A35 Chideock AQMA

Air quality (NO_2) analysis

Client: Highways England

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Record of changes

Released to	Version	Reason for change	Date
Highways England	1.0	Initial draft for comment	December 23rd 2020
Highways England	1.1	Inclusion of Oct & Dec 2020 speed survey data	January 26th 2021
Highways England	1.2	Incorporation of client comments	February 12th 2021
Highways England	1.3	Incorporation of additional client comments	February 16th 2021
Highways England	1.4	Final report approved by client	April 15th 2021

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Contents

1. Air Quality Management Area

Chideock is a small village on the A35 in West Dorset, on the south coast between Lyme Regis and Bridport. Dwellings are situated either side of the A35 (trunk road) going through the village with dwellings immediately adjacent to a steep incline leaving the village going west. An air quality management area (AQMA) for nitrogen dioxide (NO_2) was declared in 2007 along the A35 as annual average NO_2 concentrations exceeded the annual mean objective of 40µg/m^3. The boundary of the Chideock AQMA was revised in 2012, removing the eastern half of the village from the AQMA, as measured annual mean NO_2 concentrations were below their objective. The current extent of the AQMA is illustrated in Figure 1 (shaded pink).

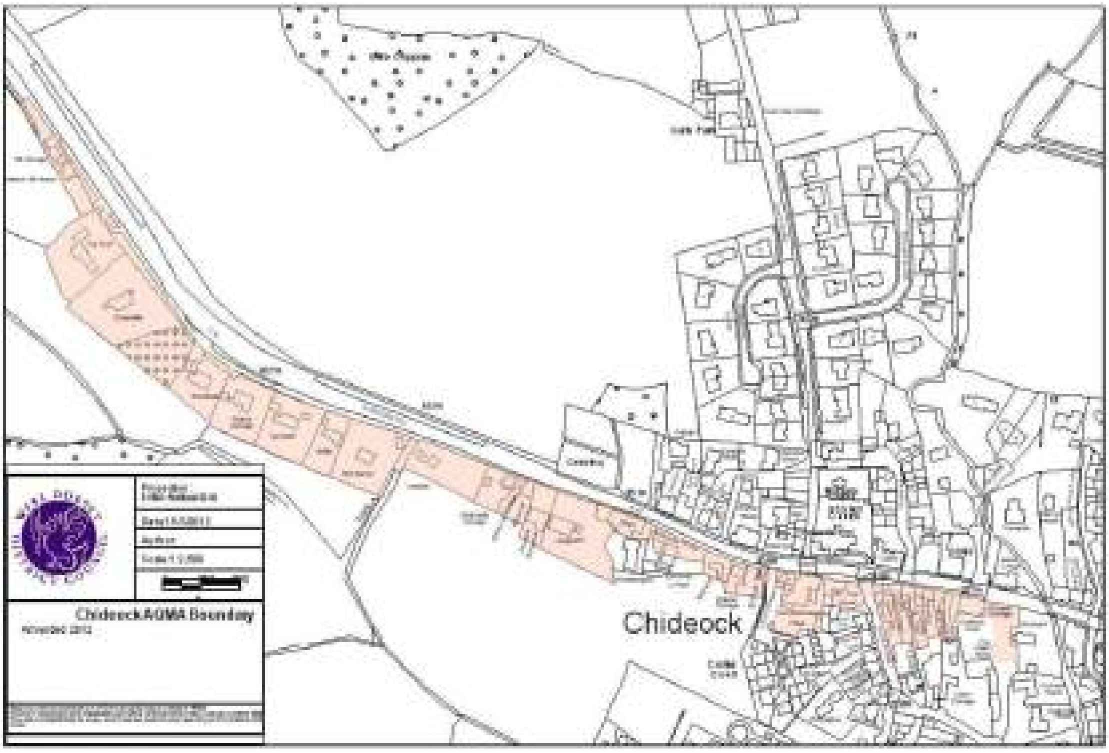

Figure 1: Chideock AQMA boundary (as amended in 2012)

2. Highway gradient

As stated previously, there is a steep incline leaving the village in a westerly direction. The difference in vertical elevation between the eastern extremity of the AQMA and the western extremity is approximately 66 meters, over a distance of approximately 800 meters, resulting in an average gradient of 4.75 degrees (8.31%, or 1 in 12). The gradient within the AQMA becomes generally steeper towards the west, with the gradient within the AQMA east of the old 40mph speed limit sign (location indicated in Figure 2 by the red marker) being approximately 3.37 degrees (5.89%, or 1 in 17) on average, whilst the gradient within the AQMA west of the old 40mph speed limit sign is approximately 5.82 degrees (10.19%, or 1 in 10). Steeper gradients are normally associated with higher exhaust emissions as engines have to work harder to overcome the effect of the gradient as they travel uphill.

3. Air quality

Figure 2 illustrates the locations of the local authority NO_2 diffusion tubes within Chideock (both within and outside the AQMA), denoted by the yellow drawing pin symbols. Table 1 presents the annual mean concentrations of NO_2 observed from 2013 to 2019 inclusive. Further location details of the monitoring sites can be found in Annex A.

It can be seen that two of the local authority diffusion tube locations in 2019 are in excess of 40 µg/m^3, Diff 727 and N14. Both of these local authority diffusion tubes are adjacent to the westbound (uphill) carriageway.

Diffusion tube 727 is located on a building façade, 1 meter from the kerb on the southern (westbound) side of the A35, approximately 8 meters west of the old 40mph speed limit sign. Diffusion tube N14 is located adjacent to Hill House on the southern (westbound) side of the A35, at the western extremity of the AQMA (on the steepest part of the hill).

