retiming the signals would not impact on westbound traffic during any time period as the improvement scheme implemented in 2015 optimised the signals to reduce queuing at Woodside Terrace.

	No change in overall volume (AADT)
2 - Signalise the A472/B4471 as a Priority Junction and introduce an eastbound queue detector	Assume the impacts on speed are as above though rather than increasing queue lengths at the A472/A467 Junction is it likely that queues on the B4471 may marginally increase. Signalising this junction should prevent drivers on the A472 stopping to let traffic merge from the B4471 and therefore improve traffic flow up the hill during the morning peak hour. This is assumed to not impact the eastbound direction during the other peaks. Equally, the option will have no effect on the westbound direction. No change in overall volume (AADT).
7 - Reclassify National Speed Limit to 50mph on the A472 Hafod-yr-Ynys Road	Traffic data shows that only a small number of vehicles were above 50 mph so assume this measure will make no significant difference to average speeds.
11 - Demolish Dwellings at Woodside Terrace and Re-align Road	Removal of the majority of buildings on the south side of Woodside Terrace including Woodside shops and `Yr Adfa'. This first modelling was to help ascertain the minimum number of properties to be demolished.
13 - Peak Hour HGV Bans	Assume peak hour bans in place between 0700-1000 and 1600-1900. Includes the following HGV classes: 3-Axle Articulated Vehicle or Rigid Vehicle & Trailer, 4-Axle Articulated Vehicle or Rigid Vehicle & Trailer 5-Axle Articulated Vehicle or Rigid Vehicle & Trailer 6 (or more) Axle Articulated Vehicle or Rigid Vehicle & Trailer B-Double or Heavy Truck & Trailer Double or Triple Heavy Truck & 2 (or more) Trailers Automatic Traffic Count data from surveys undertaken in May 2018 indicates that peak hour HGVs account for approximately 35% of total daily HGVs. It is assumed that half of these (17.5% of the daily total) find alternative routes or result in businesses to relocate, whilst half of the HGVs would remain on the corridor though be displaced to off peak times. As such, a 17.5% reduction in annual average HGV flows was assumed. Also allowance for a nominal 5% increase in peak hour speeds to reflect the removal of HGVs during peak hours was made.
15 - Emissions Barrier	Model the impact of barriers similar to noise barriers that would be erected to inhibit dispersion of emissions onto the building façade on the south side of Woodside Terrace.
20 - Rear Access to Properties and Install NO_2 Filtration	No change to the modelled concentrations – just a change to personal exposure as access to the residential housing will be from the rear only. The footpath to the front of Woodside Terrace would remain to enable access to the allocated car parking.
26 - Clean Air Zone / Low Emission Zone	Assume all vehicles to be either Euro 6/VI diesel and Euro 4 petrol 24/7. No changes to flows or speeds.
27 – Public Awareness Raising Campaign	No modelling as this is a public campaign measure with no measurable behaviour change

28 - Bypass	Trip rates indicate that the total daily trip rate for a resident dwelling in this location is 4.370 trips per dwelling per day. Assuming all through traffic is removed from Woodside Terrace and the only remain traffic is for the 50 or so properties on or near Woodside terrace the AADT would be approximately (50*4.370) 218.5 vehicles in a 'with bypass scenario'.

2 Modelling methods

2.1 Model description

The GRAL/GRAMM modelling system (hereafter called 'GRAL') was used in this study. Dispersion modelling in complex terrain such as this is challenging and is especially so when low wind speeds arising from flows around buildings and other obstacles influence ambient air quality. Given the high NO_2 values measured at the Hafod-yr-Ynys AURN station (annual mean = 70 µg m^{-3} in 2017) we believe that a more sophisticated micro-scale air quality modelling method is required than would normally be the case for such a small domain with relatively few road sources. This will ensure that in accurately capturing the baseline we set the conditions to be able to accurately model the effect of emissions reduction measures. Detailed information on the model is given in Appendix 1.

2.2 Emissions modelling system

2.2.1 Derivation of local emission factors

There has been much uncertainty in the use of national emission factors (known as COPERT factors) and how representative they are to real-world emissions. While the most recent set of emission factors take this into account to some degree, there remains large uncertainty as to how emissions behave in an environment such as the gradient at Woodside Terrace. To provide a robust study a field monitoring campaign using an OPUS instrument was undertaken and used to derive local emission factors to underpin the modelling and assessment of measures. Full details of this monitoring are provided in Appendix 2 and illustrative outputs are given below.

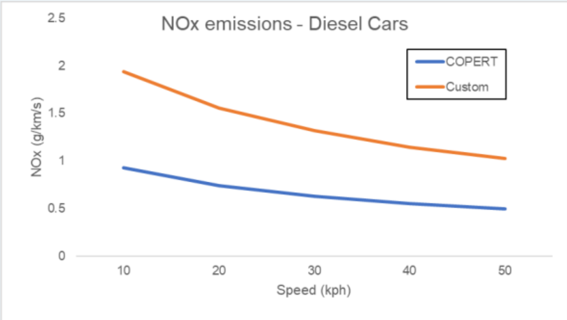
2.2.2 Illustrative outputs from the emissions model

In Figure 14 below shows the difference in vehicle NOx emissions measured at Hafod-yr-ynys compared to those derived using the national emission factors (COPERT). All vehicle categories were quite significantly underestimated by COPERT though the results are very specific to this case and cannot be assumed to hold elsewhere. Most vehicle emissions are 2 or more times greater in Hadod-yr-Ynys than national emission factors would have suggested.

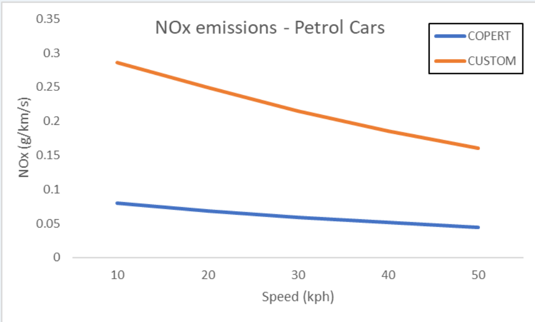
Under each plot the linear relationship is provided between the pre and post OPUS emission estimates with the coefficient of determination for each.

The reasons for the divergence are not clear, though the effect of the gradient through the street canyon is likely the most important factor.

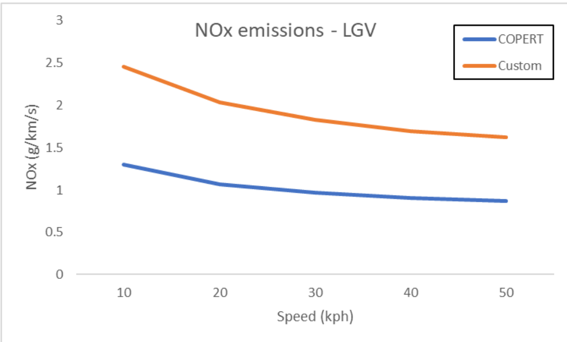
Figure 14: Comparison of modelled emission rates from COPERT 5 Vs COPERT/OPUS



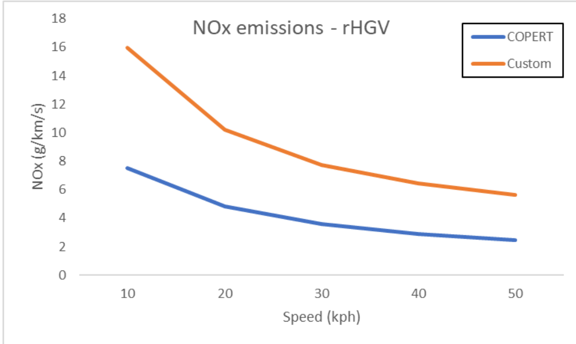
y = 2.1113x - 0.0112 (y is OPUS/COPERT in all plots)



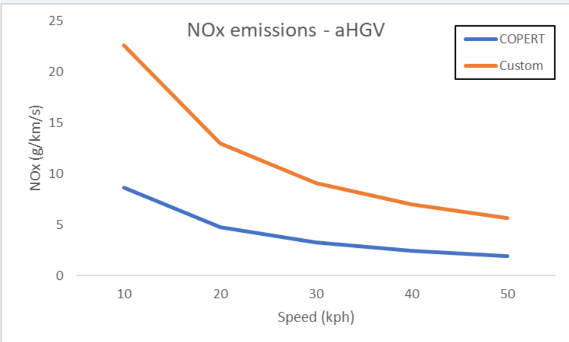
y = 3.5976x + 0.0008



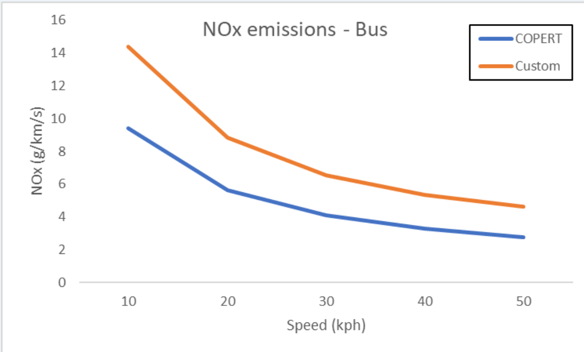
y = 1.8999x - 0.0136



y = 2.0658x + 0.4159



y = 2.5243x + 0.8558



y = 1.4731x + 0.5053

2.3 Model domain

Hafod-yr-Ynys is a village on the A472 road between Pontypool and Crumlin in Caerphilly county borough, south-east Wales. The area of interest for this study is immediately east of the junction of the A467 at Crumlin with the A472. The A472 is the principle road of interest in this study, the road traffic on which has been causing exceedances of NO_2 standards at housing a few hundred metres east of the junction.

2.4 Topographical character

The dispersion situation at Hafod-yr-Ynys is complicated by both regional and local topography. The area is hilly with elevations varying sharply by a few hundred metres close to the site. The obvious street canyon topography in the street is compounded by the upward gradient of the road itself. Traffic climbs the gradient as it travels east from the junction, likely increasing their emissions, the impact of which are compounded by the canyon morphology.

Regional terrain is shown in Figure 15: and 16 shows local topography. The road sits in a quite pronounced valley. Figure 17 also shows the orientation of the street gradient included in the air quality modelling. The microscale model domain is quite small but is sufficient to capture the main drivers for the NO_2 problem along Hafod-yr-Ynys Road.

Figure 15: Terrain data used in the study

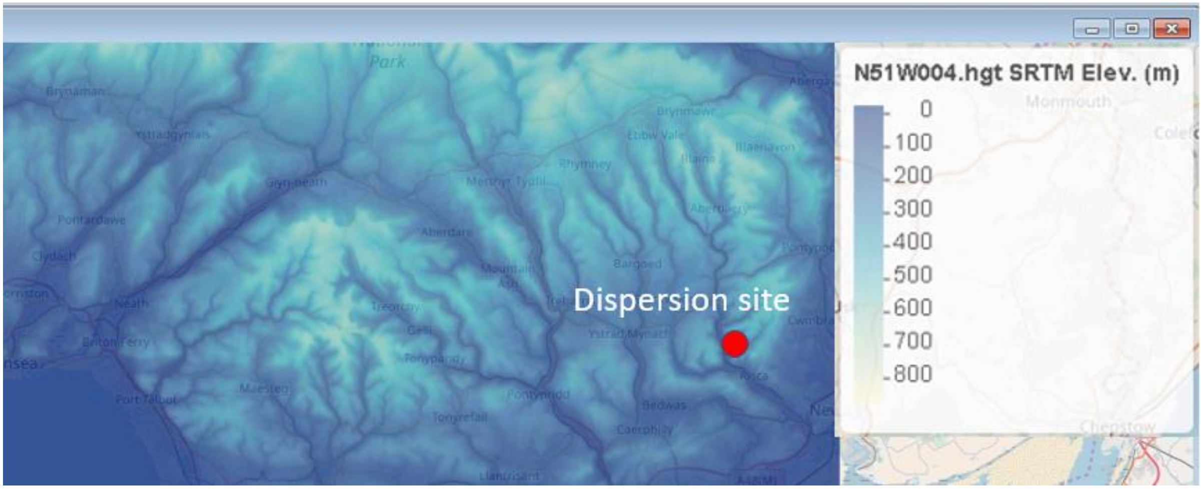


Figure 16: 3D mapping of the model domain

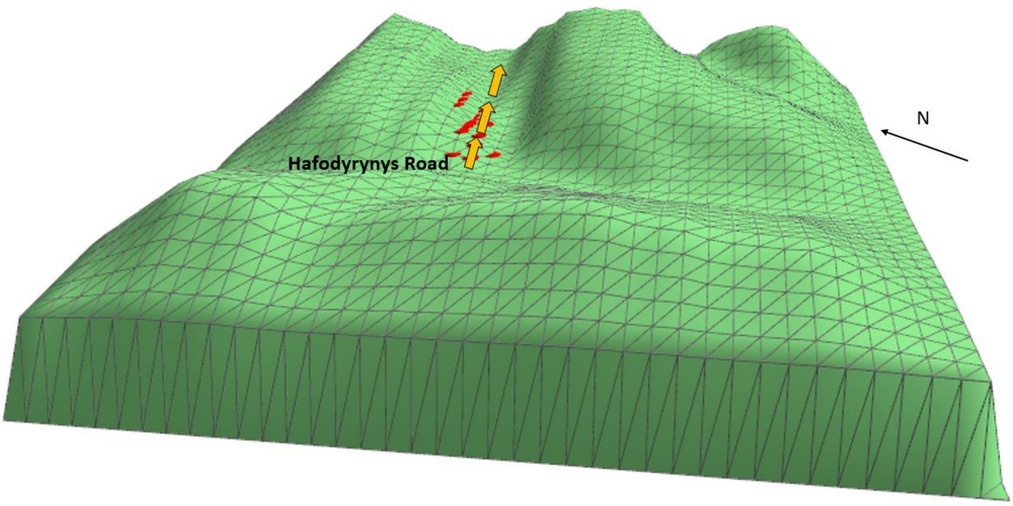
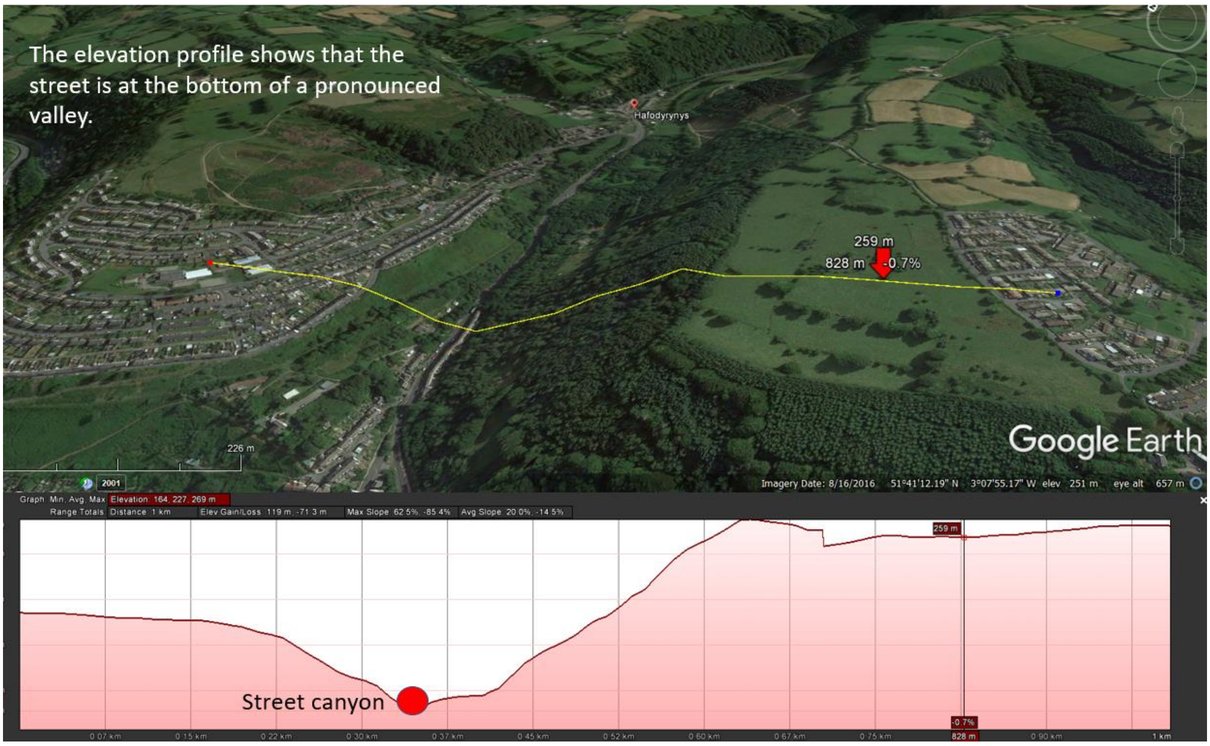


Figure 17: Elevation profile across the Hafod-yr-Ynys valley (source: Google Earth)



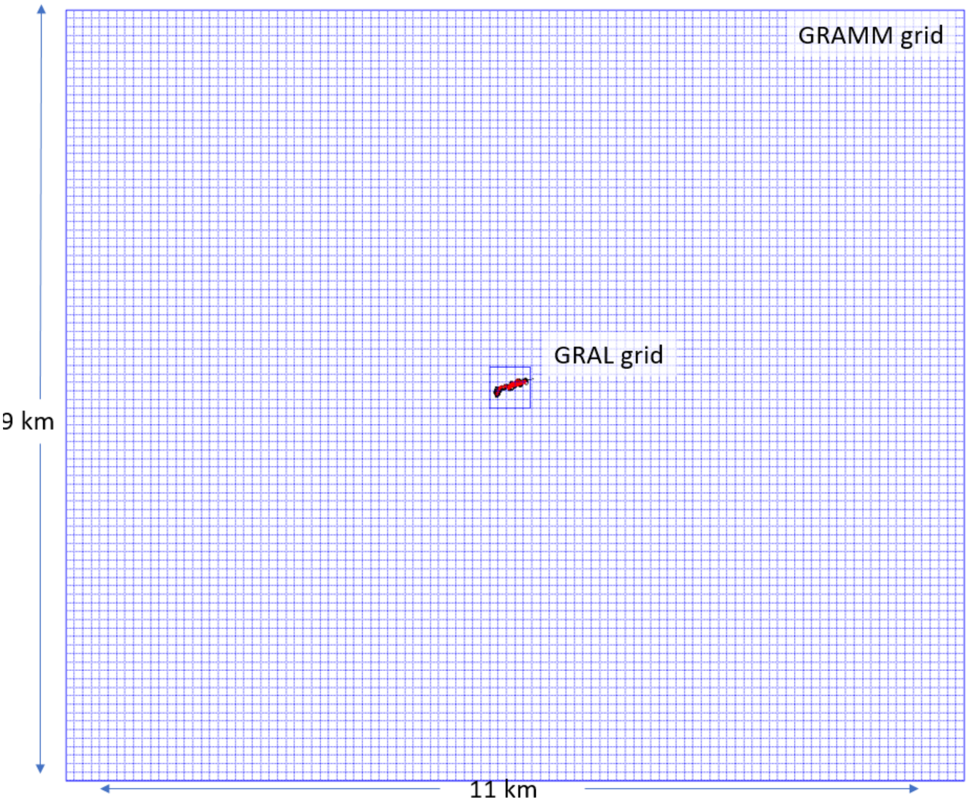
2.5 Domain design

2.5.1 Nesting the domains

Two model domains were set up, one the GRAMM grid which was for an area 9 km x 11km with a resolution of 50m. Terrain data was sourced[4] which influenced the weather model over this wider area. A second model domain, the GRAL was set up inside the GRAMM grid with a much higher resolution of 1.5 m and included the Hafodyrynys Road for the micro-simulation model testing. The nested domains are shown in Figure 18.

[4] https://dds.cr.usgs.gov/srtm/version2_1/SRTM3/Eurasia/

Figure 18: Domain representation in GRAMM



3 Traffic conditions

The modelling for this report is based on quite simple traffic data. Later stages will use detailed traffic modelling, but this was not available to build this version of the dispersion model at this preliminary stage. The traffic situation is not overly complex- it only involves a single road so assumptions for the scenarios have been developed for this stage.

To model the emissions from road traffic we used an average speed on the link which accounts for both uphill and downhill components in the traffic. The average speed used was assumed constant through the day- though it is a weighted average which takes account of slower speeds in the peak periods and faster speeds in the off-peak hours.

The traffic conditions used are as follows:

1) Annual average daily traffic[5] (DfT)
2) Average speed (km/h)
3) Cars (%)
4) Rigid HGV (%)
5) Arctic HGV (%)
6) LGV (%)
7) Motorcycle (%)

[5] https://www.dft.gov.uk/traffic-counts/

4 Air quality modelling

4.1 GRAL domain

The domain used in the micro-scale model is shown in Figure 20 below. The domain is modelled at a horizontal resolution of 1.5m. The flow field model comprises 240 x 120 cells with 15 heights. The concentration model is set to print values at 1.5 m relative to ground level throughout the domain.

Figure 19: GRAL modelling domain

4.2 Topography

The topography data used in GRAMM is too coarse to use in GRAL without causing major artefacts in the concentrations- GRAL interprets terrain as a series of 'steps', so if there are large changes in height in the steps, the micro-scale flow model will interpret these as blocks similar conceptually to buildings.

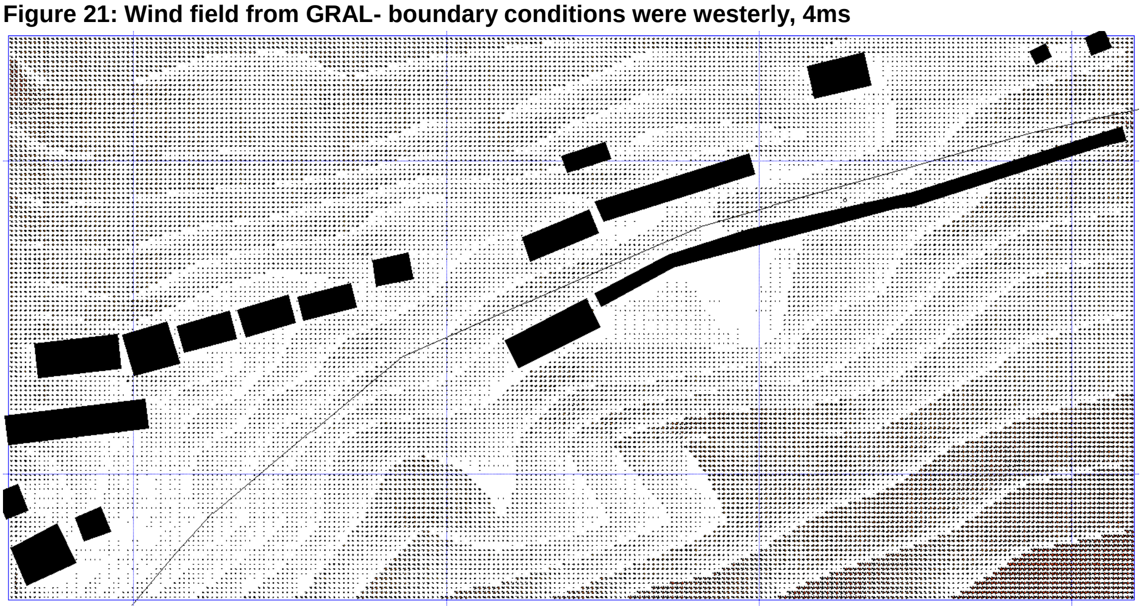
To avoid this, a micro-scale terrain model using data from Google Earth was created to include the terrain across a grid of 200 points. A python program was developed to interpolate between the 200 values, yielding around 1 million points at an interval of about 0.1m. GRAL takes the terrain file and converts it to the same x, y resolution as the defined flow field.

Figure 20: 200 height points used to build terrain model in GRAL

4.3 Meteorology

Measured weather data from Cardiff Airport were input to a weather model which took account of topography over a 11km x 9 km area centred on Hafod-yr-ynys. An example of the winds produced by the flow-field model is shown in Figure 21 below. The example is for a westerly wind and we can observe the effects of obstacles and terrain in the data (the lines show wind direction and the darker grey areas show higher wind speeds). A pocket of stagnant air lies behind Woodside Terrace (white area), while faster wind speeds are at the edge of the modelling domain at distance from the buildings.

Figure 21: Wind field from GRAL- boundary conditions were westerly, 4ms



4.4 Background NOx

Non-road background concentrations of NOx were obtained from the Defra UK-Air website. The component from road traffic was removed to avoid double counting. The background NOx climate in Hafod-yr-Ynys is quite low, with an average value at the model domain of around 9 µg/m^3. The low background value further reinforces the very dominant effect of local traffic on the NO_2 climate in the area.

4.5 Emissions

Emissions of NOx were modelled as described previously. Conversion to NO_2 was done using an empirical relationship derived by running the Defra NOx to NO_2 calculator with regional outputs for Caerphilly.

4.6 Conversion to NO_2

The GRAL results require conversion with an empirically derived equation. A conversion function specific to the study was derived which used the default values for f-NO_2 in the Defra NOx to NO_2 calculator (0.28 in 2017 for 'All UK Traffic').

The background value was input into the Defra NOx to NO_2 calculator along with the diffusion tube results provided by CCBC to obtain a conversion curve that was applied to the modelled NOx concentrations. A 4th order polynomial expression was obtained which explains 99.999% of the variance in the relationship between total NOx and total NO_2. The expression is provided in Equation 1 below.

Equation 1

$$NO2 = -0.0000000041x^4 + 0.0000046117x^3 - 0.0019480281x^2 + 0.5073764794x + 3.2761150469$$

where x = total NOx

5 Baseline results

5.1 Model validation

Agreement between the modelled values and the observed values was very good. The road NOx component was underpredicted by about 5% and overall NO_2 was underpredicted by <1% with a root mean square value of 5 µg/m^3 - this is a good result given the very high NO_2 concentrations which have been measured at Woodside Terrace. The model validation data and plots for road NOx and total NO_2 are provided in Table 2 and Figure 22 and 23.

Table 2: Model validation data for annual mean NO_2

Site	Measured NO_2 (µg/m3)	Modelled NO_2 (µg/m3)	Error (µg/m3)
CCBC48	42.0	50.6	+8.6
CCBC60	35.0	36.9	+1.9
CCBC83	59.0	63.0	+4.0
CCBC79	59.0	53.5	-5.5
Auto site	70.0	64.3	-5.7
		RMSE	*5.1*

Figure 22: Model validation plot for road NOx component

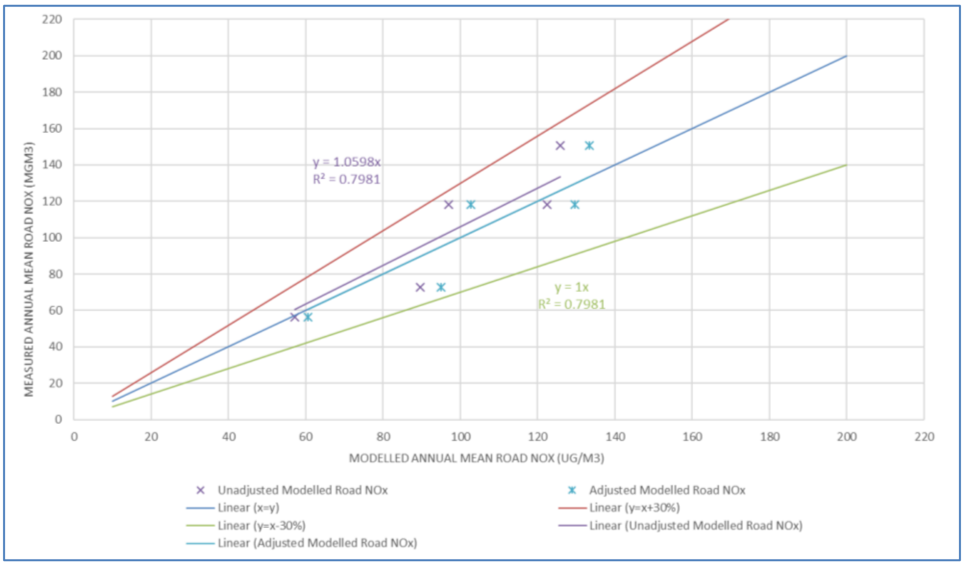
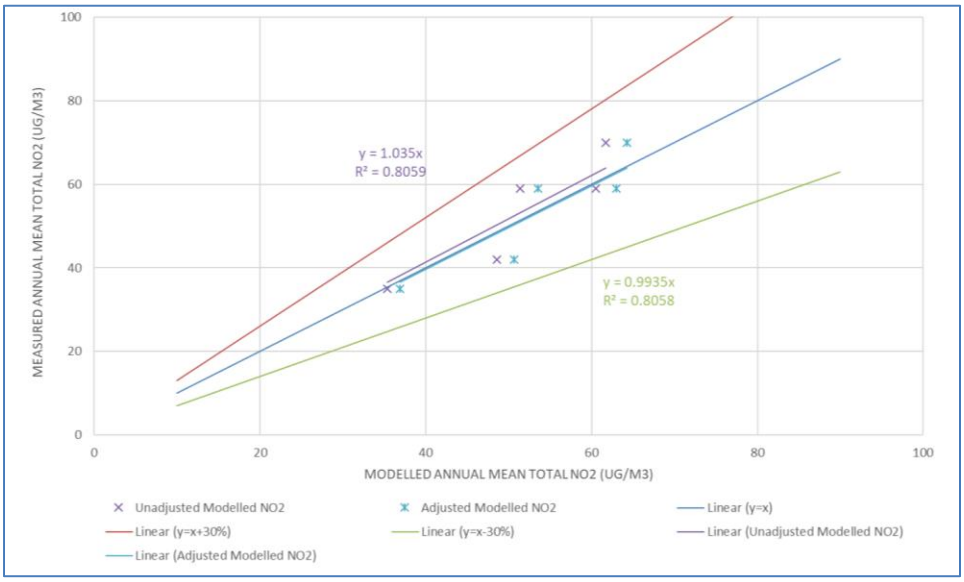


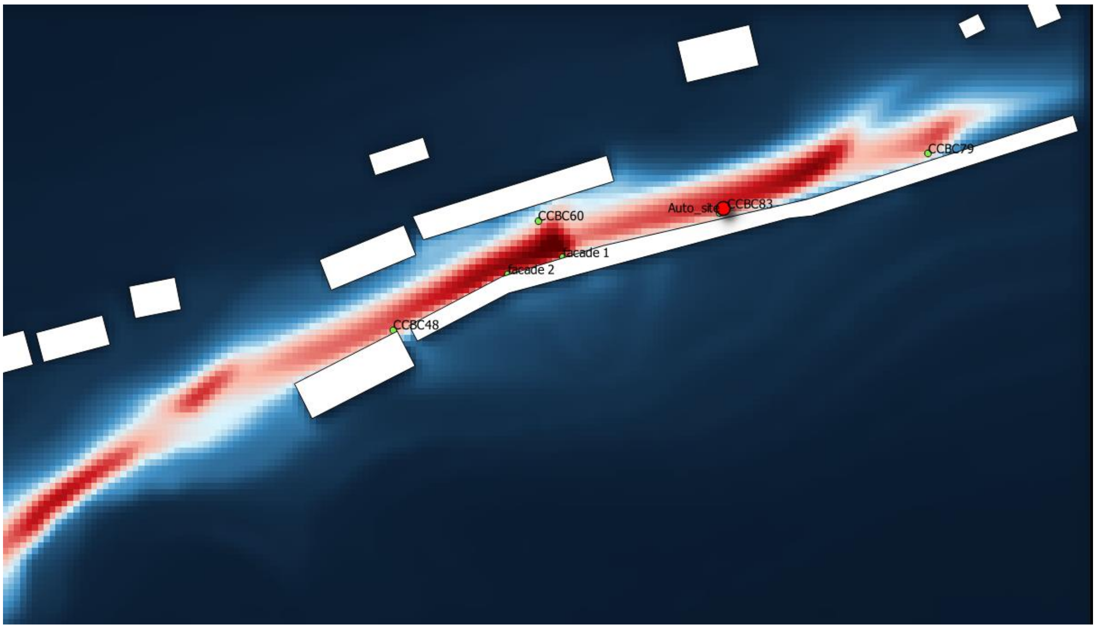
Figure 23: Model validation plot for total NO_2 component



5.2 Receptor locations to aid comparison of scenarios

As the modelled concentrations vary significantly along and across Woodside Terrace, a number of locations have been identified to aid comparison of modelled annual average concentrations with and without the selected measures. These receptors are shown below in Figure 24 and include the automatic monitoring site (Auto_site); four diffusion tube monitoring sites (CCBC48, 60, 83 and 79); and two locations at the building façade (façade 1 & 2).

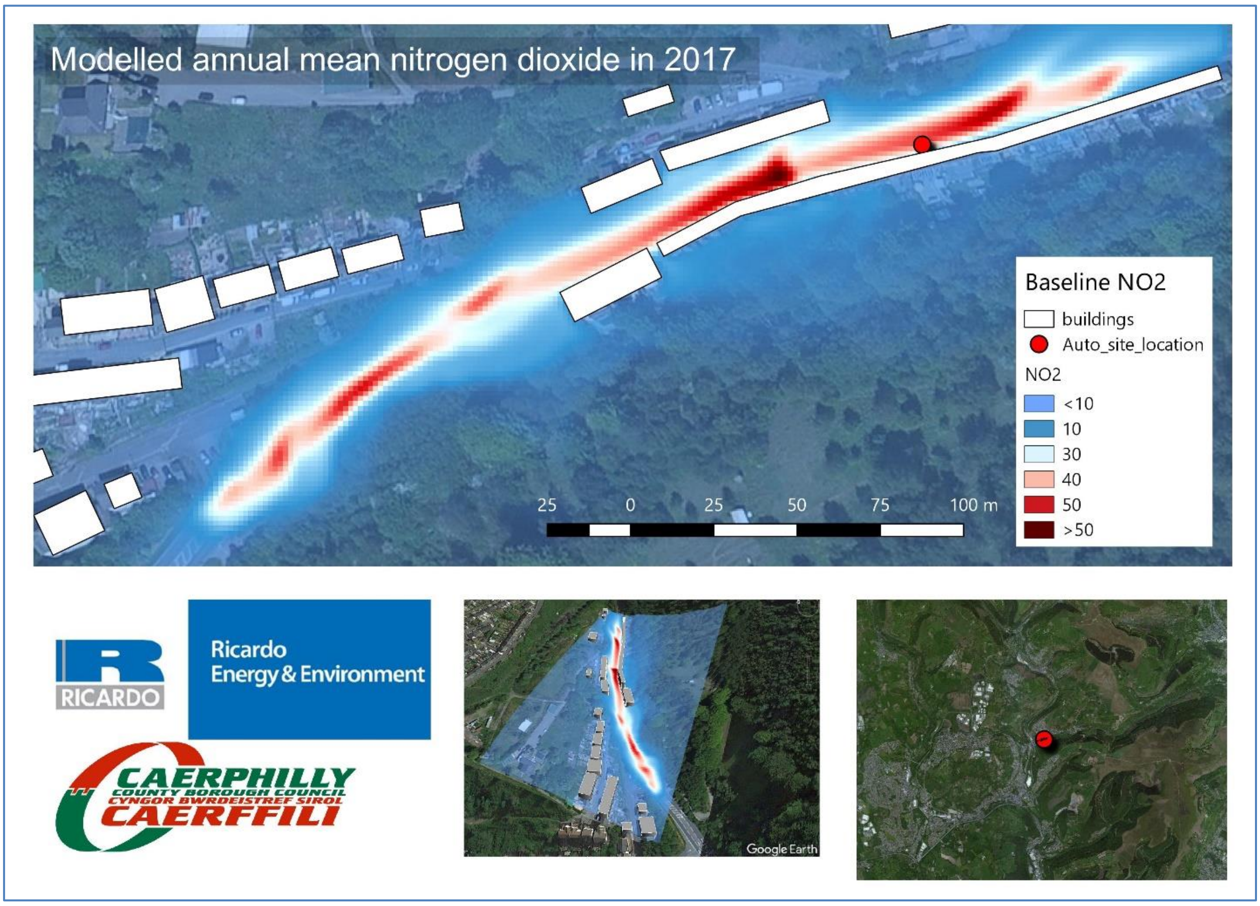
Figure 24: Receptors where annual average concentrations of NO_2 are compared with and without the potential measures



5.3 Visualisation of NO_2 concentration- baseline conditions

Figure 25: shows the modelled NO_2 climate along Woodside Terrace in 2017. As we can see there are areas of significant exceedance of the NO_2 annual mean objective through the street.

Figure 25: Visualisation of modelled concentrations of NO_2 for 2017



Concentrations vary significantly along and across Woodside Terrace, although it should be noted that the above are preliminary modelled results and fuller analysis will be undertaken as part of the Stage 3 study which will rely on more robust traffic input data. The concentrations follow a "wavy" style presentation which is expected in a street canyon where there is complex turbulence and air pockets where the shearing of the wind creates forces that produce eddies. Annual average modelled concentrations at the selected receptor locations are given below.