Figure 2: Local authority diffusion tube locations in Chideock (base map © Google Earth)

Table 1: Local Authority NO_2 Diffusion Tube Results

		NO_2 Annual Mean Concentration (µg/m^3) – Bias adjusted						
Site ID	**Location**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
722	Hope Cottage	19.5	26.8	16.8	19.7	23.0	19.9	17.2
723	St Giles Church	25.8	22.9	20.8				
724	Duck St	**42.9**	36.7	36.7	**47.7**	**41.9**	38.0	36.4
725	George Inn	27.2	26.2	23.1	25.5	28.2	24.2	19.5
726	Village Hall	**45.4**	**41.8**	39.2	**47.8**	**40.9**	39.2	38.7
727	Whitecroft	**55.3**	**53.0**	**50.0**	**58.9**	**56.5**	**57.2**	**52.5**
728	Warren House	29.4	25.6	23.4	27.0	26.7	24.8	23.8
738	Greenhills				20.5	17.9	18.4	16.4
N14	Hill House						**90.0**	**80.2**
Notes: Concentrations in **bold** indicate an exceedance of the annual mean NO_2 objective of 40µg/m^3								

In February 2019, Highways England in partnership with Dorset Council deployed eight additional diffusion tubes within the Chideock AQMA. Figure 3 illustrates the locations of the Highways England NO_2 diffusion tubes. Table 2 presents the annual mean NO_2 concentrations observed in 2019 (based on 11 months data). It can be seen that the Highways England diffusion tubes recorded exceedances of the 40 μg/m^3 annual mean objective at five of the eight monitoring locations.

Figure 3: Highways England diffusion tube locations in Chideock (base map © Google Earth)

Table 2: Highways England NO_2 Diffusion Tube Results

		NO_2 Annual Mean Concentration (μg/m^3) – Bias adjusted
Site ID	**Location**	**2019**
H1	Duck St (mounted on sign)	22.7
H2	Bay Tree House	32.3
H3	Willens Cottage	34.1
H4	Village Hall	**46.1**
H5	Southside Cottage	**46.3**
H6	Langdon	**75.6**
H7	Yew Tree House	**48.1**
H8	The Clock	**45.9**
Notes: Concentrations in **bold** indicate an exceedance of the annual mean NO_2 objective of 40μg/m^3		

The NO_2 concentration measured at diffusion tube H8 may be influenced by its relative proximity to the highway carriageway. H8 is located 1.4 meters from the carriageway, whilst H2 and H3 are located 2.8 meters and 1.9 meters from the carriageway respectively.

4. Observed air quality, traffic flow and traffic speed

Residential properties in the western section of the AQMA on Chideock Hill are located on the southern side of the A35, adjacent to the westbound (uphill) highway carriageway. Hourly westbound traffic count data were obtained from the nearest available permanent traffic count sites which are located to the east and west of Chideock as illustrated by the yellow markers in Figure 4.

Figure 4: Permanent traffic count locations east and west of Chideock (base map © Google Earth)

Aggregate hourly westbound traffic speed data were obtained from the National Traffic Information Service (NTIS), specifically NTIS links 125033401 & 125033501, which are spatially broadly coincident with the A35 from Chideock Village Hall to the western extremity of the AQMA. Both traffic flow and traffic speed data were aggregated to monthly time periods to be consistent with the available monthly NO_2 diffusion tube data. Hourly traffic speeds were weighted by hourly traffic flows to derive representative monthly traffic speed values.

It can be seen from Figure 5 that the pattern of traffic flow is highly seasonal, with traffic flow peaking in the month of August due to holiday traffic, whilst being at a minimum in January. In normal times, traffic speeds are seen to follow an opposite pattern, with speeds lower during the congested summer months, and higher during the winter months. The impact of the introduction of the temporary 30mph speed limit on Chideock Hill in late September 2019 (discussed in Section 5) can be seen in Figure 5, with traffic speeds suppressed from September 2019 onwards, relative to previous years. The impact of roadworks on traffic speeds in the summer of 2020 can also be seen, as can the impact of the Covid-19 lockdown on traffic flows from late March 2020 onwards.

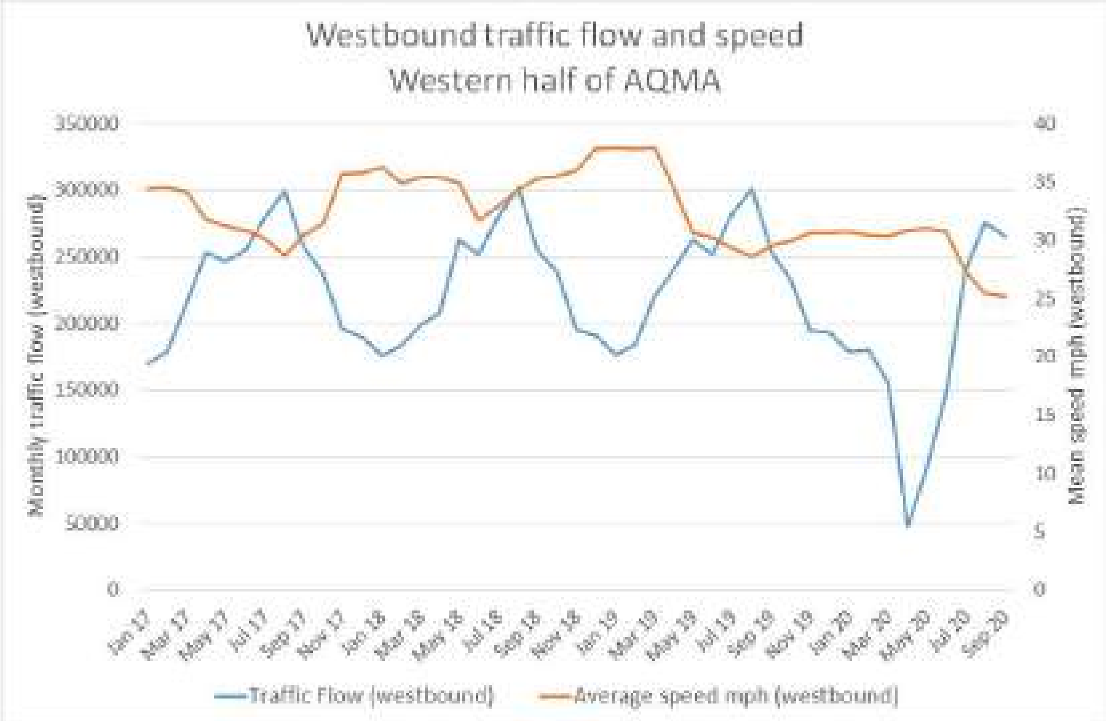

Figure 5: Monthly westbound traffic flow and average speed (western half of AQMA)