Table 3: Model data for annual mean NO_2 at selected receptor locations

Site	Modelled NO_2 ($\mu g\ m^{-3}$)
CCBC48	57.9
CCBC60	36.9
CCBC83	68.9
CCBC79	53.6
Auto Site	64.3
Façade 1	86.7
Façade 2	96.2

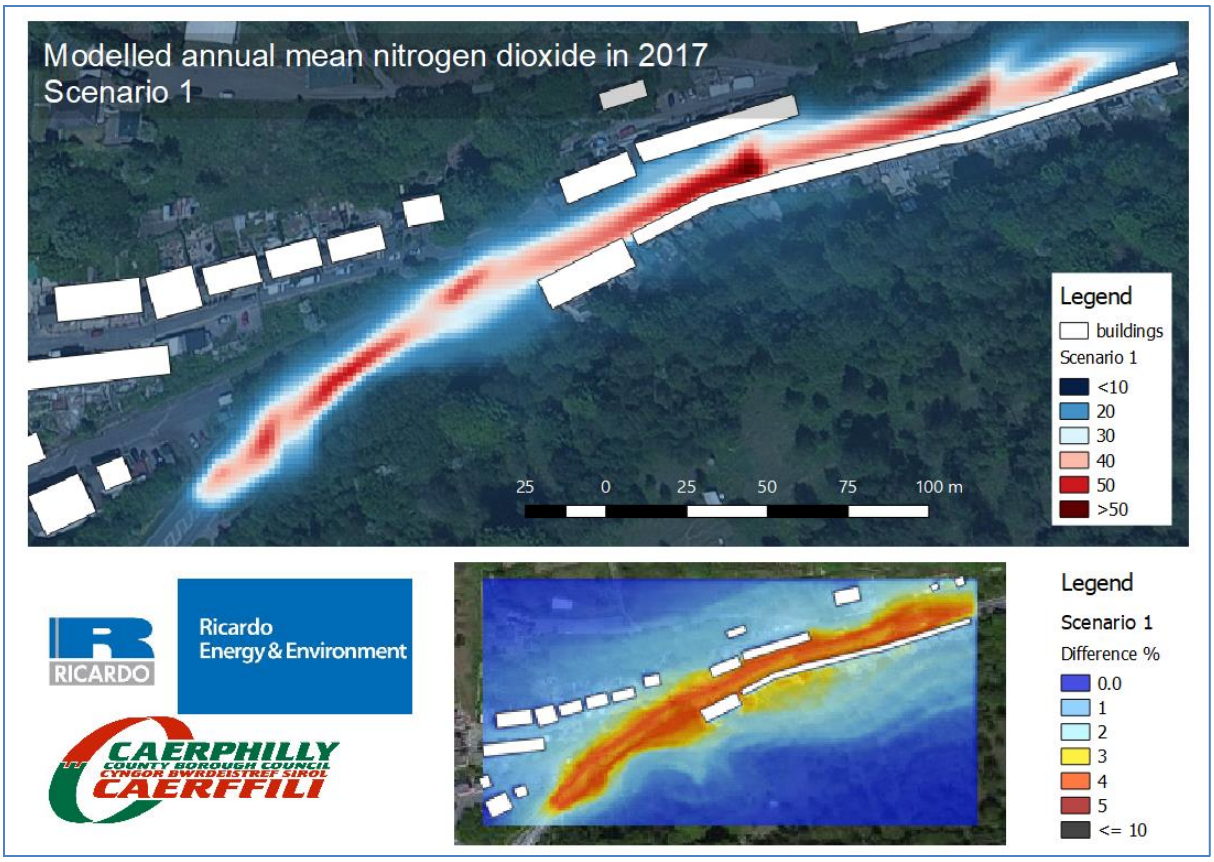
6 Scenario results

For each emission reduction scenario, both modelled NO_2 concentrations and a NO_2 reduction percentage plot are provided. Some of the NO_2 changes are quite subtle and are better illustrated with difference plots than the absolute NO_2 concentrations. As is shown, Scenarios 1 and 13 offer only small reductions of a few percent NO_2, whereas Scenarios 26 and 28 offer dramatic reductions in NO_2 concentrations.

6.1 Scenario 1 **Change Signal Timings at Crumlin Junction**

Retiming the Crumlin junction signals is intended to hold peak hour traffic back at the junction at the bottom of the hill to allow free flow traffic conditions going up the hill. Prior to the junction improvements at Crumlin Junction in 2015, traffic did not queue up the hill at Woodside Terrace. No change in overall volume (AADT).

Figure 26: Visualisation of modelled concentrations of NO_2 for 2017- Scenario 1



Predicted concentrations of NO_2 from this measure are lower compared to the baseline in all receptor locations Figure 26 and Table 4. However, these are only minor reductions compared to the level needed to achieve compliance with the limit value of 40 µg m^{-3}.

Table 4 Model data for annual mean NO_2 at selected receptor locations

Site	Modelled NO_2 (µg m^{-3})	
	Baseline (no measure)	Scenario 1
CCBC48	57.9	55.1
CCBC60	36.9	35.1
CCBC83	68.9	65.6
CCBC79	53.6	51.0
Auto Site	64.3	61.2
Façade 1	86.7	82.5
Façade 2	96.2	91.5

6.2 Scenario 2 Signalise the A472/B4471 as a Priority Junction and introduce an eastbound queue detector

While the overall impact on speed in this measure is similar to that in Scenario 1 above, the means of achieving this impact differs. Signalising this junction should prevent drivers on the A472 stopping to let traffic merge from the B4471 and therefore improve traffic flow up the hill during the morning peak hour.

This will not impact the eastbound direction during the other peaks. Equally, the option will have no effect on the westbound direction. No change in overall volume (AADT).

As the impact on average speed is similar to that in Scenario 1, the impact on the predicted NO_2 concentrations will be equally similar.

6.3 Scenario 11 Demolish Dwellings at Woodside Terrace and Re-align Road

This preliminary assessment considered the impact of removal of the majority of the terraced residential dwellings on Woodside Terrace, but retained the three dwellings downhill from the bus stop which are separated from the main row of terraces. Should this scenario prove to be effective then a number of sensitivities tests will be undertaken as part of the next detailed Stage 3 including the removal of all dwellings on this side of the road.

Figure 27: Visualisation of Scenario 11

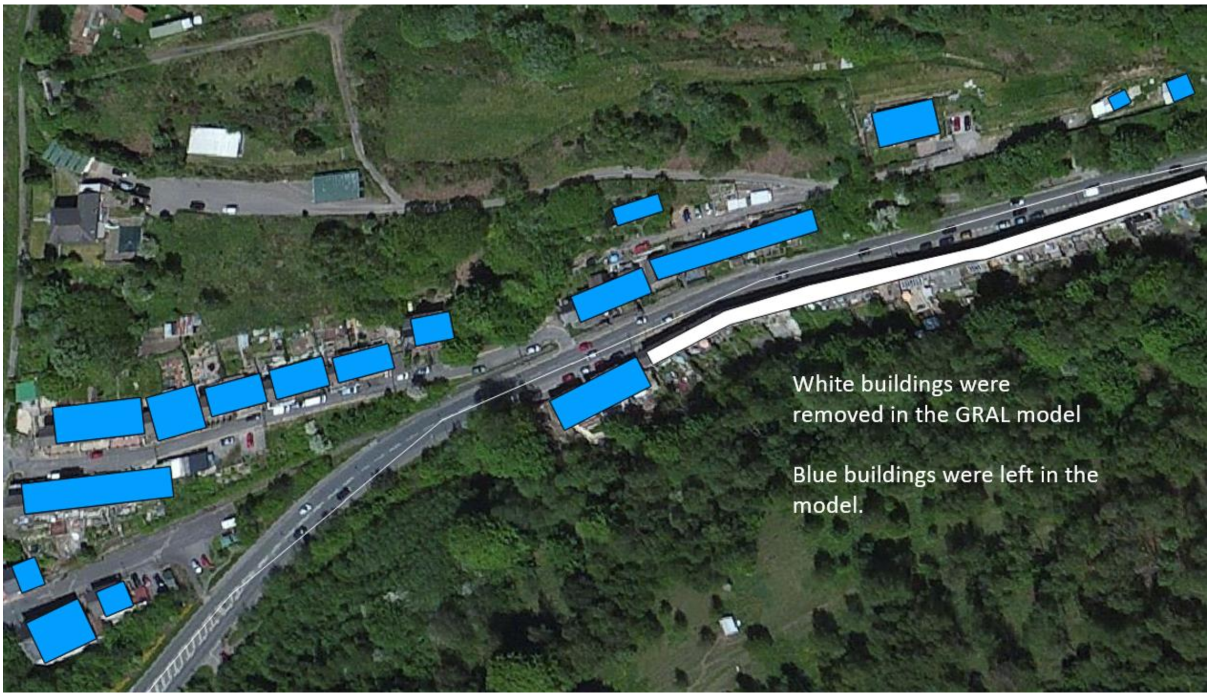
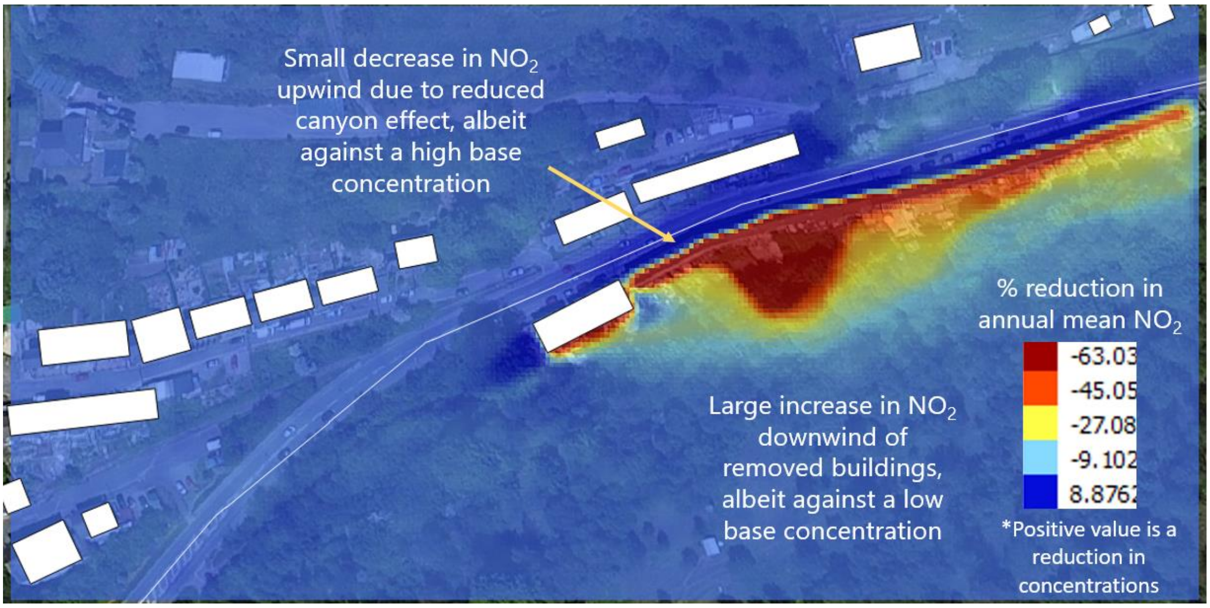


Figure 28: Visualisation of difference in modelled concentrations of NO_2 for 2017- Scenario 11



Predicted NO_2 concentrations show significant reductions at diffusion tube locations, (a complete list of results is displayed in Table 5). CCBC60 (close to residential dwelling to the northside of the road and also at location CCBC79 close to the top of the hill. However, at other locations concentrations remain over the limit value, particularly at the 3 dwellings retained in this scenario on the south of the road where concentrations increase with the removal of the other dwellings. This is likely to be due to the increased turbulence which pushes the emissions further back from the kerbside. With the removal of all residential dwellings on the southside, exposure is removed in the areas with retained high concentration levels. Concentrations of NO_2 at the properties to the north of Woodside Terrace show a reduction by about 8% with the removal of the terraces. This preliminary model indicates that the removal of all residential properties on the southside of the road should be considered further in the next detailed Stage 3 work programme.

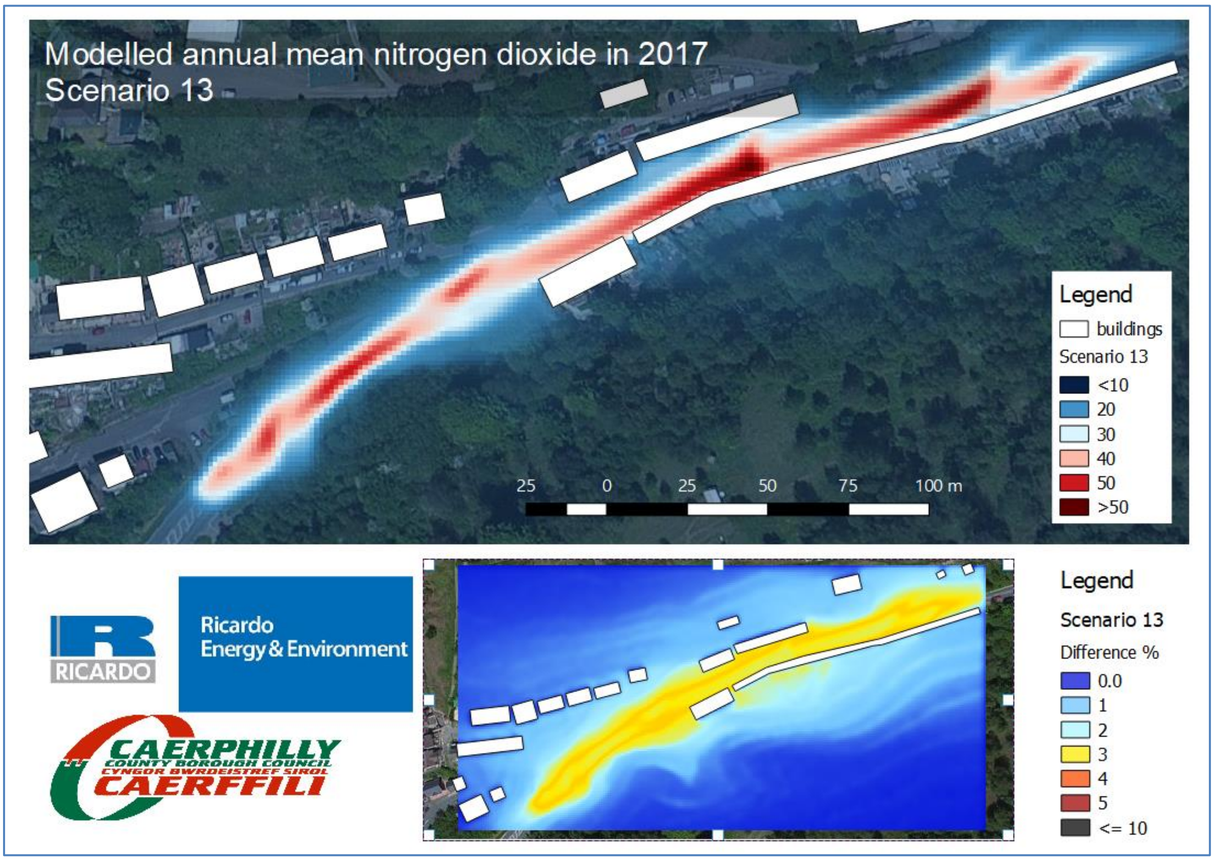
Table 5: Model data for annual mean NO_2 at selected receptor locations

Site	Modelled NO_2 ($\mu g\ m^{-3}$)	
	Baseline (no measure)	Scenario 11
CCBC48	57.9	58.2
CCBC60	36.9	29.2
CCBC83	68.9	59.0
CCBC79	53.6	34.4
Auto Site	64.3	54.3
Façade 1	86.7	68.5
Façade 2	96.2	55.5

6.4 Scenario 13 Peak Hour HGV Bans

This scenario assumes a peak hour bans in place between 0700-1000 and 1600-1900 for articulated and rigid HGVs. Automatic Traffic Count data from surveys undertaken in May 2018 indicates that peak hour HGVs account for approximately 35% of total daily HGVs. It is assumed that half of these (17.5% of the daily total) find alternative routes or result in businesses to relocate, whilst half of the HGVs would remain on the corridor though be displaced to off peak times

Figure 29: Visualisation of modelled concentrations of NO_2 for 2017- Scenario 13



Predicted concentrations from this measure only show a minimal reduction and concentrations remain very elevated compared to the limit value of 40 µg m^{-3}.

Table 6: Model data for annual mean NO_2 at selected receptor locations

Site	Modelled NO_2 (µg m^{-3})	
	Baseline (no measure)	Scenario 13
CCBC48	57.9	55.7
CCBC60	36.9	35.5
CCBC83	68.9	66.3
CCBC79	53.6	51.6
Auto Site	64.3	61.9
Façade 1	86.7	83.4
Façade 2	96.2	92.5

6.5 Scenario 15 Emissions Barrier

Model the impact of barriers erected similar to noise barriers. This barrier was assumed to be 4m in height and located in front of the terraced houses (Figure 30). Should this preliminary assessment indicate this measure could be effective in reducing exposure to the pollution levels, further sensitivity tests will be undertaken in the more detailed Stage 3 work programme. This would include detailed barrier design with access routes from the roadside to the frontage of the houses.

Figure 30: Visualisation of Scenario 15

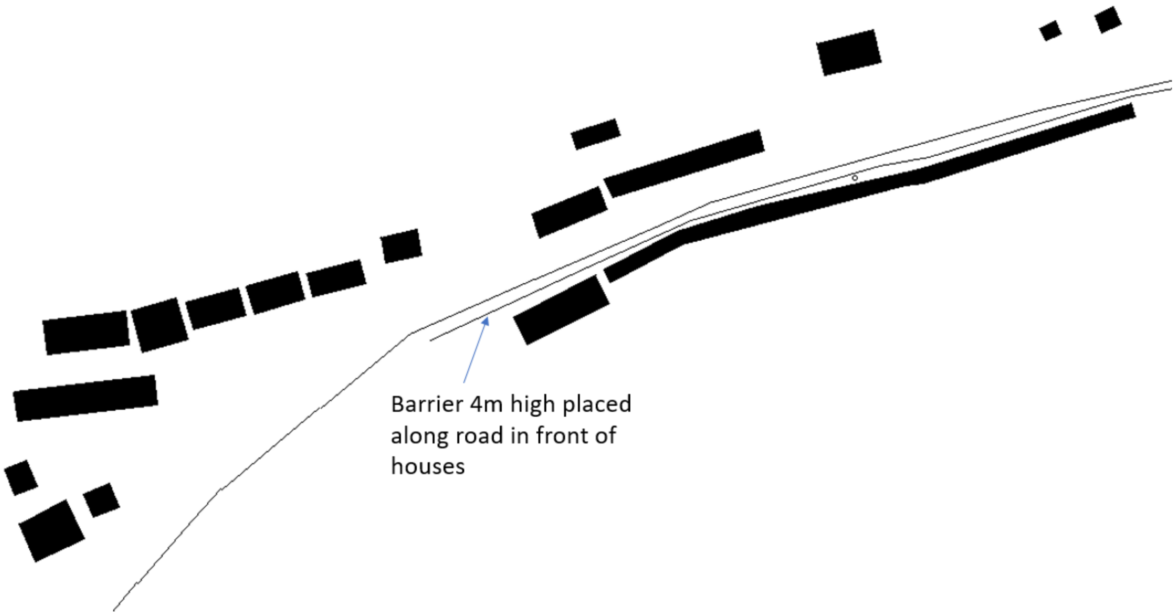
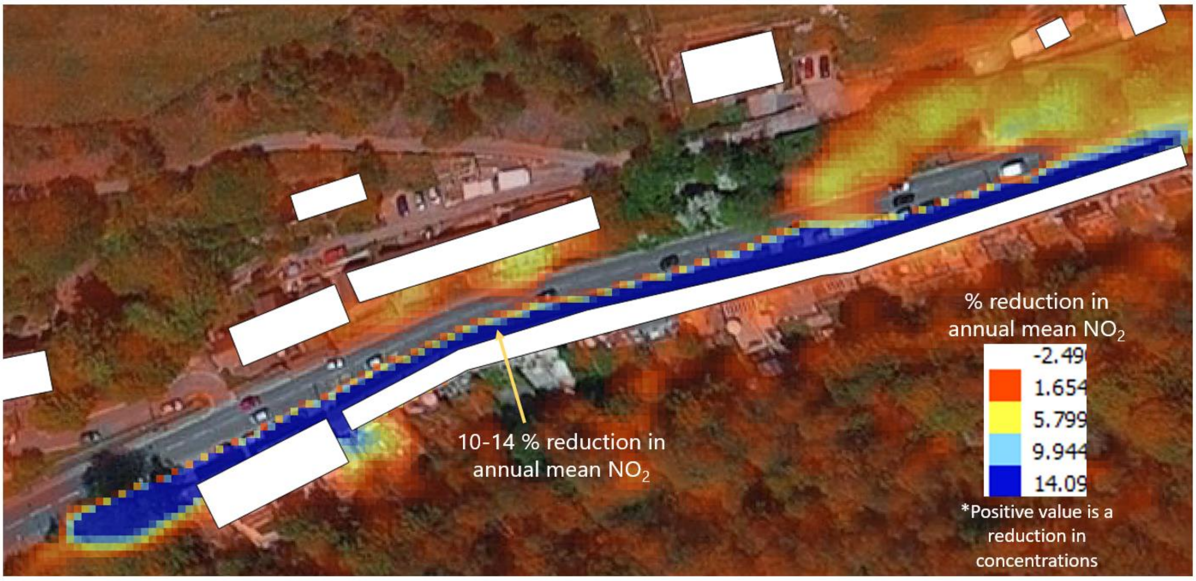


Figure 31: Visualisation of difference in modelled concentrations of NO_2 for 2017- Scenario 15

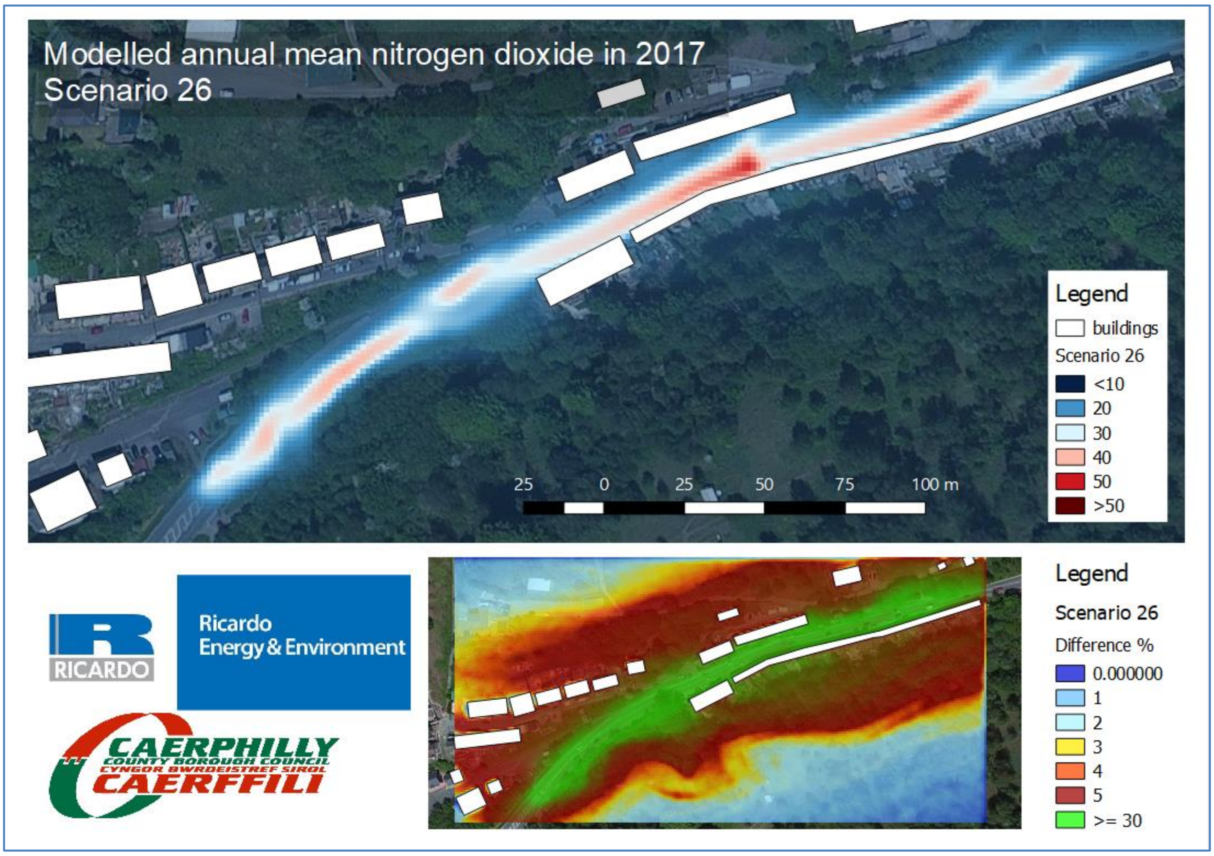


Preliminary results indicate that this would bring the area closer to compliance with the limit value but concentrations still remain over 40 µg m^{-3}. Dispersion of emissions is inhibited but as this measure does not result in lower emissions, then concentrations on the roadside of the barrier are likely to be further elevated, and levels behind the barrier whilst lower, they remain in exceedance as the emissions rise over the barrier with the road vehicle turbulence.

6.6 Scenario 26 Clean Air Zone / Low Emission Zone

This scenario assumes that the area is declared a "Clean Air Zone" aligned to the Welsh Government's framework on Clean Air Zones. For this scenario test it has been assumed that all vehicles to be either Euro 6/VI diesel and Euro 4 petrol 24/7 and no changes to flows or speeds were made. At this preliminary stage should this measure appear effective further detailed design should be considered at the Stage 3 study next regarding how the measure could be implemented and enforced and the wider economic and social impacts.

Figure 32: Visualisation of difference in modelled concentrations of NO_2 for 2017- Scenario 26



Predicted concentrations in Figure 32 show significant reductions with the measure (Table 7). However, this preliminary modelling at two locations on the building façade show high concentrations with the measure in place. This is most likely due to the elevated real world emissions given the steep gradient, even from the most recent vehicles.

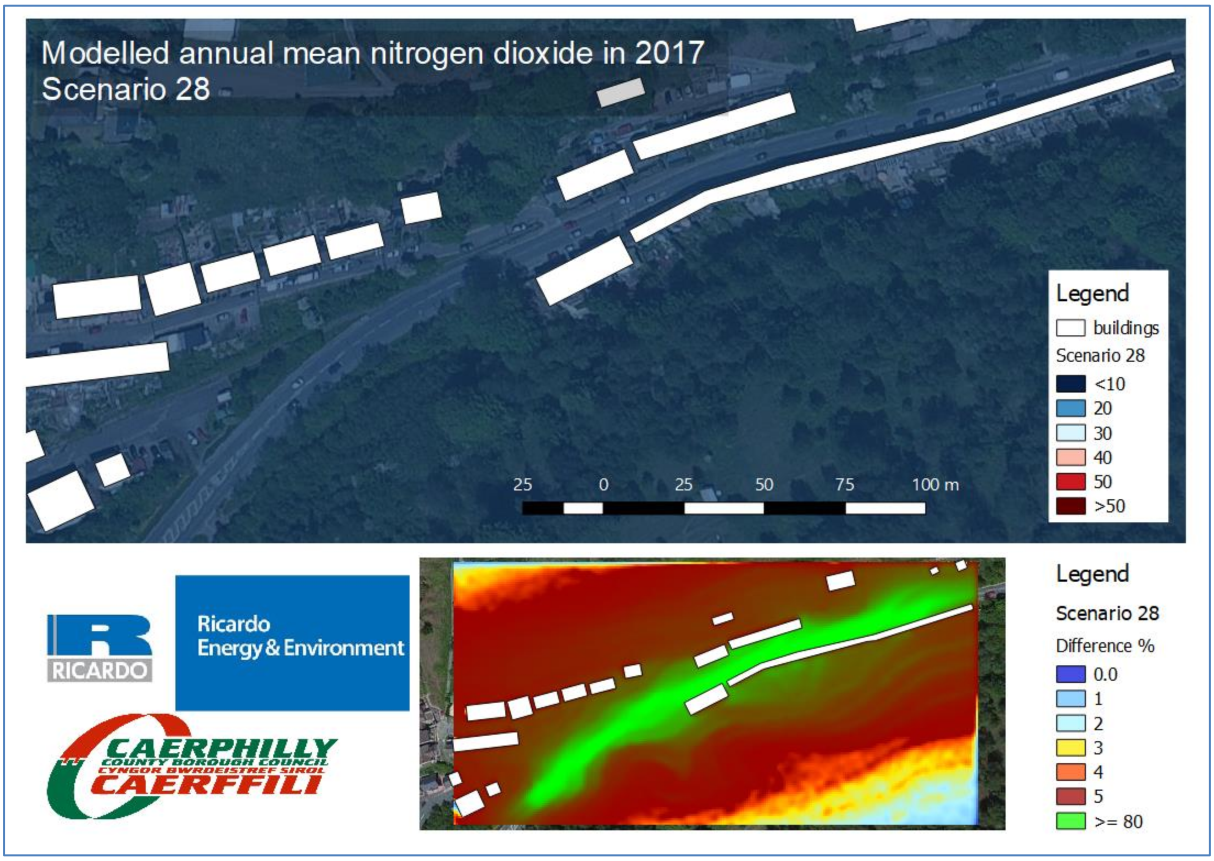
Table 7: Model data for annual mean NO_2 at selected receptor locations

Site	Modelled NO_2 (µg m^{-3})	
	Baseline (no measure)	Scenario 26
CCBC48	57.9	40.9
CCBC60	36.9	26.3
CCBC83	68.9	48.8
CCBC79	53.6	37.9
Auto Site	64.3	45.5
Façade 1	86.7	61.2
Façade 2	96.2	67.8

6.7 Scenario 28 – Bypass

This measure is based on the evidence that journey trip rates indicate that the total daily trip rate for a resident dwelling in this location is 4.370 trips per dwelling per day. Assuming all through traffic is removed from Woodside Terrace and the only remain traffic is for the 50 or so properties on or near Woodside Terrace the AADT would be approximately (50*4.370) 218.5 vehicles in a 'with bypass scenario'.

Figure 33: Visualisation of difference in modelled concentrations of NO_2 for 2017- Scenario 28



This scenario brings substantial reduction in NO_2 concentrations as expected. However, the timescales to design, plan and construct a bypass are lengthy.

Table 8: Model data for annual mean NO_2 at selected receptor locations

Site	Modelled NO_2 (µg m^{-3})	
	Baseline (no measure)	Scenario 28
CCBC48	57.9	7.9
CCBC60	36.9	7.6
CCBC83	68.9	8.2
CCBC79	53.6	7.9
Auto Site	64.3	8.1
Façade 1	86.7	8.5
Façade 2	96.2	8.7

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Appendices

Appendix 1: GRAL/GRAMM Model
Appendix 2: Meteorological Modelling
Appendix 3: Vehicle Emission Roadside Survey

Appendix 1 - the GRAL/GRAMM Model

The GRAL/GRAMM modelling system (hereafter called 'GRAL') was developed by the Graz University of Technology, Institute for Internal Combustion Engines. GRAL is a sophisticated, non-steady state air quality model which has been used extensively in Europe.

A full description of the operation of the modelling system is available in (Öttl and Kuntner, 2018). For a full scientific description of the system and the results of numerous validation studies the reader is referred to the model documentation (Öttl, 2018). The main physical assumptions and some validation exercises have been documented in several peer reviewed journals. The model documentation describes the physics, the numerical aspects of the model as well as the validation of GRAL.

For the purposes of this study we have followed the advice set out in the guidance note provided by the developers of GRAL (Öttl and Kuntner, 2017). In this report we provide a basic summary of the modelling system.

The GRAL system is a coupled Eulerian (GRAMM and GRAL wind fields) and Lagrangian model (GRAL dispersion). GRAL calculates optionally with its own prognostic or diagnostic wind field model. Depending on the influence of topography and land use, the GRAL calculation area can be approached by the wind with free flow, or alternatively it can be initialized by the flow properties of GRAMM wind fields. GRAMM works on a mesoscale area the influence of topography, land use and soil properties. GRAL adds in a smaller, nested area on the micro scale the influence of buildings and highly resolved terrain details. In prognostic mode it works according to the German VDI3783/9 standard for modelling microscale meteorology.

GRAL fulfils the requirements of the national Austrian regulation for dispersion calculation RVS 04.02.12 - Dispersion of Air Pollutants at transport routes and tunnel portals. GRAL is recommended by the National Health and Medical Research Council, Australian Government, as dispersion model for regulatory purposes for road tunnel portal emissions (NHMRC, 2008).

The basic principle of Lagrangian models is the tracing/tracking of a multitude of fictitious particles moving on trajectories within a 3D wind-field. The position of these particles is calculated according to the following basic equation:

$$x_{i,new} = x_{i,old} + (\bar{u}_i + u_i') \cdot \Delta t$$

Where $x_{i,new}$ denotes the new position in space (with i = 1,2,3), and $x_{i,old}$ denotes the previous position, $\bar{u}_i$ the mean velocity component and u_i' the fluctuating (random, stochastic) part due to turbulence of the particle movement and Δt is a time increment. The frequency of particles passing the counting grid relates the Lagrangian perspective with the Eulerian one.

7.1 Justification for the use of GRAL

Dispersion modelling in complex terrain is challenging and is especially so when low wind speeds arising from flows around buildings and other obstacles influence ambient air quality. Given the high NO2 values measured at the Hafod-yr-Ynys AURN station (annual mean = 70 µgm3 in 2017) we believe that a more sophisticated micro-scale air quality modelling method is required than would normally be the case for such a small domain with relatively few road sources. This will ensure that in accurately capturing the baseline we set the conditions to be able to accurately model the effect of emissions reduction measures.

The Hafod-Yr-Ynys location presents a set of topographical factors which complicate air quality modelling there. These can be summarised thus:

1) The road transects an obvious street canyon which is asymmetrical- the north elevation is higher than the south
2) The street canyon lies within a valley. The wider topography of the area comprises many hills and valleys.
3) The street canyon has an upwards gradient running from West to East

In isolation each of these factors would present a challenge for dispersion models commonly used in the UK. The confluence of all of these factors has led us to select the GRAL modelling suite which is well suited to deal with these additional challenges. It is useful to summarise the key technical challenges for this modelling study, alongside key technical decisions we have taken so that we may meet them.

Table A1 Key technical challenges for the dispersion modelling study

Technical challenge	Action	Comment
The roadway is surrounded by buildings which complicates wind flows and affects concentrations of NO2	We chose the GRAL model for the study as it can accurately model the flow disturbance caused by buildings and the effect on air quality The GRAL model was run in prognostic mode, this aligning the modelling study with European standards for micro-scale meteorological and air quality modelling	It was very important to select a model which has proven ability in cases where buildings- perhaps even single buildings- are having an influence on the baseline conditions. Additionally, a few of the abatement measures involve placement of screening barriers or removal of buildings, which would be difficult to model well in more standard approaches
The road is situated in hilly terrain which means that single station based meteorological data may not be representative in the domain	GRAL wind field model initialised with GRAMM wind fields as boundary conditions. We used station-based meteorology and built a stability class estimation model to derive the met data to initialise GRAMM The effect of regional topography on surface winds is therefore accounted for by the time the regional winds reach our microscale GRAL domain	The area is reasonably distant from the closest surface meteorological stations. Therefore, it was decided to use the GRAMM model to develop regional wind fields which are terrain following. GRAMM requires only wind data and Pasquill-Gifford stability estimates for each simulation time step. We derived a stability model based on well-known methods (US-EPA, 2000)
Traffic travels up and down a gradient through the street canyon which will have a substantial effect on emission of NOx and perhaps f-NO2	A bespoke emissions model based on COPERT5 has been built for the project. This includes the harmonisation of ambient exhaust emissions from the OPUS measurement campaign carried out in an early phase of the project.	The harmonisation of real-world in-situ measurements of traffic emissions with a well- known international emissions model provides the 'best of both worlds'. We can use COPERT to provide reliable speed/emission curves, which are scaled by the relationship to ambient measurements.
The mitigation scenarios involve both emissions and structural interventions	Traffic activity or fleet changes are 'emission change' scenarios, whereas building reconfiguration changes are 'topographical change' scenarios. Our methodology can accommodate both.	If there were no confounding topographical issues a simpler modelling framework would likely suffice. The combination of the types of mitigation measures give further credence to our approaches.