Table 3 presents the monthly diffusion tube data, traffic flow data (westbound), and traffic speed data (westbound) from January 2017 to September 2020 inclusive, for the section of the AQMA west of Chideock Village Hall. Figures 6 and 7 present the available monthly diffusion tube data for the local authority and Highways England sites respectively. It can be seen from the data that the highest NO_2 values are generally observed in the summer months when traffic flows are at their peak. The impact of the Covid-19 lockdown on NO_2 concentrations is also clearly visible in Table 3 and Figure 6, where the reduction in traffic volumes during lockdown results in an associated reduction in absolute NO_2 emissions.

The relationship between NO_2 concentrations, traffic volumes, and traffic speeds is further explored in Figures 8 to 13 inclusive. Scatter plots are presented for a sample of local authority and Highways England diffusion tube monitoring sites. In each case, measured NO_2 concentrations are plotted against traffic flow and traffic speed respectively. In addition, a linear 'least squares' (or regression) line is fitted to each data set. It should be noted at this point that the available time series sample size for the local authority sites is significantly larger than for the Highways England monitoring sites (which only commenced in February 2019). It should also be remembered that, for any particular monitoring location, highway gradient will be a constant contributory factor influencing vehicle emissions.

Table 3: Monthly diffusion tube, traffic flow and speed data

		Diffusion tube data (non bias adjusted)									Westbound	
		728	726	H4	727	H5	H6	H7	738	N14	Traffic Flow	Mean speed (mph)
2017	January	27.6	46.6		59.7				25.1		170221	34.4
	February	25.6	39.6		47.4				20.7		179424	34.5
	March	28.0	48.0		57.0				19.5		216163	34.2
	April	33.0	40.8		80.2				17.3		253200	31.8
	May	30.3	46.8		65.2				21.5		246512	31.2
	June	27.9	51.0		72.8				16.1		254910	30.8
	July	23.2	41.5		63.9				10.9		280240	30.1
	August	27.6	50.0		78.4				16.9		299615	28.7
	September										257610	30.5
	October	22.8	47.4		70.6				15.9		237212	31.4
	November	28.4	47.1		59.8				19.2		196230	35.7
	December	24.0	38.5		53.6				16.2		189100	35.8
2018	January	24.9	44.9		50.1				22.7		176173	36.3
	February	25.6	36.1		53.9				22.8		183708	34.9
	March	24.5	35.5		51.5				15.9		198989	35.4
	April	32.7	40.9		64.7				21.1		208650	35.4
	May	34.4	55.1		80.9				23.9		262632	34.9
	June	28.6	47.8		74.0				22.6		251520	31.7
	July	30.5	62.4		88.4				15.6		280612	32.9
	August	28.7	54.6		73.8				19.0	122.4	301692	34.3
	September	26.1	42.8		67.4				18.7	99.8	254850	35.3
	October	31.4	39.8		63.2				24.1	103.3	238824	35.5
	November	22.7	30.3		48.2				19.3		195180	35.9
	December	24.7	37.7		55.5				22.3	79.2	191146	37.8
2019	January	28.1	40.5		55.7				18.3	79.2	177010	38.0
	February	30.2	45.6	59.3	58.2	54.7	82.2	38.7	18.5	98.4	184296	37.9
	March	29.8	43.1	51.9	68.3	54.9	93.2	47.6	20.3	95.5	219821	38.0
	April	35.4	42.0	60.3	56.5	57.5	97.8	41.7	25.0	99.3	240390	34.5
	May	31.8	48.4	58.5	75.1	55.4	104.3	40.1	18.3	113.7	262973	30.6
	June	27.9	45.2	50.4	63.3	57.8	88.3	65.3	20.1	107.0	251670	30.2
	July	27.9	53.7	65.7	70.0	68.1	108.1	72.8	16.8	90.6	281852	29.3
	August	24.6	55.8	64.7	77.9	66.3	104.5	82.1	16.8	117.2	301320	28.6
	September	23.7	47.5	51.9	58.2	53.8	90.4	65.6	20.8	93.7	253350	29.6
	October	20.5	39.9	42.8	55.9	41.2	69.1	56.0	18.9	86.7	232717	29.9
	November	28.8	39.7	38.6	47.0	37.8	55.3	47.4	18.2	62.7	194220	30.7
	December	19.9	33.0	39.1	38.9	37.5	62.4	50.6	14.9	62.2	193471	30.7
2020	January	22.5	35.3	33.9	54.3	37.1	60.1	47.6	18.8	67.1	179521	30.7
	February	16.7	34.4		43.7				15.0	62.1	180119	30.4
	March	9.8	14.5		18.3				7.8	30.1	155620	30.3
	April	14.0	19.0		24.0					36.0	48300	30.8
	May	12.0	22.0		26.0				10.0	47.0	91574	31.0
	June	15.0	27.0	34.0	35.0	36.0	49.0	39.0	9.0	53.0	148170	30.8
	July	20.0	37.0	39.0	49.0	35.0	58.0	51.0	10.0	71.0	239847	27.3
	August	24.0	36.0	40.0	48.0	45.0	55.0	50.0	15.0	84.0	275776	25.5
	September	23.0	35.0	42.0	51.0	41.0	62.0	48.0	16.0	75.0	265770	25.2