Appendix 2 - Meteorological Modelling

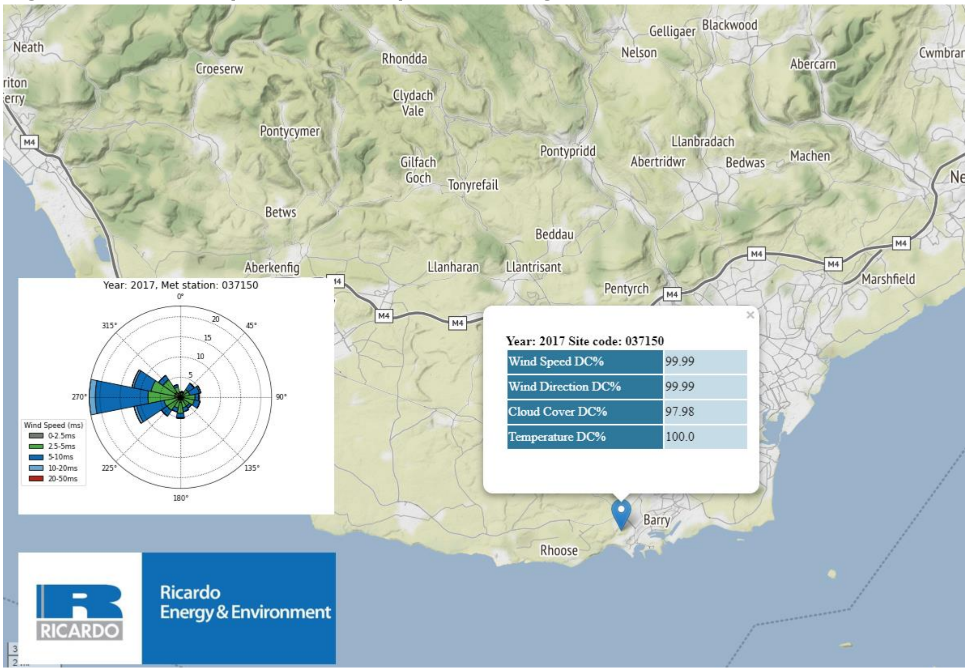
7.2 Acquisition of data and preprocessing

GRAL requires hourly meteorological data from a measurement station to provide boundary conditions to the GRAMM mesoscale meteorological modelling. We obtained hourly meteorological data for Cardiff Airport for 2017 and processed the data using our RapidMET system. The processing deals with missing data in the surface meteorological record and follows established USEPA protocols (US-EPA, 2000). The steps are embedded into a python program and proceed as follows:

1) Obtain meteorological data in ISH format from international database for our selected station (in our case Cardiff Airport
2) Repeat the procedure for two further stations, which will be used to fill gaps in the Cardiff records
3) Create hourly average met records for Cardiff and the two substitute stations
4) Analyse the Cardiff data for gaps and perform interpolation across a maximum gap of three hours where missing records are found
5) Check the interpolated record for gaps and substitute in from site two if it has data for the missing period
6) Repeat the gap check and substitute data from site three if gaps still persist after substituting site two data in
7) Finally, check the file for completeness and produce statistics for data capture for wind speed, direction and cloud cover.

RapidMET produces a location diagram and wind rose for the chosen site after the processing has been completed- the output also includes the data capture statistics. In this case data capture rates are excellent (>95% for all important metrics).

Figure A1 RapidMET map showing met station and data quality metrics



The GRAMM model requires an estimate of atmospheric stability each hour. The most commonly used classification of atmospheric stability was developed by Pasquill and Gifford (Pasquill, 1961; Gifford, 1961). They defined six classes, named A to F, with A the most unstable class, D neutral atmosphere, and F the most stable class.

The GRAL developers recommend using the Solar radiation/delta-T (SRDT) scheme (US-EPA, 2000) to calculate stability but this requires hourly estimates of solar radiation. Solar radiation data was not included in the measurements at Cardiff Airport, but were estimated using Equation 2 below from cloud cover data and solar angle. The position of the sun each hour in 2017 was calculated using the Excel calculator available from NOAA. Then the solar radiation (*R*) in W/m2 was computed using the scheme by Holstag and van Ulden, 1983:

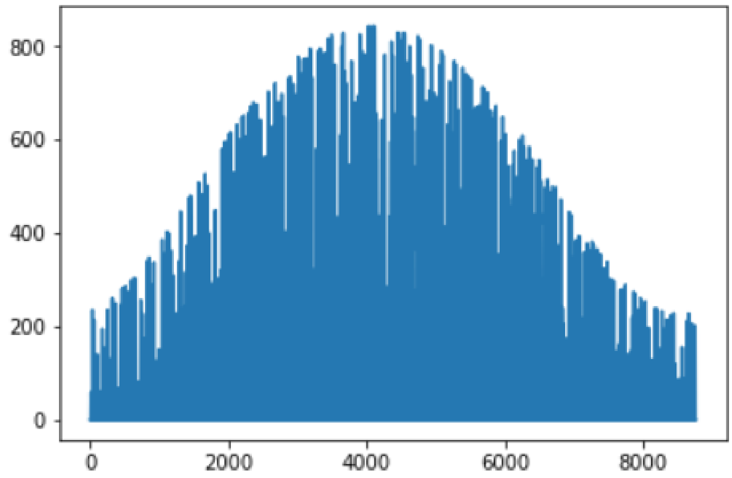
Equation 2 $$R = (990 \sin \varphi - 30)(1 - 0.75n^{3.4})$$

The results of our solar radiation calculator applied to the Cardiff data is shown in Figure A1 below. We can see the expected increase in solar radiation in the summer months relating to the higher solar angle and greater number of sunlit hours in each day. We can also see the solar radiation budget being modulated by cloud cover (the cause of the troughs in the data).

Figure A1 Temporal variation in solar radiation calculated for Cardiff Airport in 2017 (x axis = hour of year; y axis = solar radiation (W/m^2)

```
df['solar_radiation'].plot()
```

```
Out[34]: <matplotlib.axes._subplots.AxesSubplot at 0xb0a1f28>
```

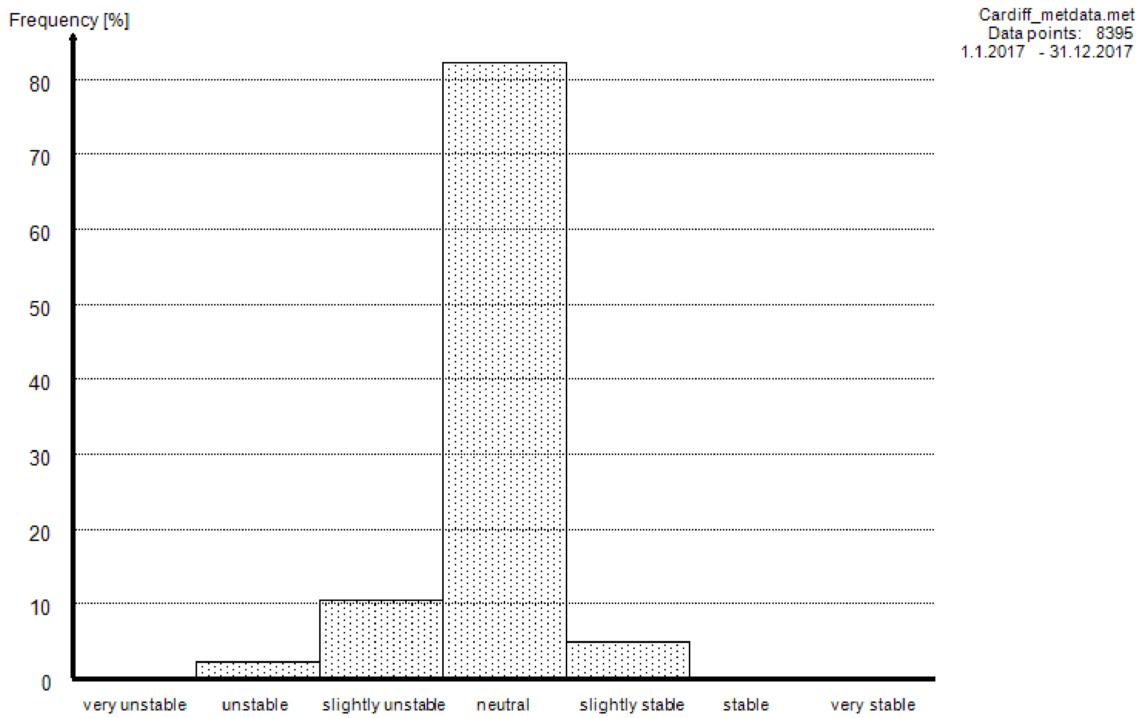


The SRDT scheme further requires a determination of whether each hour is in the day or night (‘D’ or ‘N’). We simply assumed that solar angle values <0 represent pre-sunrise conditions- these were assigned ‘N’ in the data set, with ‘D’ for cases with solar elevation > 0. This allows us to compute stability class based on our synthesised parameters, from the ground observations from Cardiff Airport.

It should be noted that we did not have access to delta T measurements (temperature Vs height), which are suggested in the SRDT method as a means of informing stability estimation in the evening hours- if the temperature gradient is <0 (i.e. temperature decreases with height) the assumption is that there is slight turbulence in the lower atmosphere, if the gradient is >0 it is assumed that the lower atmosphere is more stable. Since we did not have delta T measurements we assumed the temperature gradient was always <0. In practice this only affects a few hours per year so will have virtually no bearing on the annual mean concentrations predicted in this study.

The stability estimates were as expected- neutral and slightly unstable conditions predominate over the course of the year, with much fewer instances of highly unstable or highly stable conditions. A breakdown of the stability class estimates is shown in Figure A-2.

Figure A-2 Histogram of stability classes for Cardiff Airport in 2017



When the stability class estimates had been added to the 2017 meteorological data it was formatted according to the requirements of the GRAMM model, before being used to initialise the GRAMM runs.

7.3 GRAMM meteorological modelling

The GRAMM meteorological pre-processor is a fully featured mesoscale meteorological model with similarities to other codes such as WRF and MM5. The GRAMM model meets the requirements of Austrian standard VDI3783/7 for mesoscale weather modelling so can be used with confidence in other countries.

The steps in running the GRAMM meteorological model are as follows:

1) Obtain meteorological data in the correct format (in our case the Cardiff data with our added stability estimates)
2) Design the GRAMM domain (dimensional scale, resolution etc)
3) Add topographical data and process it to produce a GRAMM “grid”
4) Run the model for automatically computed ‘weather situations’ (unique combinations of wind speed, direction and stability class)

7.3.1 Meteorological input data

The main input to GRAMM is our processed surface station data from Cardiff Airport in 2017- with the addition of estimates of atmospheric stability. GRAMM analyses the met record and calculates the number of unique combinations of winds and stability, termed ‘weather situations’. The run time is directly related to the number of unique weather situations, so it is recommended to use class based wind data. We also limited the number of wind directions to 16 by setting each sector to be 22.5 degrees. These steps reduced the number of weather situations from several hundred to 212, which still requires about 12 hours of computation to produce the wind fields which will be consumed by GRAL.

Other GRAMM parameters were set as follows (closely aligning with recommendations in the user manual:

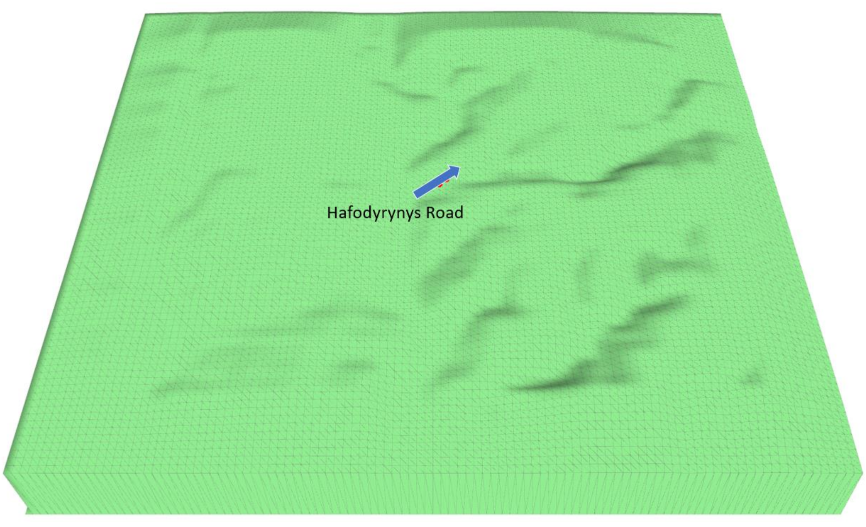
- Horizontal grid resolution (m)- 100
- Vertical thickness of first layer (m) - 10
- Number of vertical layers – 15
- Vertical stretching factor – 1.40
- Maximum relative layer height (m) – 3874
- Number of smoothing cells around topography input – 10
- Modelling time (s) – 3600
- Relaxation velocity – 0.10
- Relaxation scalars – 0.10

7.3.2 Influence of topography

The topographical input to GRAMM was obtained from the Shuttle Radar Topography Mission website via Ricardo's UKTerrain R program[6].The data was clipped to the same dimensions as the intended GRAMM domain in ArcMap, before converting it to ESRI-ASCII format as required by GRAMM.

A 3D view of the data in the GRAMM GUI is shown in Figure A-3 below. We can see that the general topographical features of interest are retained (e.g. the valley which contains the Hafod-yr-Ynys street canyon). This provides confidence that the wind fields used in the GRAL model will have any regional topographical influences included.

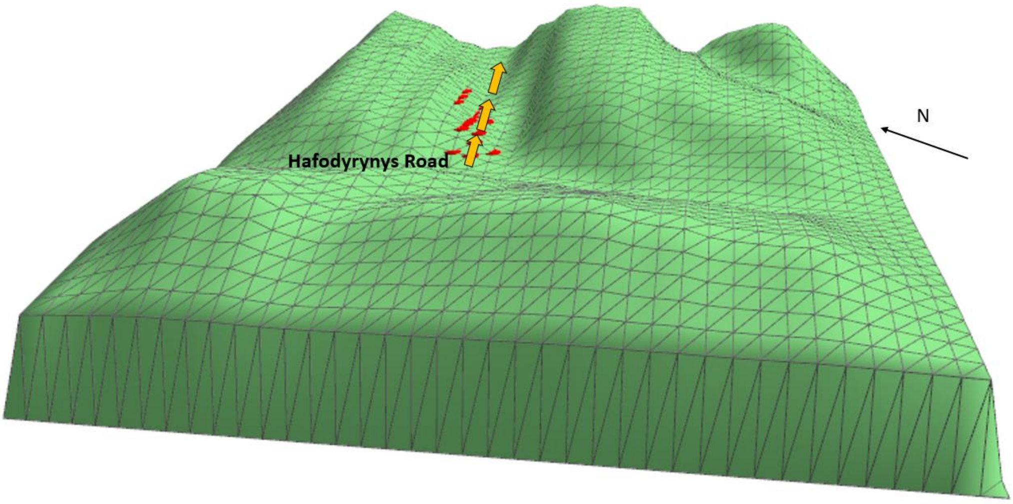
Figure A-3 Topography in the GRAMM model (note the Hafod-yr-Ynys valley)



The close-up elevations in the GRAMM model are further shown in Figure A-4 below. We can see that the main topographical features of note in the earlier satellite imagery are also present in the GRAMM model. The image shows the direction of the upwards gradient through the street canyon to help orientate the reader.

Figure A-4 Close up topography in the GRAMM model (note the Hafod-yr-Ynys valley)

[6] https://github.com/scottlynn73/ukterrain


Hafodyrynys Road
N

Appendix 3 - Vehicle Emissions Roadside Survey

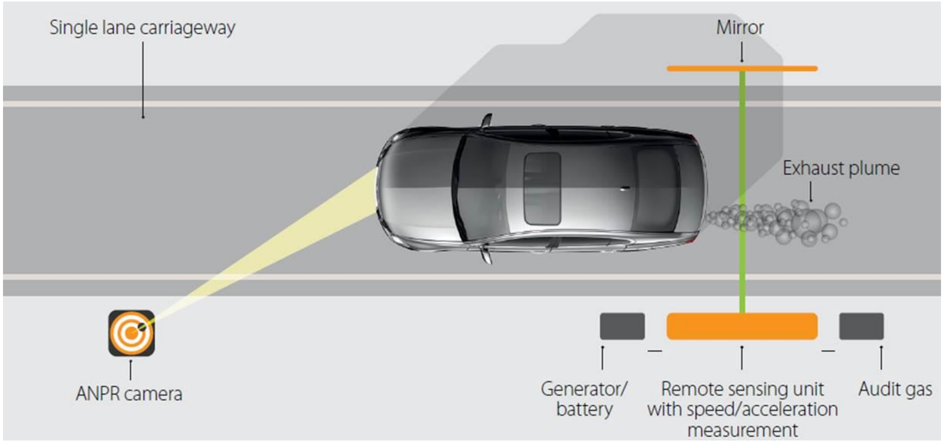
7.4 Introduction

There has been much uncertainty in the use of national emission factors and how representative they are to real-world emissions. While the most recent set of emission factors take this into account to some degree, there remains large uncertainty as to how emissions behave in an environment such as the gradient in Woodside Terrace. To provide a robust study a field monitoring campaign was undertaken and used to derive local emission factors to underpin the modelling and assessment of measures. The data are reported below.

7.5 Field campaign

To investigate the real-world emissions of vehicles travelling on the A472 at Woodside Terrace and the impact of the road gradient on emissions, a field campaign was undertaken to measure vehicle emissions during a four-week period. Remote sensing measurements were made using a commercial remote sensing instrument, the AccuScan RSD-5000 instrument supplied by OPUS Inspection. The set-up of the remote sensing instrument is shown in FigureA-6. The remote sensing unit consists of a focused bean if non-dispersive Infrared radiation (NDIR) and Ultraviolet (UV) light which are directed across a single carriage way of a road to a mirror from which the light is returned to the detectors in the remote sensing unit. The exhaust plume of passing vehicles intersect the IR and UV beams and the concentrations ratios nitrogen monoxide (NO), nitrogen dioxide (NO_2), carbon monoxide (CO), hydrocarbons (HC), particulates (PM) and ammonia (NH_3) as to CO_2 are recorded. This work focuses on emissions of NO_x (NO + NO_2) and NO_2, therefore the emissions of other pollutants are not reported here. Alongside the emissions measurements, the speed and acceleration of the vehicle is recorded and an ANPR camera is positioned to record the number plate.

FigureA-6. Setup of the OPUS Inspection RSD5000 instrument



Remote sensing measurements were undertaken at the two sites are shown in Figure A-7. The first measurement site (Site 1) was located a few hundred meters down from the Hafod-yr-ynys monitoring station on a portion of the road with significant gradient. This was identified as the most suitable measurement location that was close to the monitoring station and met the safe operating requirements for the remote sensing instrument. The second location (Site 2) is located close to the top of the hill near to the junction with Swyfryd Road. Site 2 was located on a section of road with significantly lower gradient than Site 1. Table A2 summarises details of the monitoring site locations. In total, over 65,000 vehicle emissions measurements were recorded during the measurement campaign.

Measurements were undertaken for several hours each day, with measurements recorded between the hours of 6am and 6pm during the period of the measurement campaign to capture traffic at the morning and evening peak, as well as at other less busy periods. Different time periods were targeted on different days during the campaign.

Figure A-7. Locations of remote sensing measurement sites and the location of Hafod-yr-ynys Roadside monitoring station.

Table A2: Site details.