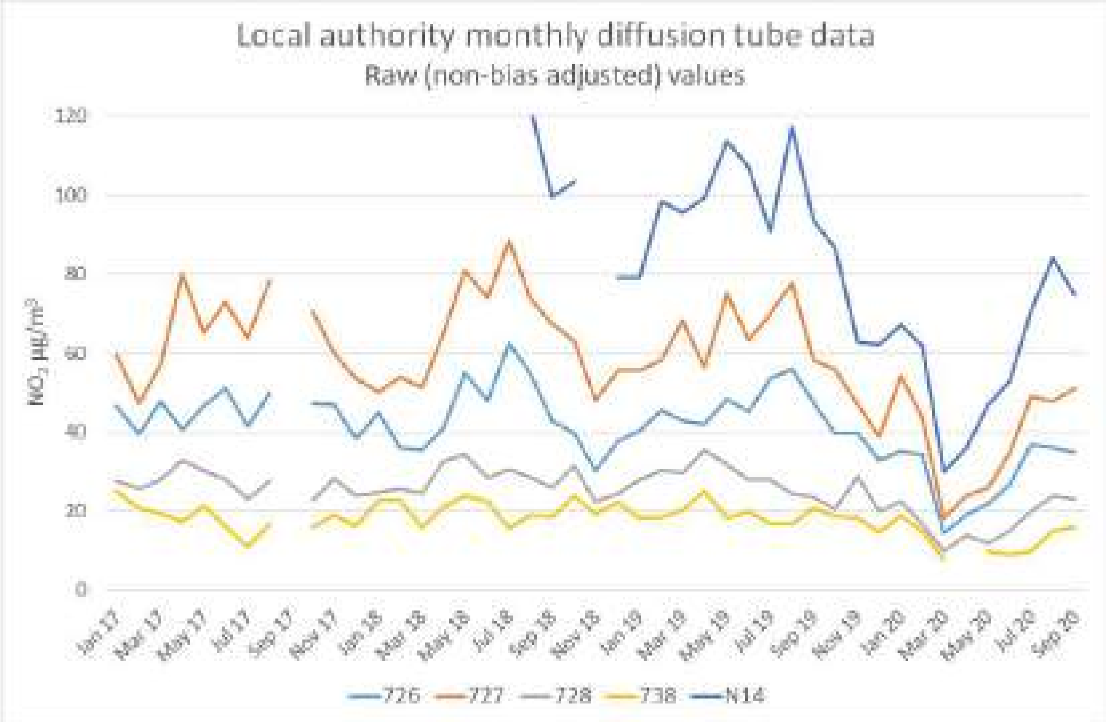

Figure 6: Local authority monthly diffusion tube data (western half of AQMA)

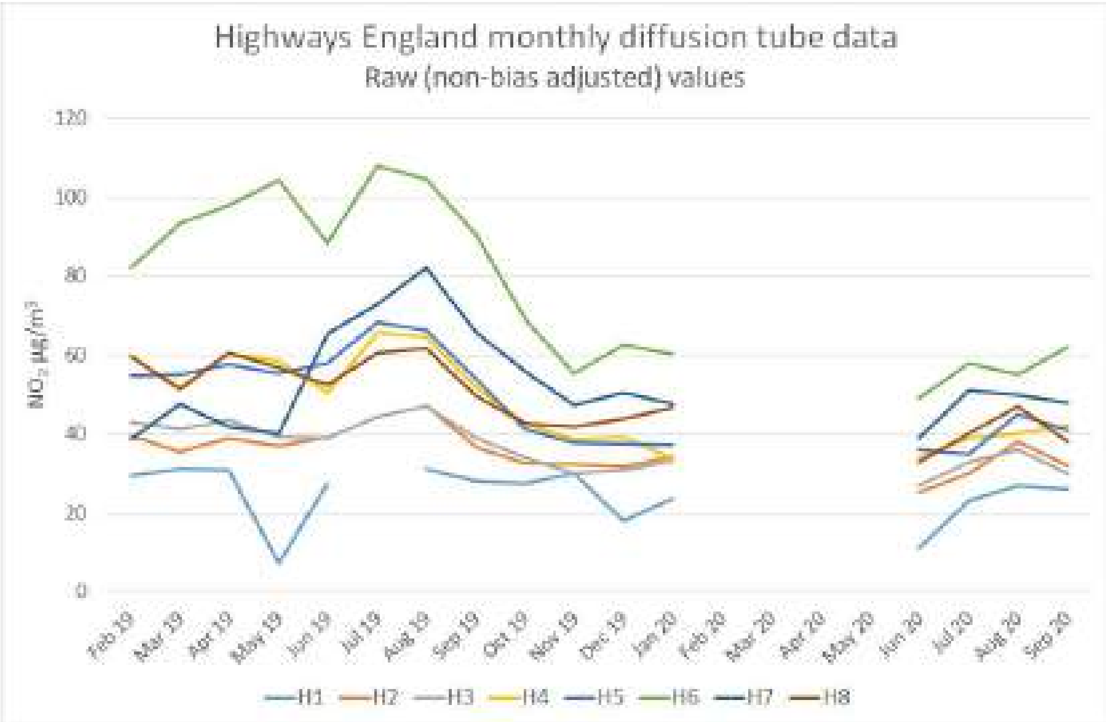

Figure 7: Highways England monthly diffusion tube data[1]

[1] Diffusion tubes were not deployed during the period February to May 2020 inclusive due to logistical difficulties

Two general observations can be made from these scatter plots. Firstly, there is a better defined relationship between NO_2 concentrations and traffic volume than there is between NO_2 concentrations and traffic speed. In the case of traffic volume, the data is more closely grouped, whereas with traffic speed there is more scatter. Secondly, the steeper slope of the regression lines indicate a stronger positive relationship between NO_2 concentrations and traffic volumes, whereas the positive slope of the regression lines for traffic speed is less pronounced (and indeed for site H7, with a small sample size, is negative). These observations are borne out by further statistical analysis.

Table 4 presents the correlation coefficients (Pearson's 'r') between the three variables, monthly NO_2, traffic volume, and traffic speed. Correlation does not give any indication of the direction of *causality*, but it is a commonly used measure of the size of an effect. A Pearson's correlation coefficient ('r') value of +1 indicates a perfect positive relationship; a coefficient of -1 indicates a perfect negative relationship; a coefficient of 0 indicates no linear relationship at all.

In Table 4, green shading is indicative of a large effect size, amber shading indicates a moderate effect size, and red indicates a smaller effect[2].

Table 4: Correlation coefficients (Pearson's 'r')

	NO_2 vs Traffic volume	**NO_2 vs Speed**	**Traffic volume vs Speed**
728 Warren House	0.57	0.38	-0.28
726 Village Hall	0.74	0.11	-0.28
H4 Village Hall	0.57	0.34	-0.47
727 Whitecroft	0.80	0.11	-0.28
H5 Southside Cottage	0.61	0.27	-0.47
H6 Langdon	0.57	0.34	-0.47
H7 Yew Tree House	0.65	-0.36	-0.47
738 Greenhills	0.14	0.51	-0.37
N14 Hill House	0.82	0.25	-0.18

It can be seen that there is a relatively strong positive correlation between NO_2 concentration and traffic volume for most locations, whereas the positive correlation between NO_2 concentration and traffic speed is generally weaker (and indeed negative at diffusion tube H7, albeit with a relatively small sample size). Diffusion tube 738 at Greenhills appears to be a statistical outlier in this analysis (it also has the lowest absolute level of NO_2 concentrations). As perhaps expected, the correlation between traffic volume and speed is negative.

[2] The definition of large, medium, and small statistical effect size is somewhat subjective and dependent on context, but values of 0.1, 0.3, and 0.5 are commonly used by statisticians to characterise 'small', 'medium', and 'large' effects respectively. Note also that 'r' is not measured on a linear scale.