	Site 1: on hill	Site 2: top of hill
Dates	Mon 11th – Fri 15th September 2017 Mon 30th April – Fri 4th May 2018	Tues 8th – Fri 11th April 2018 Mon 14th –Wed 16th May 2018
Latitude	51.6797°	51.6823°
Longitude	-3.1228°	-3.1366°
Direction	Eastbound, towards Pontypool	Eastbound, towards Pontypool
Gradient	6.6%	2.5%
Number of measurements (valid vehicle measurements)*	36,548 (30,9447)	31,328 (24,909)

* Not all measurements can be matched to a vehicle or provide valid emissions measurements. The value in parentheses is the number of valid NO_x measurements for which the measurement could be matched to vehicle information.

7.6 Data processing and analysis

The vehicle emissions remote sensing instrument returns emissions for each vehicle measured, the speed and acceleration of the vehicle, ambient temperature, pressure and humidity, and an image of the vehicle. The vehicle number plate is extracted from each image using a semi-automated process. The image is first passed through the on-line automatic number plate recognition software OpenALPR[7], and if this fails to find a match above a specified confidence interval then an operator reviews and manually types in the number plate. The number plates are then matched to a detailed database of

[7] https://www.openalpr.com/

vehicle details provided by CDL Vehicle Information Services Ltd and derived from DVLA and SMMT databases. In total, over a hundred fields of vehicle information are returned, including details of vehicle make, model, size and weight, fuel, year of registration and, where available, mileage at last MOT. Vehicle details are matched to the measured emissions returned from the remote sensing instrument using a custom program written in the R-programming language[8] and stored in a database.

The remainder of this section describes the subsequent data processing undertaken to (1) convert the measured vehicle emissions from g/kg fuel to the g/km units used in emissions inventories and (2) compare the emissions factors from remote sensing to inventory emission factors from COPERT.

7.6.1 Calculation of emissions in grams per kilometer

The remote sensing instrument measures emissions of the pollutants nitrogen monoxide (NO), nitrogen dioxide (NO_2), carbon monoxide (CO), hydrocarbons (HC), particulates (PM) and ammonia (NH_3) as a ratio to CO_2. Through combustion equations, this ratio can readily be converted to the units of grams per kilogram of fuel consumed (g/kg fuel). Emissions both as ratios to CO_2 and in g/kg fuel are returned as an output from the instrument. Emissions inventories used in modelling provide vehicle emission factors in units of grams per kilometer. In order to compare inventory emission factors and real-world emission factors from remote sensing, and to provide alternative real-world emission factors for modelling, it is necessary to convert the vehicle emissions from the remote sensing measurements from units of grams per kilogram of fuel to grams per kilometer.

7.6.1.1 Light duty vehicles

A recent study from the CONOX project[9] established a methodology to undertake this conversion for light duty vehicles (cars and vans)[10] and this method is applied in this work. The basis of this method is to provide an estimate of the instantaneous fuel consumption of the vehicle under the driving conditions of the remote sensing measurement in order to calculate grams of pollutant per second or per km driven. The following steps are required to compute emissions in g/km:

Step 1: Calculate vehicle specific power (VSP). VSP which is defined as the engine power divided by the vehicle mass, and accounts for the main power consumers of the vehicle including acceleration, rolling resistance, air resistance, road gradient, transmissions losses and auxiliary power demand. VSP can be calculated from the measured vehicle speed (*v*; ms^{-1}), acceleration (*a*, ms^{-2}) and mass (m, ton) and the gradient of the road (*Grad*, defined as the altitude (m) / distance (m)) according to Equation 1:

$$\boldsymbol{VSP} = \frac{(2500+R_0\times v+R_1\times v^2+c_d\times A\times 0.6\times v^3)\times 1.08}{m\times 1000} + \boldsymbol{v}\times \mathbf{1.08}\times(\mathbf{1.04}\times \boldsymbol{a}+\boldsymbol{g}*\boldsymbol{Grad}) \qquad (1)$$

R_0 (N) and R_1 (N/ms^{-1}) are road load coefficient of the vehicle from rolling resistance and friction losses in bearings. C_d is the aerodynamic drag coefficient and A is the frontal area of the vehicle.
Borgen-Kleefeld et al.[10] provide a set of generic coefficients for R_0, R_1 and cd*A for diesel and petrol cars and vans within a set of weight categories derived from PHEM model simulations. The coefficients used in this work are presented in Appendix 1.

Step 2: Fuel consumption (FC; g/h) is calculated using a polynomial equation for the fuel consumption characteristic curve that links fuel consumption to VSP and vehicle mass (Equation 2). Parameterization of the coefficient A, B and C is provided by Borgen-Kleefeld et al.[10] based on PHEM model simulations of fuel consumption under a range of driving conditions for petrol and diesel cars and vans within a set of weight categories. The Coefficient used in this work are presented in Appendix 1.

$$\boldsymbol{FC}\left[\tfrac{g}{h}\right] = [\boldsymbol{A}\times \boldsymbol{VSP}^2+\boldsymbol{B}\times \boldsymbol{VSP}+\boldsymbol{C}]\times \boldsymbol{m} \qquad (2)$$

[8] https://www.r-project.org/
[9] The CONOX project commissioned by the Federal Office for the Environment (FOEN) aims to pool, share and analyse European remote sensing data.
[10] J. Borken-Kleefeld, S. Hausberger, P. McClintock, J. Tate, D. Carslaw, Y. Bernard and Å Sjödin, Comparing emission rates derived from remote sensing with PEMS and chassis dynamometer tests – CONOX Task 1 report, Commissioned by Federal Office for the Environment, Switzerland,

When negative fuel flow values are calculated, the fuel consumption is set equal to zero. This situation is indicative of mechanical breaking and leads to extrapolation of the fuel consumption into non-existing negative power ranges of engines.

Step 3: Conversion of fuel consumption in g/h to units of g/km is performed by dividing by the vehicle speed.

$$FC\left(\frac{g}{km}\right) = \frac{FC\left(\frac{g}{h}\right)}{v\left(\frac{km}{h}\right)} \quad (3)$$

Step 4: Convert the remote sensing emission rates (RS) in g/kg fuel into g/km using the fuel flow calculated according to Equation 4:

$$RS\left(\frac{g}{km}\right) = RS\left(\frac{g}{kg}\right) \times \frac{FC\left(\frac{g}{km}\right)}{1000} \quad (4)$$

7.6.1.2 Heavy duty vehicles

The work undertaken as part of the CONOX project did not consider the conversion of remote sensing emissions from g/kg fuel to g/km for heavy duty vehicles (buses and HGVs) and a parameterized formulation to carry out this conversion is not available in the literature. Therefore, a simplified approach has been developed to provide an estimate of emissions in g/km from the remote sensing instrument. This method makes the approximation that the CO_2 emission factors from COPERT at the speed that a vehicle is travelling represents the instantaneous emissions of CO_2 at the point of measurement when the road gradient is zero.

The road gradient will impact emissions of CO_2 as higher gradients will be expected to result in higher power demand and therefore higher fuel consumption and CO_2 emissions for vehicles of the same mass travelling at the same speed and acceleration. Zhang *et al*.[11] provide a formula linking instantaneous VSP for heavy duty vehicles to vehicle velocity (v; m/s), acceleration (m/s^2), the angle of road gradient (θ) and vehicle weight (m; ton):

$$VSP_{HDV} = v \times (a + 9.807 \times \sin\theta + 0.186333) + \frac{3.702456}{m} \quad (5)$$

To account for the impact of road gradient a scaling factor is applied calculated from the ratio of VSP at for a vehicle measurement at the road gradient of the measurement (VSP_θ) to the VSP for the vehicle under the same acceleration and speed with conditions of zero road gradient. Overall the emission factors in g/km from the remote sensing measurements (RS_{HDV}(g/km)) were calculated using Equation 6, where EF_{CO2} is the COPERT emission factor for CO_2 for a vehicle at the measured vehicle speed, $[X]/[CO_2]$ is the ratio of the pollutant of interest to CO_2, as measured by the remote sensing instrument and m_x/m_{CO2} is the mass ratio of the pollutant of interest to CO_2.

$$RS_{HDV}\left(\frac{g}{km}\right) = \frac{[X]}{[CO_2]} EF_{CO2}\left(\frac{g}{km}\right) \times \frac{VSP_\theta}{VSP_0} \times \frac{m_X}{m_{co2}} \quad (6)$$

For vehicles with negative acceleration (deceleration) it is assumed that ratio VSP_θ/VSP_0 is equal to one.

7.6.2 Comparison to inventory emission factors

It is informative to make a comparison between COPERT vehicle emission factors used in UK emission inventories and modelling, and the real-world emission factors measured by remote sensing. COPERT provides speed dependent emission factors grouped by vehicle type, fuel type, euro standard and vehicle engine size or weight. To undertake this comparison a process was written in R to assign each

[11] W. Zhang, J. Lu, P. Xu and Y. Zhang, Moving towards Sustainability: road Grades and On-Road Emissions of Heavy-Duty Vehicles – A Case Study, Sustainability 2015, 7, 12644-12671.

vehicle emissions measurement to a COPERT vehicle category based on the vehicle information contained in the database of measurements. The corresponding COPERT emission factor was then matched to the measurement based on the assigned COPERT vehicle category and the vehicle speed recorded along site the remote sensing emissions measurement.

For a small proportion of the vehicle measurements (~5-10%) valid speed and acceleration measurements were not recorded. Additionally, details of the Euro standard of the vehicle was also missing for a small proportion of vehicles. Gap filling was undertaken to maximize the measurements that could be assigned a COPERT emission factor. Speed and acceleration were filled in based on the average of the speed and acceleration recorded for vehicles of the same type (Car, LGV or HDV) at the same measurement site. Euro standard was filled in based on the date of registration of a vehicle and the date at which each Euro standard came into force.

For Euro 5 HGVs COPERT provide different emission factors for vehicles fitted with Selective Catalytic Reduction (SCR) and Exhaust Gas Recirculation (EGR) abatement technologies. The vehicle details obtained from CDL Vehicle Information Services Ltd do not include details of a vehicles abatement equipment. The NAEI provides figures for the proportion of Euro 5 buses and HGVs fitted with SCR and for both vehicle types 75% for vehicles are fitted with SCR and 25% with SCR. Therefore, where applicable, the majority of the results presented below compare the derived real-world emission factors to the COPERT emission factors for the appropriate vehicle class fitted with SCR. A more detailed analysis was undertaken for the real-world emission factors generated for use in modelling (see section XXX) where the comparator COPERT emission factors are an average of SCR and EGR emission factors, weighed by the proportion of SCR and EGR vehicles in the fleet.

For HGVs and buses emission factors depend on vehicle load and the slope of the road. No information on the vehicle load is available for vehicles measured during the remote sensing field campaign. Therefore COPERT emission factors for HGVs and buses at 50% load are considered the most appropriate comparator, consistent with approaches taken in the NAEI and air quality modelling. Local Air Quality Management Technical Guidance (TG16)[12] provides details of how to adjust COPERT emission factors at zero gradient in local air quality modelling studies to account for the effect of road gradient on emissions. Equation 7 is the general equation for the amended speed-related EF for vehicles on a slope:

$$EF_2 = EF_1(1 + G \times [C_1 \times v + C_2]) \qquad (7)$$

Where EF_1 is the emission factor for vehicles travelling at speed v on a level road (g/km), EF_2 is the revised emission factor for vehicles travelling uphill at the same speed v (g/km), v is the vehicle speed (m/s), G is the gradient of the hill expressed as a decimal fraction (e.g. 2% road gradient is expressed as 0.02) and C_1 and C_2 are the gradient coefficients that differ according to vehicle type. Uphill EF_2 would be greater than EF_1 and downhill (when G is negative) EF_2 would be smaller than EF_1. When the percentage downhill slope is greater than 2.5% (G < -0.025) the guidance provided is to set G = -0.025. To make the most appropriate comparison between real world emission factors from remote sensing and inventory emission factors use in local air quality modelling, the COPERT emission factors are adjusted according to Equation 7.

7.6.3 Data averaging

The measurement of the instantaneous emissions from a single vehicle with remote sensing does not provide sufficient information to make conclusions on emissions for a vehicle type. The great value of remote sensing is in the large number of measurements that can be recorded over a field campaign. This allows data to be grouped by suitable vehicle categories (e.g. vehicle type, fuel type and Euro standard) and the data within each category averaged to show trend across the attributes. The data

[12] Defra, Local Air Quality Management – Technical Guidance (TG16), February 2018, https://laqm.defra.gov.uk/documents/LAQM-TG16-February-18-v1.pdf

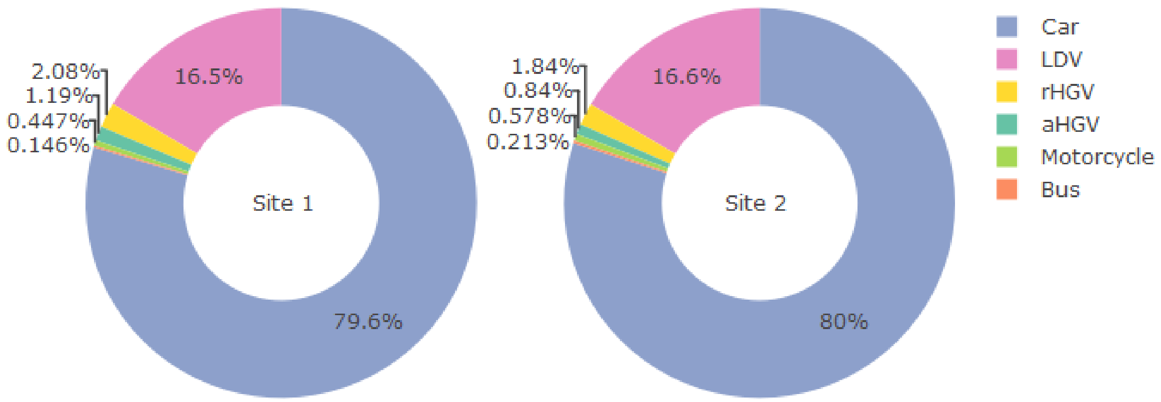
presented in the results section will typically present an average emission factor for a vehicle category with an error bar representing the 95% confidence interval in the measurement. The grouping of data was undertaken in R and the mean and confidence interval were calculated using the bootMeanDF function in OpenAir, an R package for air quality data analysis. In this project measurements are typically provided for the two sites separately to understand the impact of road gradient on the vehicle emissions recorded.

7.7 Results and Discussion

7.7.1 Fleet composition

The camera set up alongside the remote sensing instrument records the number plate of passing vehicles which is matched to a set of vehicle details. Figure presents the proportion of the fleet by vehicle type at the two sites where remote sensing measurements were recorded. The plots show that cars are the main vehicle type making up about 80% of the fleet recorded. Vans (LDVs) made up 16.5% of the fleet at site 1 (on hill) and 16.6% of the fleet at site 2 (top of hill) and HGVs, buses and motorcycles make up the remainder of the fleet. The fleet recorded at the sites is very similar, as would be expected for two measurement locations on the same stretch of road. There is a small bias against the capture of number plates of heavy vehicles as a result of how the camera is set-up at the roadside during the remote sensing measurements. Therefore, it is likely that HGVs and buses are to a small extent under-represented in FigureA-8.

Figure A-8. Fleet composition by measurement location and vehicle type.



Vehicle emissions show a strong dependence on the fuel used by the vehicles. FigureA-9 shows that on the A472 51% of cars recorded were diesel fueled and 48% were petrol fuels. Only a small fraction of cars were hybrids or used an alternative fuel. More than 99% of vans were diesel fueled and almost all HGVs and buses recorded were diesel fueled.

Figure A-9. Car and van (LDV) fuel type

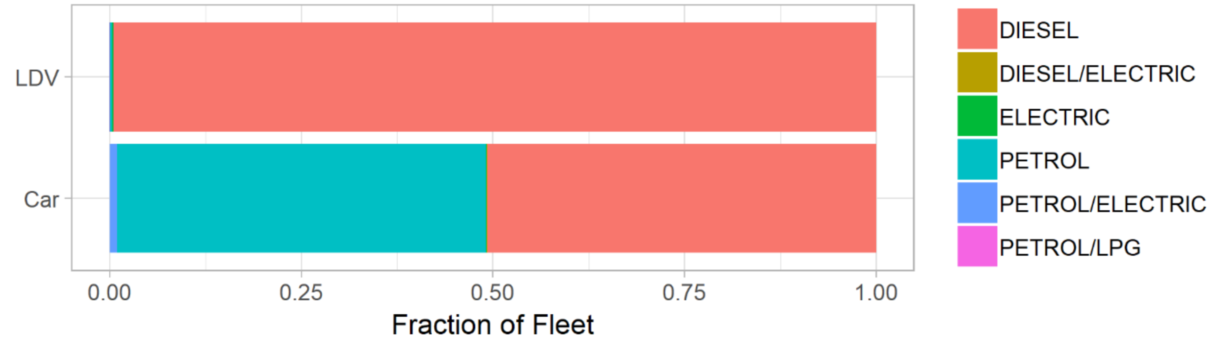
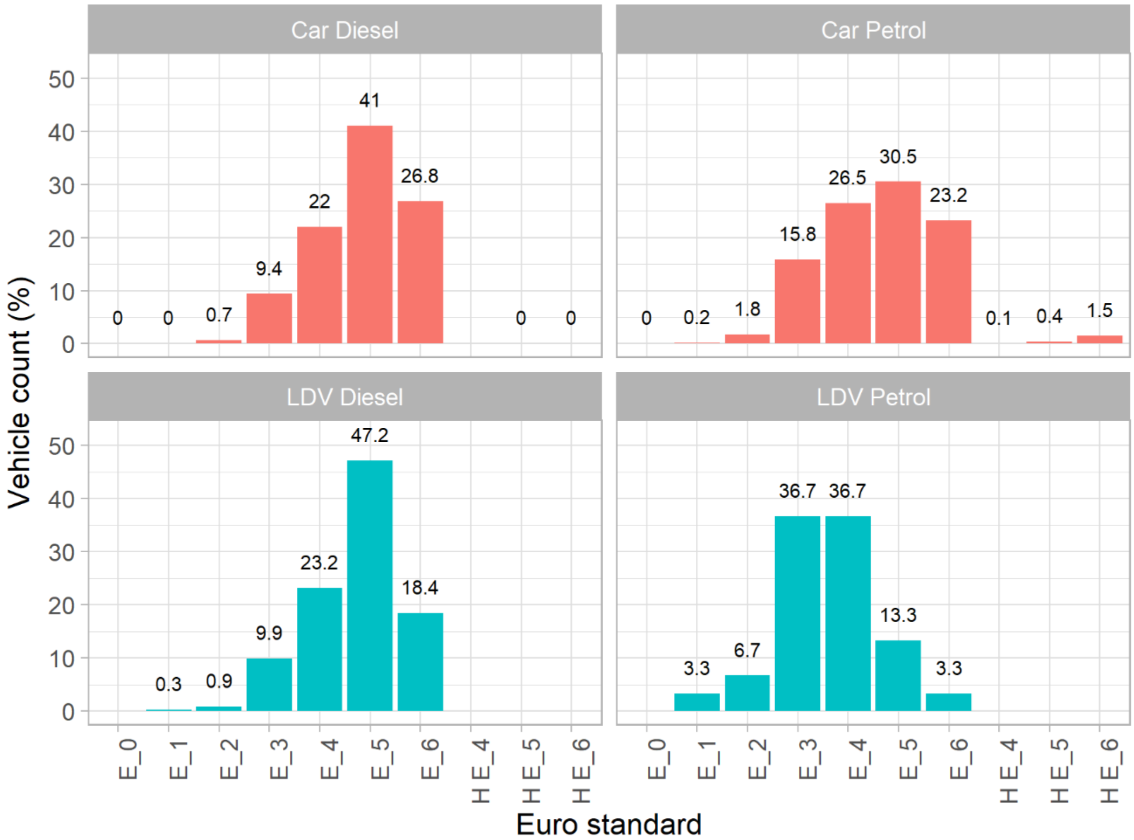


Figure A-10. Proportion of vehicles by Euro standard for petrol and diesel cars and vans (LDV). On the x-axis, Euro standards labelled E_N represent conventional vehicles of Euro standard N and those labelled HE_N represent hybrid vehicles of Euro standard N, where N is the number of the Euro standard.

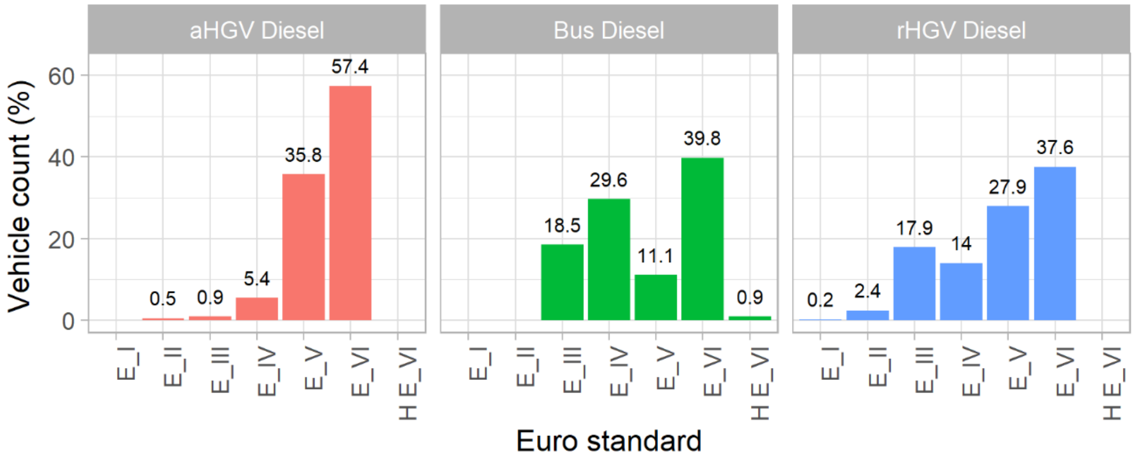


European legislation sets out emissions limits that new vehicles must meet under specific test conditions and these emission standards are periodically updated to increase the stringency of emission limits. Figure and Figure present the proportion of vehicles by European emissions standard (Euro standard) by vehicle and fuel type. Figure-FigureA-10 show that:

- Petrol and diesel cars of Euro standard 4 to 6 are the most prevalent vehicle types on the A472
- Diesel vans are a significant proportion of the fleet, and almost half of these vehicles Euro 5
- Rigid and articulated HGVs make up a small proportion of the fleet and relatively new Euro VI HGVs are the most prevalent Euro standard
- Buses, motorcycles and petrol vans make up only a small proportion of the fleet, therefore the fleet captured may not be full representative of the Euro standards of the local fleet.

The modelling reported in this document combines information on the fleet with real world emission factors derived from the remote sensing measurements to show the source apportionment of vehicle emissions to the different categories of vehicles and demonstrate which vehicles provide the greatest contribution to emissions on the A472.

Figure A-11. Proportion of vehicles by Euro standard for petrol and diesel cars and vans (LDV). On the x-axis, Euro standards labelled E_N represent conventional vehicles of Euro standard N and those labelled HE_N represent hybrid vehicles of Euro standard N, where N is the number of the Euro standard in roman numerals.



7.7.2 Impact of vehicle age on NO_x and NO_2 emissions

The data show the following on the influence of vehicle age on NOx emissions:

- There was no difference between NOx emission factors in g per kg fuel at the two measurement locations
- On conversion to g per km emission factors are higher for Site 1 (on hill), driven primarily by the higher road gradient. The vehicle requires additional power to get up the hill. Speed and acceleration are similar at the two locations.
- Emission factors by euro standard: for diesel vehicles we see that emissions are similar for Euro 5 vehicles and earlier, but there is a drop in the real-world emissions for Euro 6. Petrol vehicles show a decline in NOx emissions with each Euro standard (the abatement systems work)
- Real-world emissions for cars and generally for vans are higher than the COPERT EFs used in modelling, particularly at the location with significant gradient.
- For HGVs and buses the real-world emission factors are broadly similar to COPERT after the gradient correction has been applied. Somewhat limited by small vehicle counts, particularly for buses and early Euro standards of HGVs.
- Emissions factors by year of registration show broadly the same trends, but show some evidence that there is continued improvement in Euro 6 emissions with the staged introduction of more stringent tests which include a real world driving components.
- For diesel cars and vans there is evidence that NO_2 emissions in g per km are similar at both measurement locations, therefore fNO_2 is different at the two locations.

Figure A-12. NO_x emission factors in grams per kg fuel for diesel and petrol cars and diesel vans (LDV) by Euro standard and site.

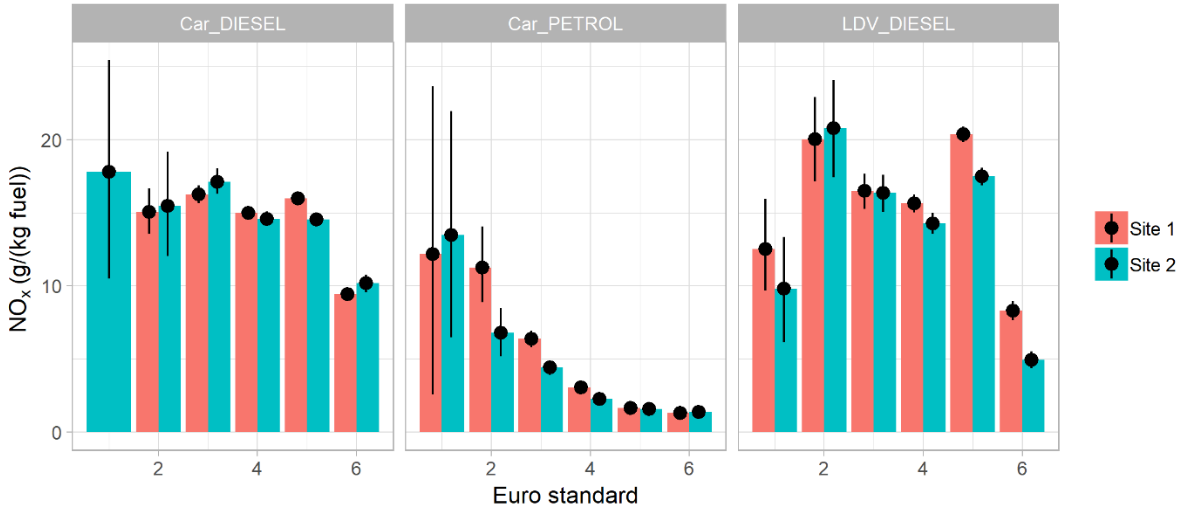
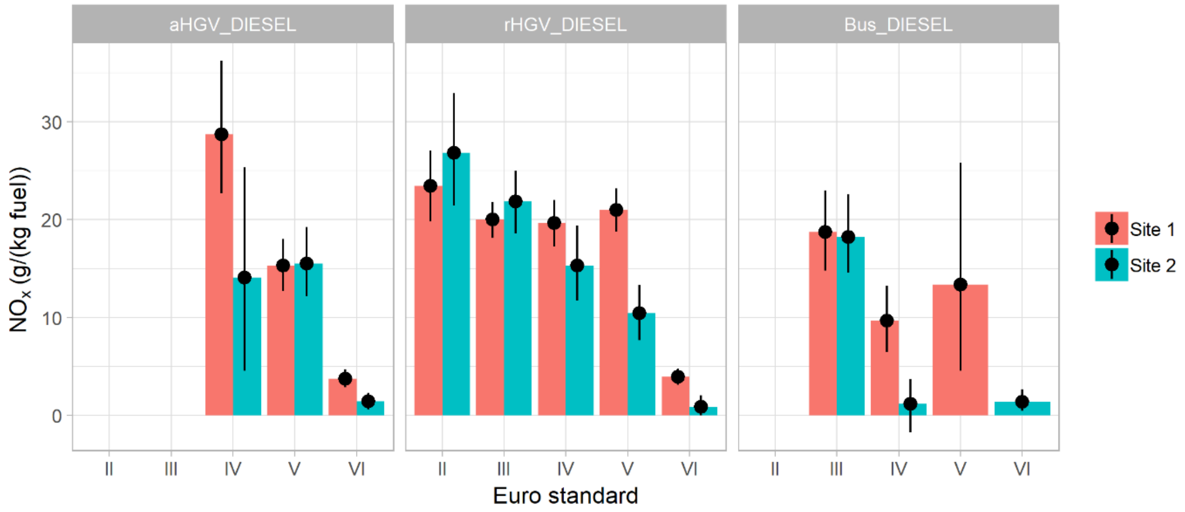
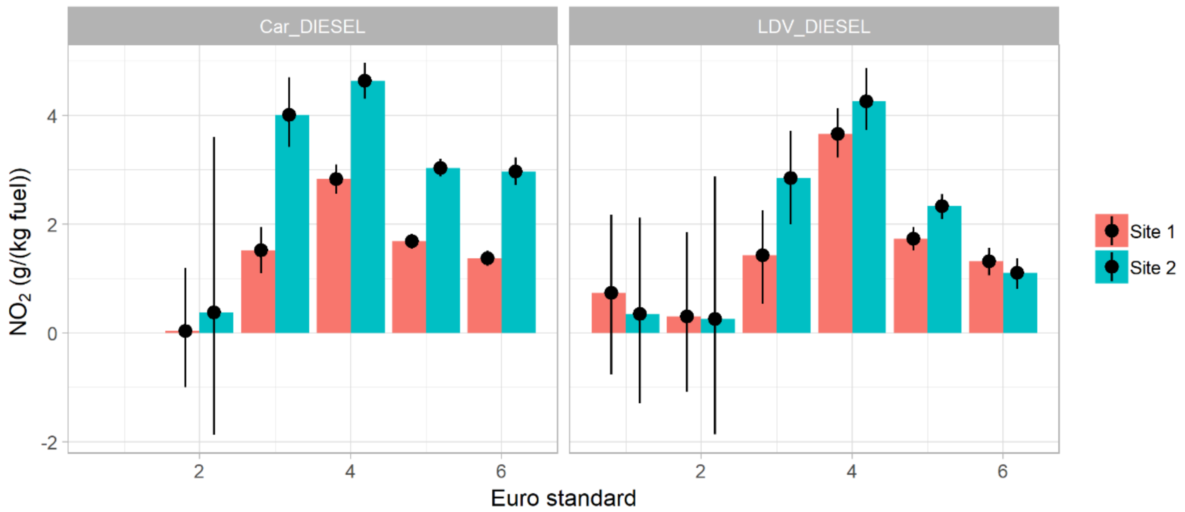


Figure A-13. NO_x emission factors in grams per kg fuel for articulated and rigid HGVs and buses by Euro standard and site.



FigureA-14. NO_2 emission factors in grams per kg fuel for diesel cars and vans (LDVs) by Euro standard and site.



FigureA-15. NO_x emission factors in grams per kilometre for diesel and petrol cars and diesel vans (LDV) by Euro standard and site.

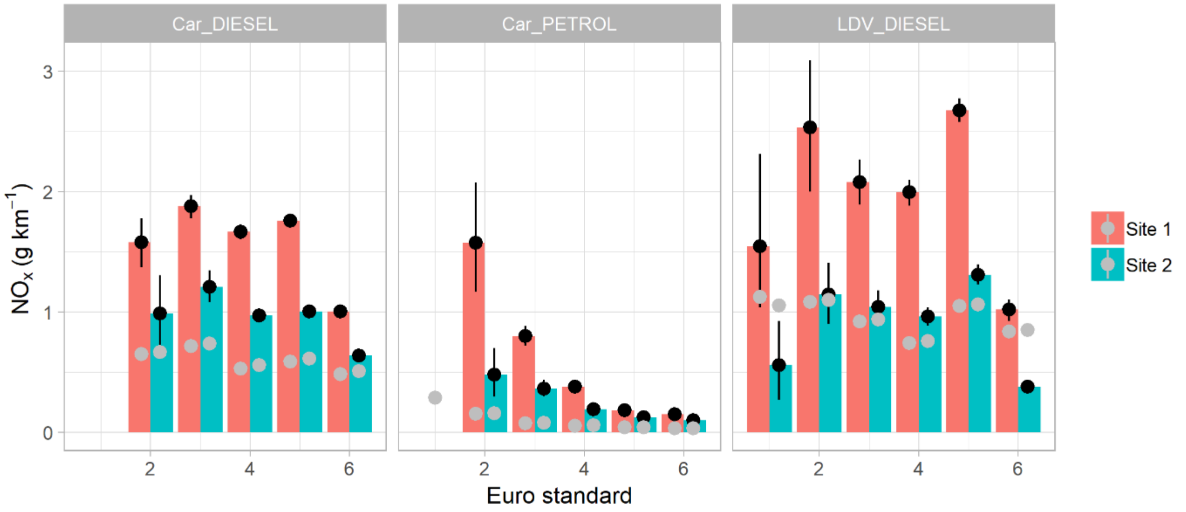


Figure A-16. NOx emission factors in grams per kilometre for articulated and rigid HGVs and buses by Euro standard and site.

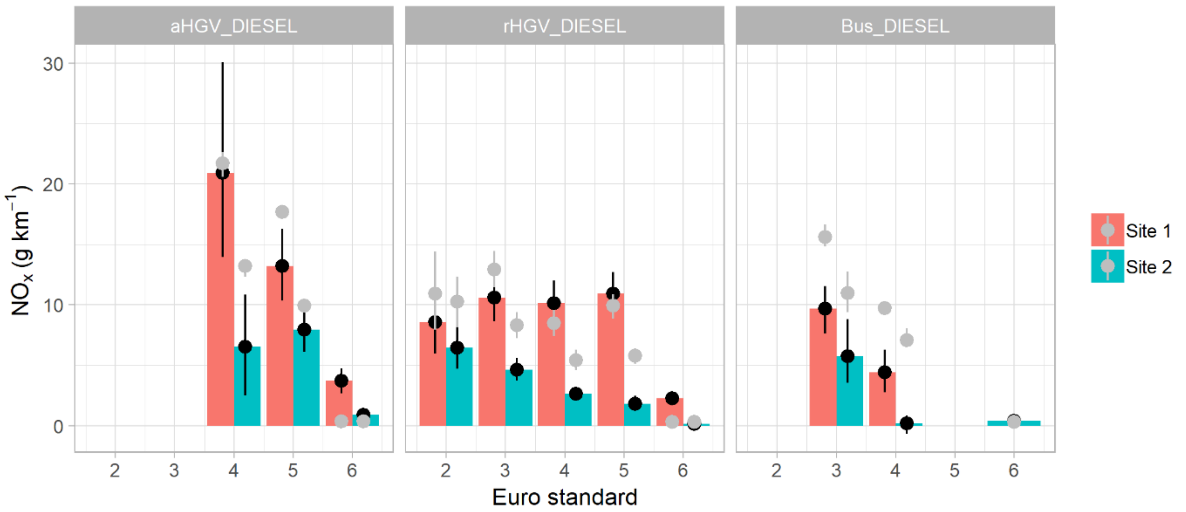
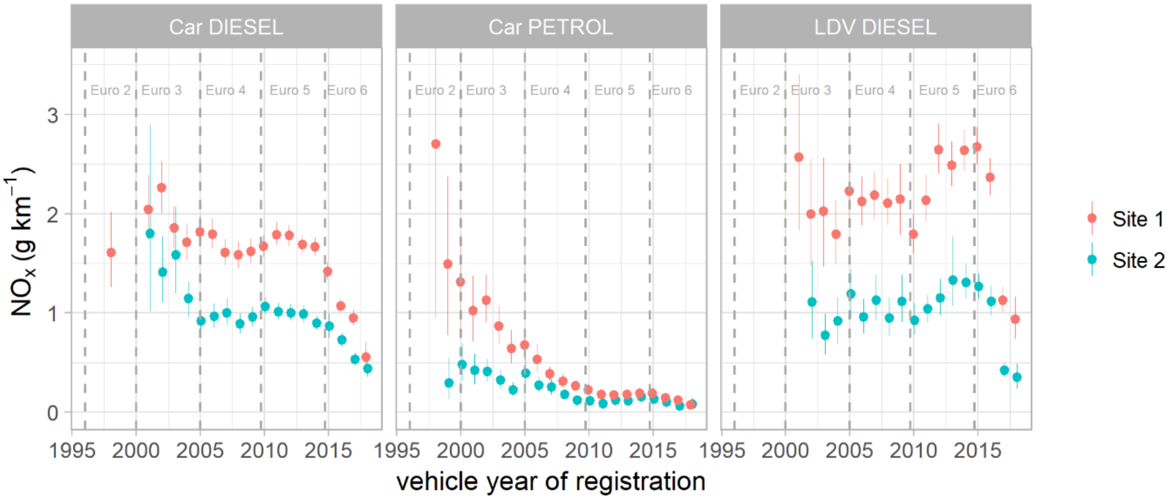
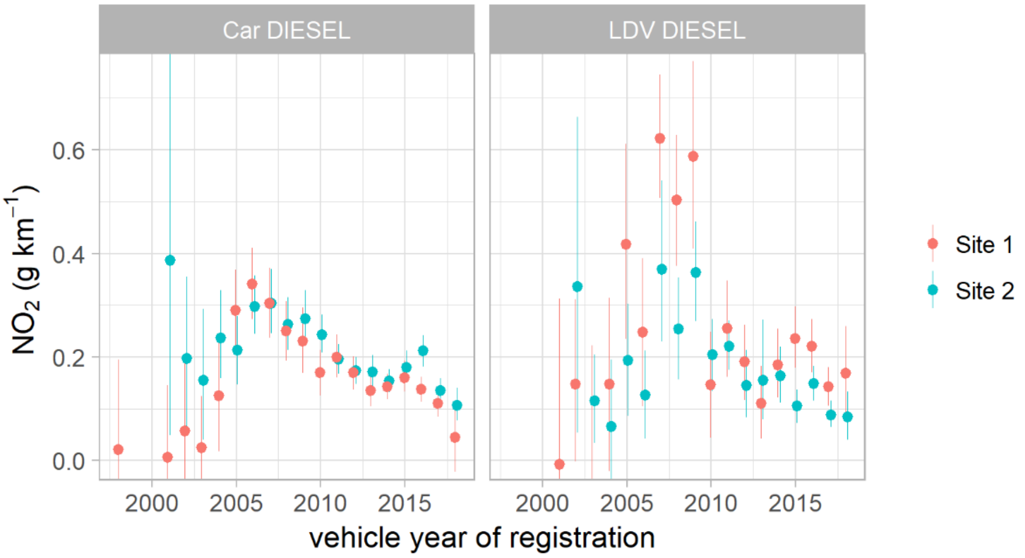


Figure A-17. NOx emissions g/km by year of registration for diesel and petrol cars and diesel vans (LDVs). The grey dashed vertical lines indicate the year at which European emission standards came into force for new type approvals, existing previously type approved vehicles must meet the Euro standard one year later.