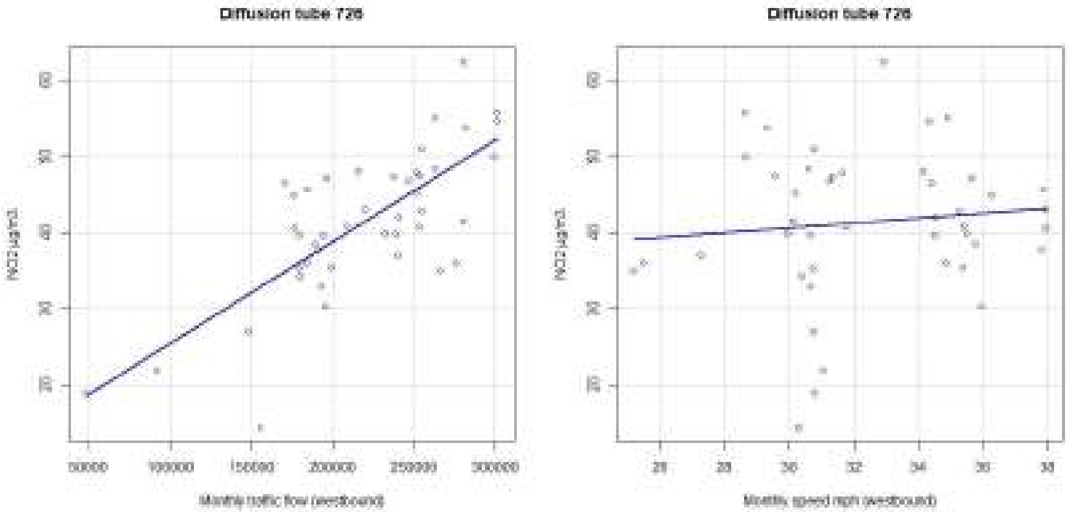

Figure 8: Diffusion tube 726 – Scatter plot NO_2 vs (a) traffic flow & (b) speed

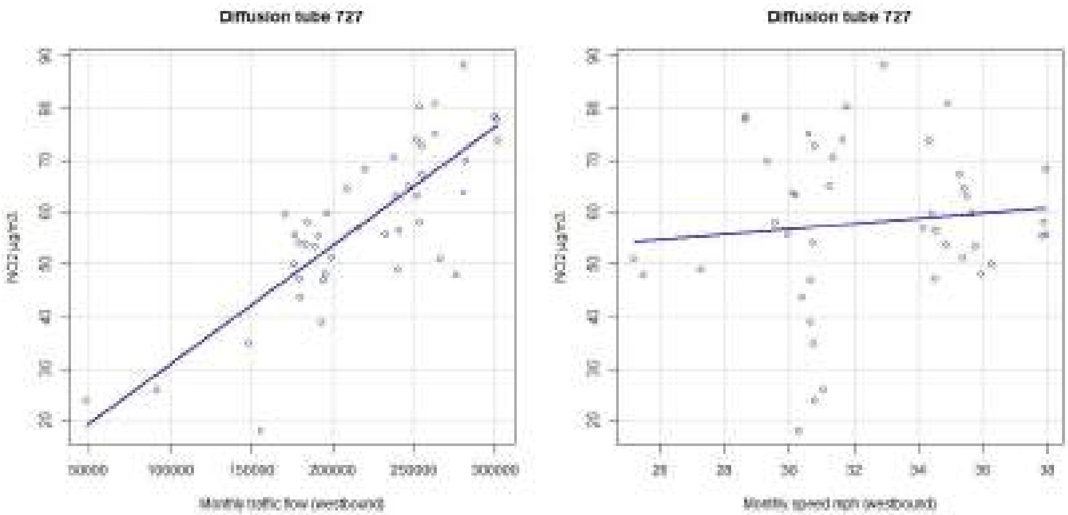

Figure 9: Diffusion tube 727 – Scatter plot NO_2 vs (a) traffic flow & (b) speed

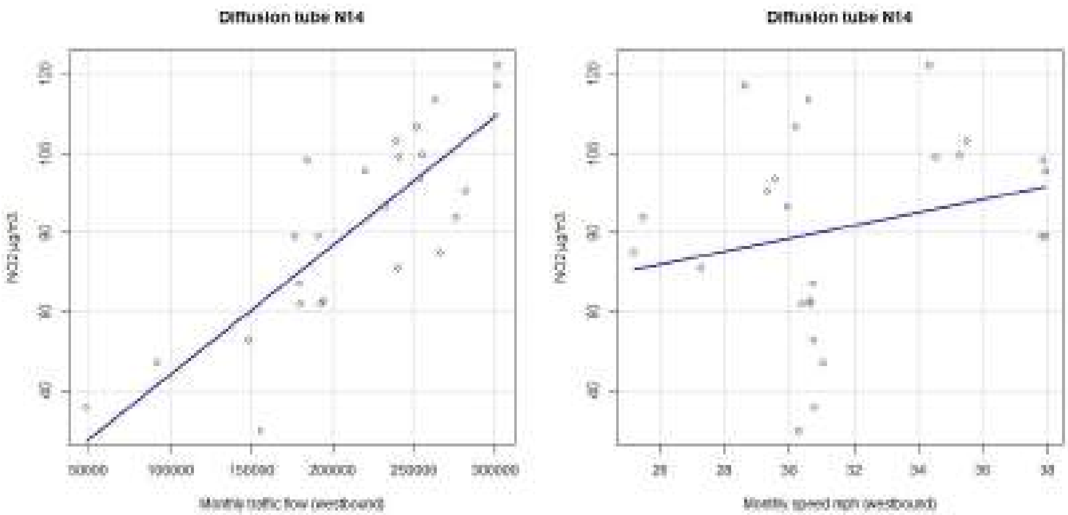

Figure 10: Diffusion tube N14 – Scatter plot NO_2 vs (a) traffic flow & (b) speed

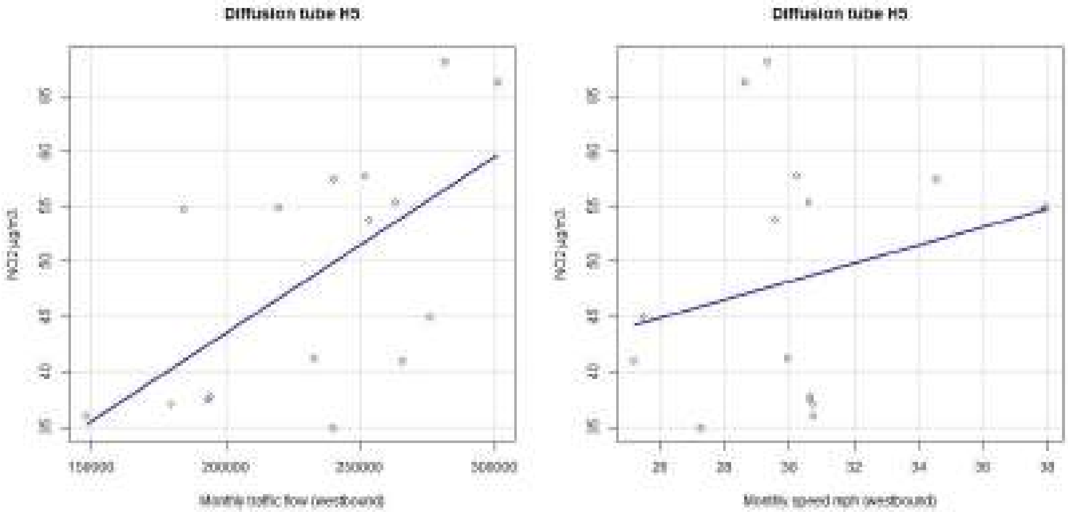

Figure 11: Diffusion tube H5 – Scatter plot NO_2 vs (a) traffic flow & (b) speed

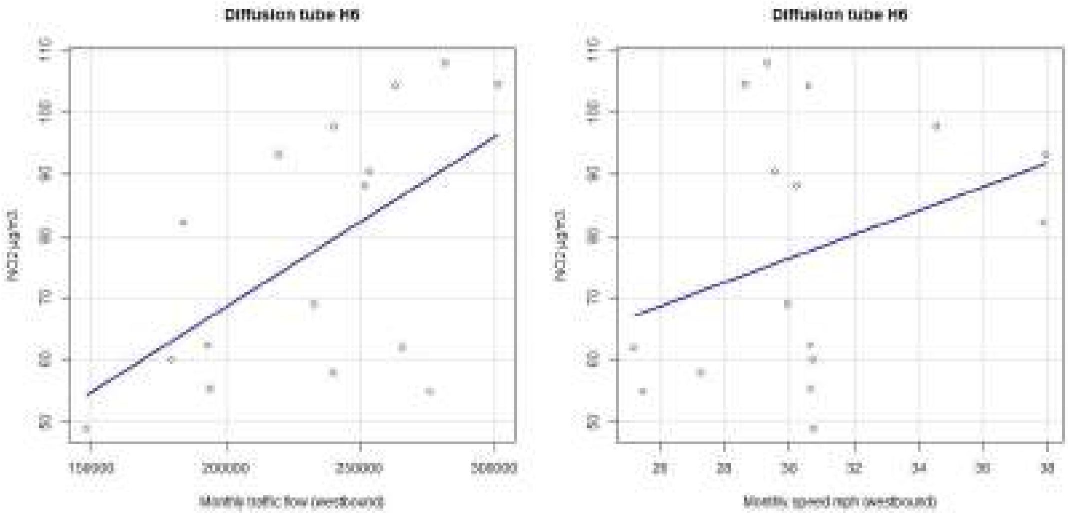

Figure 12: Diffusion tube H6 – Scatter plot NO_2 vs (a) traffic flow & (b) speed

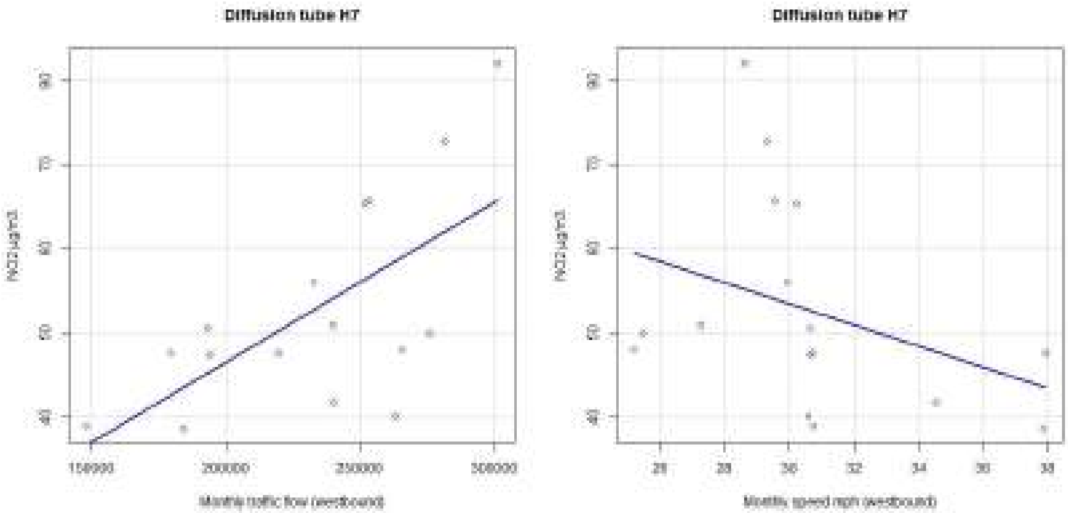

Figure 13: Diffusion tube H7 – Scatter plot NO_2 vs (a) traffic flow & (b) speed

Simple linear regression analysis was carried out to further explore the relations between NO_2 concentrations, traffic volume, and traffic speed. Model 1 attempts to explain NO_2 concentrations using only traffic flow. Model 2 attempts to explain NO_2 concentrations using only traffic speed. Finally, Model 3 uses multiple linear regression to attempt to explain NO_2 concentrations using both traffic flow and traffic speed. Model parameters and results are presented in Tables 5, 6, and 7.

Table 5: Linear regression 'Model 1' parameters ($NO_2 = b_0 + b_1$ Traffic flow)

Location	Intercept (b_0)	b_1	R^2	F-statistic	Significance
728 Warren House	12.10	6.08E-05	0.32	19.88	$p < 0.001$
726 Village Hall	12.07	1.34E-04	0.55	52.03	$p < 0.001$
H4 Village Hall	14.30	1.46E-04	0.33	6.77	$p < 0.05$
727 Whitecroft	8.10	2.28E-04	0.63	72.38	$p < 0.001$
H5 Southside Cottage	11.51	1.60E-04	0.38	8.50	$p < 0.05$
H6 Langdon	13.52	2.75E-04	0.32	6.71	$p < 0.05$
H7 Yew Tree House	8.31	1.91E-04	0.42	10.04	$p < 0.01$
738 Greenhills	15.27	1.24E-05	0.02	0.81	ns
N14 Hill House	11.37	3.27E-04	0.67	46.14	$p < 0.001$

Table 6: Linear regression 'Model 2' parameters ($NO_2 = b_0 + b_1$ Traffic speed)

Location	Intercept (b_0)	b_1	R^2	F-statistic	Significance
728 Warren House	4.07	6.58E-01	0.14	6.93	$p < 0.05$
726 Village Hall	30.99	3.19E-01	0.01	0.51	ns
H4 Village Hall	17.07	1.02E+00	0.11	1.81	ns
727 Whitecroft	41.57	5.08E-01	0.01	0.50	ns
H5 Southside Cottage	23.54	8.23E-01	0.07	1.08	ns
H6 Langdon	18.41	1.93E+00	0.11	1.82	ns
H7 Yew Tree House	91.04	-1.25E+00	0.13	2.08	ns
738 Greenhills	-2.88	6.44E-01	0.26	14.26	$p < 0.001$
N14 Hill House	29.38	1.64E+00	0.06	1.49	ns

Table 7: Multiple linear regression 'Model 3' parameters ($NO_2 = b_0 + b_1$ Traffic flow + b_2 Traffic speed)

Location	Intercept (b_0)	b_1	t-test	b_2	t-test	R^2	F-stat.	Significance
728 Warren House	-24.97	7.86E-05	$p < 0.001$	1.02E+00	$p < 0.001$	0.64	35.73	$p < 0.001$
726 Village Hall	-24.96	1.51E-04	$p < 0.001$	1.02E+00	$p < 0.001$	0.67	40.70	$p < 0.001$
H4 Village Hall	-79.54	2.40E-04	$p < 0.001$	2.35E+00	$p < 0.001$	0.80	25.92	$p < 0.001$
727 Whitecroft	-53.60	2.58E-04	$p < 0.001$	1.70E+00	$p < 0.001$	0.75	63.08	$p < 0.001$
H5 Southside Cottage	-76.21	2.48E-04	$p < 0.001$	2.20E+00	$p < 0.001$	0.78	22.75	$p < 0.001$
H6 Langdon	-163.87	4.52E-04	$p < 0.001$	4.45E+00	$p < 0.001$	0.80	25.69	$p < 0.001$
H7 Yew Tree House	18.13	1.81E-04	$p < 0.05$	-2.46E-01	ns	0.42	4.74	$p < 0.05$
738 Greenhills	-16.35	3.41E-05	$p < 0.01$	8.24E-01	$p < 0.001$	0.38	12.45	$p < 0.001$
N14 Hill House	-79.48	3.55E-04	$p < 0.001$	2.67E+00	$p < 0.001$	0.82	51.58	$p < 0.001$

It can be seen that Model 1 is moderately successful in explaining NO_2 concentrations using only traffic flow, in particular for the local authority diffusion tube sites with higher NO_2 concentrations and larger sample size (726, 727, & N14). Model 2 is not successful in explaining NO_2 concentrations using only traffic speeds. Combining traffic flow and traffic speed in Model 3 improves model performance. It should be noted, however, that these simple linear regression models have only been created to help explore the relationships between variables, over the range of the observed data, and not to be utilised for forecasting. There is no 'a prior' reason to assume that the relationships are in fact linear. However, the analysis has helped to demonstrate that traffic flow is generally a much better explanatory variable for NO_2 concentrations than traffic speed, but adding traffic speed to traffic flow improves model performance in most cases.