FigureA-18. NO_2 emissions in g/km by year of registration for diesel cars and vans (LDVs).



7.7.3 Mileage effects

As road vehicles age and their mileage increases there is a risk that emissions of some pollutants increase. Older vehicles tend to have higher emissions because they use less sophisticated emissions control technology than newer vehicles. However, they can also have higher emissions because these control systems deteriorate over time. Vehicle emission remote sensing data is highly valuable in this respect because the full fleet is measured and that of course includes many older vehicles.

Figure shows how the emissions of NO_x vary for passenger cars depending on fuel type, Euro standard and the mileage of the vehicle. Vehicle mileage is based on the mileage at last MOT and therefore is available for cars aged 3 years and over, an MOT is not required for newer vehicles. No attempt has been made to extrapolate the additional mileage travelled since the date of the most recent MOT, therefore the mileage assigned to each vehicle is likely to be lower than actual vehicle mileage. For recent models of petrol cars (Euro 5 and 6) there is very little evidence that the emissions worsen with higher mileages. However, for older vehicles up to Euro 4 there is a clear increase in emissions as the vehicle mileage increases. Interestingly, low mileage petrol cars (up to about 70,000 miles) all tend to have low emissions. Therefore, just because a vehicle is old (e.g. a Euro 3 vehicle, typically manufactured between 2000 and 2004 and hence 14 to 18 years old), it does not mean the emissions are high.

The results for diesel passenger cars also show some indication of an effect of vehicle mileage on emissions, although the effect is less pronounced than for petrol cars. However, the main difference is the higher absolute emissions of NO_x for diesel cars compared with petrol cars. FigureA-20 shows that mileage appears to have little influence on NO_2 emissions from diesel cars.

The trends in the emissions with age at the two measurement locations is generally similar, with the most significant difference being the higher absolute emission of NO_x at site 1 with the higher road gradient. The NO_2 emissions measured are very similar at both sites.

Figure A-19. Effect of vehicle mileage on emissions of NO_x for petrol and diesel passenger cars split by Euro standard at monitoring location site 1 (on hill) and site 2 (top of hill) on AA472 Woodside Terrace.

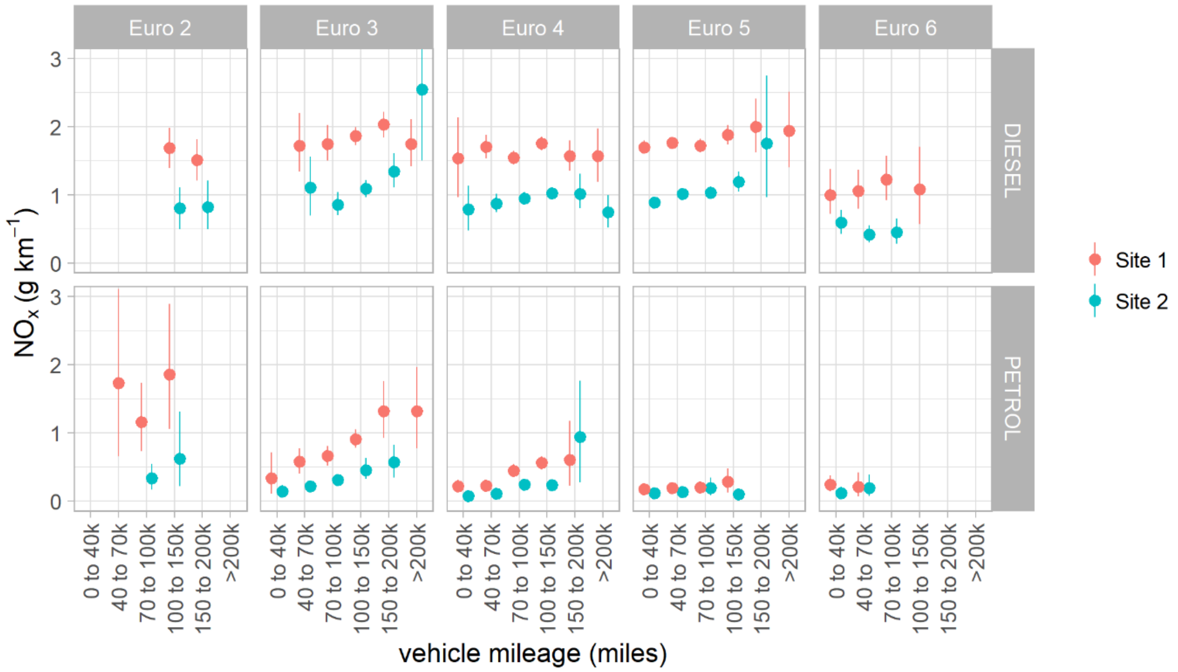
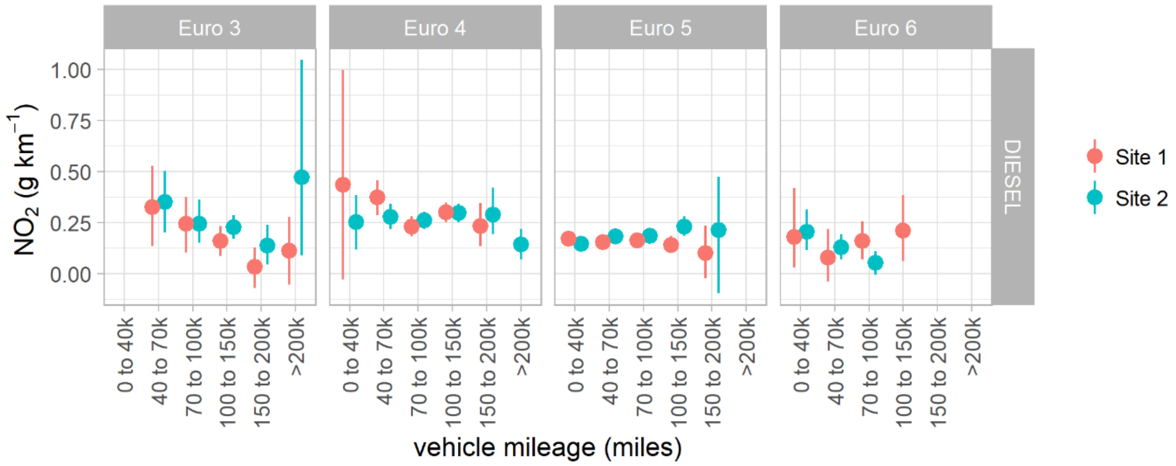


Figure A-20. Effect of vehicle mileage on emissions of NO_2 for petrol and diesel passenger cars split by Euro standard at monitoring location site 1 (on hill) and site 2 (top of hill) on AA472 Woodside Terrace.



7.8 Identification of high emitting vehicles

Individual vehicles can have high emissions rates, well above the average for the vehicle type, which can indicate poor maintenance or that the vehicle is fitted with a defeat device that bypasses emissions control technologies. High emitting vehicles can provide a significant contribution to roadside emissions, therefore identifying high emitting vehicles and requiring an improvement in their emissions can prove an effective way to lower roadside emissions. Vehicle emissions remote sensing records emissions for each passing vehicle and therefore has the potential to identify high emitting vehicles.

Remote sensing has been used extensively in the US where applications include identification of high-emitting vehicles and screening out low-emitting vehicles[13]. A similar approach has been taken in a number of cities in China[14]. In this work, a threshold is set for the emissions level of each pollutant of interest to define whether a vehicle is a high-emitter or low-emitter. Vehicles operating outside of a pre-defined normal range of speed and acceleration conditions would typically be excluded so only emissions from vehicles under normal driving conditions are assessed. Vehicles are usually required to pass a remote sensing instrument multiple times. If a vehicle is repeatedly above a high emitter threshold, the vehicle owner is notified that inspection and repair is warranted and if a vehicle is repeatedly under the low emission threshold then the vehicle owner is notified that the vehicle is not required to come in for emission inspection. If a certain make or model of a vehicle is repeatedly recorded as a high emitter of one or several pollutants monitored this might be more indicative of a wider technical problem with the engine or emission control technology.

This model is not currently used for regulatory purposes in the UK or Europe. Further work would be required to verify a suitable framework and approach and to identify high emitting vehicles.

7.9 Real world emission factors for modelling

The previous sections have demonstrated that there is a difference between the COPERT NOx emission factors used in modelling and assessment, and NO_x emissions from vehicle fleet travelling on the A474 under actual driving conditions. The road gradient at this location has been shown to have significant impact on the real-world emissions. To better account for real world emissions on the A474, on the hill close to Hafod-yr-ynys monitoring station and nearby residences, an approach has been

[13] http://opusinspection.com/remote-sensing-device-technology/1602-2/

[14] ICCT, Remote sensing of motor vehicle exhaust emissions, Feburary 2018, https://www.theicct.org/publications/vehicle-emission-remote-sensing

developed to scale the COPERT NO_x emission factors to align with the real-world emission factors. It was not possible to develop entirely new speed-emission curves from the remote sensing measurements due to limitations in the number of vehicles measured and the range of vehicle speeds recorded.

Scaling factors were developed for vehicles by vehicle type (car, van, rigid and articulated HGV, and bus), fuel type and Euro standard to apply to the COPERT speed emission curves from which a real-world emission factor could be derived of any given vehicle speed. The scaling factors developed are presented in Table A3. Scaling factors were calculated by dividing the real-world emission factors calculated from the remote sensing measurements by the corresponding average COPERT emission factor for the vehicle measurements included in each classification.

Only the remote sensing data recorded at Site 1 (on hill) on the A474 were included in, therefore the real-world emission factors derived are representative of vehicle emission on the hill close to the Hafod-yr-ynys monitoring station. Traffic travels both uphill and downhill on the A474, but measurements were recorded on the up hill carriageway. To account for the ~50% of traffic travelling downhill the scaling factors to apply to COPERT for light duty vehicles (cars and vans) are an average of the real-world scaling factor for traffic derived for travelling up the hill measured during the remote sensing campaign, and a factor of 1, i.e. assuming that the COPERT EFs are correct for downhill traffic. For heavy duty vehicles (HGVs and buses), the downhill component of the scaling factor was calculated from Equation 7 assuming the average vehicle speed of 37 kph recorded for heavy duty vehicles.

COPERT NOx emissions factors are provided grouped by vehicle weight or engine size. Real-world scaling factors to apply to the COPERT speed-emission curves were not disaggregated by vehicle size or weight due to limitations in the size of the dataset. The scaling factors are developed based on measurements the local vehicle fleet and therefore factor in the vehicle size, however separate scaling factors were not provided for vehicles of different weight or engine size. Different COPERT speed emission factor curves are also provided for Euro 5 HGVs and buses fitted with EGR and SCR abatement systems. As noted in Section xxx, information on the abatement system of a vehicles measured during the remote sensing field campaign is not available, therefore the same scaling factor is assumed to apply to the COPERT speed emission curves appropriate for each abatement system.

For some vehicle classifications the proportion of vehicles in the fleet and the number of vehicle measurements available to calculate the real-world scaling factor is low. For vehicle categories with few measurements and/or a large uncertainty in the measured emission factor it was not considered appropriate to calculate a real-world emission factor based on the measurements. Instead the scaling factor is assumed to be the same as that calculated for a similar vehicle category, where this assumption is made this is noted in Table A3. For petrol vans and buses there were insufficient vehicle measurements recorded to derive real-world scaling factors. For these vehicle types, scaling factors were not derived based solely on remote sensing measurements undertaken at Hafod-yr-ynys, but are supplemented by additional vehicle measurements from other locations held within Ricardo's full database of vehicle emissions remote sensing measurements. The supplementary measurements are recorded at a number of locations throughout the UK and are not representative of the particular fleet or road slope at the Hafod-yr-ynys location but provide the best available information on real-world emissions for the vehicle categories under consideration. The impact of these assumptions on the vehicle emissions calculated is expected to be minimal as they impact a small proportion of the vehicles in the local fleet.

Modelling studies require fNO_2 in addition to NOx emission factors, where fNO_2 is the fraction of NOx as NO_2. There is evidence that for diesel cars and vans that real-world NO_2 emissions are similar for vehicles measured at Site 1 (on hill) and Site 2 (top of hill). As overall NOx emissions are significantly different at the two measurement locations, thus the fNO_2 derived is different for the on hill and flatter measurements. The recommend real world fNO_2 values provided for diesel cars and vans in Table A3 is the mean of the fNO_2 values from the remote sensing measurements on and off the hill (i.e. it is assumed that the fNO_2 from vehicles travelling downhill is equal to the fNO2 measured by remote sensing at the top of the hill). For other vehicle types there was no clear or systematic evidence that fNO_2 depends on the gradient of the road. Therefore, the real-world fNO_2 derived from the remote sensing measurements on the hill was assumed to be representative of fNO_2 for both uphill and downhill traffic.

Where there are insufficient measurements from remote sensing to provide a value for fNO2 it is assumed that the NAEI value for fNO_2 is valid. This is typically the case for early Euro standards of vehicles which make up a small proportion of the measurements. For petrol vehicles the NO_2 emissions measured are low and by and large below the detection limit of the remote sensing instrument. For petrol vehicles the NAEI value for fNO2 is assumed for all Euro standards.

Table A3. Summary of scaling factors applied to COPERT speed-emission curves to derive real world vehicle NO_x emission factors and fNO_2 factors derived from remote sensing measurements. Comments are provided where data are not derived directly from the remote sensing measurements at Caerphilly Site 1 (on hill), as described in the text.

Vehicle class	Fuel	Euro standard	NOx COPERT scaling factor	Comment	f_{no2}	
Car	Diesel	Pre-Euro	1.7205	Assume scaling factor for Euro 2	0.11	As NAEI
		Euro 1	1.7205	Assume scaling factor for Euro 2	0.11	As NAEI
		Euro 2	1.7205		0.11	As NAEI
		Euro 3	1.8145		0.1317	
		Euro 4	2.0750		0.288	
		Euro 5	2.0035		0.1354	
		Euro 6	1.5395		0.1981	
	Petrol	Pre-Euro	5.6105	Assume scaling factor for Euro 2	0.04	As NAEI
		Euro 1	5.6105	Assume scaling factor for Euro 2	0.04	As NAEI
		Euro 2	5.6105		0.04	As NAEI
		Euro 3	5.8310		0.03	As NAEI
		Euro 4	4.0655		0.03	As NAEI
		Euro 5	2.8275		0.03	As NAEI
		Euro 6	2.9010		0.02	As NAEI
Van	Diesel	Pre-Euro	1.6690	Assume scaling factor for Euro 2	0.11	As NAEI
		Euro 1	1.6690	Assume scaling factor for Euro 2	0.11	As NAEI
		Euro 2	1.6690		0.11	As NAEI
		Euro 3	1.6280		0.1187	
		Euro 4	1.8500		0.2447	
		Euro 5	1.7775		0.0924	
		Euro 6	1.1085		0.1834	

Articulated HGV	Petrol	Pre-Euro	4.5235	Derived from full Ricardo database, assume scaling factor for Euro 2	0.04	As NAEI
		Euro 1	4.5235	Derived from full Ricardo database, assume scaling factor for Euro 2	0.04	As NAEI
		Euro 2	4.5235	Derived from full Ricardo database	0.04	As NAEI
		Euro 3	3.9845	Derived from full Ricardo database	0.03	As NAEI
		Euro 4	7.4470	Derived from full Ricardo database	0.03	As NAEI
		Euro 5	15.206	Derived from full Ricardo database	0.03	As NAEI
		Euro 6	6.7555	Derived from full Ricardo database	0.02	As NAEI
	Diesel	Pre-Euro	1.30325		0.11	As NAEI
		Euro 1	1.30325		0.11	As NAEI
		Euro 2	1.30325		0.11	As NAEI
		Euro 3	1.30325		0.14	As NAEI
		Euro 4	1.30325		0.14	As NAEI
		Euro 5	1.30325		0.0832	
		Euro 6	5.39900		0.0891	
Rigid HGVs	Diesel	Pre-Euro	<14t: 1.35875 ≥14t: 1.27175	Assume scaling factor for Euro 3	0.11	As NAEI
		Euro 1	<14t: 1.35875 ≥14t: 1.27175	Assume scaling factor for Euro 3	0.11	As NAEI
		Euro 2	<14t: 1.35875 ≥14t: 1.27175	Assume scaling factor for Euro 3	0.1	As NAEI
		Euro 3	<14t: 1.35875 ≥14t: 1.27175		0.0845	
		Euro 4	<14t: 1.85525 ≥14t: 1.76825		0.023	

		Euro 5	<14t: 1.72375 ≥14t: 1.63675		0.0056	
		Euro 6	4.02250		0.0646	
Bus	Diesel	Pre-Euro	1.164875	Derived from full Ricardo database, assume scaling factor for Euro 3	0.11	As NAEI
		Euro 1	1.164875	Derived from full Ricardo database, assume scaling factor for Euro 3	0.11	As NAEI
		Euro 2	1.164875	Derived from full Ricardo database, assume scaling factor for Euro 3	0.11	As NAEI
		Euro 3	1.164875	Derived from full Ricardo database	0.3359	Derived from full Ricardo database
		Euro 4	0.894375	Derived from full Ricardo database	0.3518	Derived from full Ricardo database
		Euro 5	0.914875	Derived from full Ricardo database	0.1282	Derived from full Ricardo database
		Euro 6	5.0665	Derived from full Ricardo database	0.1053	Derived from full Ricardo database

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