5. Temporary traffic order

5.1 Background

The air quality challenge in Chideock has been under assessment for a number of years, and a range of possible intervention measures have been considered which might mitigate the air quality problem.

- *Alternative routes for HGV traffic from ports to the south west. Compare the relative performance of routes between Southampton and Honiton and inform hauliers of the results.*

This option was considered in 2013/14. Highways England commissioned a comparison of advantages/ disadvantages to HGVs travelling between Southampton and Honiton using the A303 against the A35. The trial showed that whilst the A303 route was longer, the journey times were very similar and there were potential reliability benefits and fuel cost savings to HGVs using the A303.

This was presented in the format of an article published in the Road Haulage Association and Freight Transport Association E-newsletters in January/February 2014. It is not known if or how many hauliers took notice of this information and trialled/ changed routes. It should also be noted that the HGV fleet is now significantly cleaner than in 2014 and a very significant proportion of the HGV fleet is now Euro VI compliant and so the emissions from such vehicles will represent a smaller proportion of NO_2 emissions at Chideock as demonstrated by air quality modelling work undertaken by Dorset Council.

- *Clean Air Zone. Highways England were asked to consider designation of the A35 through Chideock as a Clean Air Zone (CAZ), where more polluting vehicles are charged to enter the zone.*

This proposal was considered in 2018. Highways England is not able to introduce a CAZ on any part of the Strategic Road Network. Therefore, Highways England would not be able to impose a charging CAZ in Chideock.

- *Physical barrier. Highways England were asked to explore the potential to erect physical barriers between vehicles and receptors in Chideock to physically block the transmission of NO_2 from vehicles to homes/ receptors.*

This proposal was considered in 2018. Physical barriers are not considered to be a practicable or deliverable option given the physical constraints in the village, which include the lack of space on the A35 and between the A35 and footway/frontage of properties to be able to erect barriers. In addition, the reasons for the significant historic environment designations in the village are likely to be compromised by the erection and physical presence of such barrier systems. It should also be noted that barriers do not improve air quality they only block or limit the pathway to receptors.

- *Single file traffic management. Levels of pollution drop rapidly with distance between the source (exhaust pipe) and the receptors (footways and property frontages). Highways England explored the option of reducing the road way to a single lane to run* *down the middle of the road, thereby moving the location of vehicle exhaust further away from receptors. In order to achieve this, alternate single file traffic movements through the village would be required under traffic control signals at either end of the village.*

The proposal was studied during the summer of 2018. Traffic modelling of the resultant queue lengths of vehicles waiting at traffic signals at either end of the village would lead to unacceptable congestion and delays, impacting on neighbouring villages and communities. There was an unacceptable long period of inter-green time to clear traffic between tidal flows. The large number of private and public side roads and accesses within the village was likely to raise safety concerns in relation to conflicts with periodic direction of vehicle flow. Single file traffic movement under signal control was not recommended.

- *CCTV Survey. Undertake CCTV survey in a busy period to understand factors that might cause queues of vehicles at the western end of the village. On the basis that queued traffic may give rise to higher levels of pollution. Seven video cameras were erected to cover the western end of the village and monitored traffic over a ten day period in August 2018.*

The CCTV survey was implemented in summer 2018 and reported in autumn 2018. The CCTV footage did not provide conclusive evidence that the steep gradient westwards out of the village during periods of higher volumes, such as summer peak, was in itself a cause of queues of traffic. Obstruction to flows caused by vehicles waiting to turn right into Duck Street and North Road did not appear to be a cause of formation of excessive queues. Buses stopping at stops were seen to cause congestion regularly. Long and significant traffic queues through the village were observed frequently, but the cause of them was not identified as they were outside the range of the cameras.

- *Electric vehicle charge point facility. To provide an electric vehicle charging point within the village to provide a local facility to encourage the uptake of zero emission vehicles in the locality and to provide long distance traffic with a rapid charge facility for long journeys, to improve facilitation for zero emission vehicles.*

Highways England provided an electric vehicle charge point in Chideock car park in the centre of the village at the end of March 2020. This was facilitated with the proactive support of the Parish Council who own the carpark and who provided landowner consents.

5.2 Temporary 30mph speed limit

Highways England has given careful consideration to the possible highway management interventions to reduce exhaust emissions of nitrogen oxides within the Chideock AQMA. The analysis has shown that whilst highway gradient and traffic volumes are dominant factors in causing high pollutant emissions within the Chideock AQMA, traffic speed can be a contributory factor.

Consequently, on September 23rd 2019, a temporary traffic order was implemented on the A35 to the west of Chideock. The order had the effect of:

- Extending the 30mph speed limit up to the start of the pre-existing National Speed Limit, about 200 meters to the west of the AQMA boundary, and;
- Changing the existing National Speed Limit between Chideock and Morcombelake to a 50mph speed limit.

The proposal was to trial the impact on air quality through a temporary reduction of the 40mph zone to 30mph, with the aim of smoothing the speed of traffic and reduction of the acceleration phase close to the properties/receptors in the village.

In addition to the existing diffusion tube monitoring equipment, additional pollution monitoring has been undertaken before and during the trial to measure what, if any, the impact of the reduction in the speed limit might have on pollution levels. A vehicle activated sign reminding drivers of the new speed limit was operative for periods of the trial. Impacts of COVID-19 on traffic flows are likely to have a significant impact on the results. No decision on the termination date of the trial has yet been taken.

The physical extent of the speed limit changes are illustrated in Figure 14.

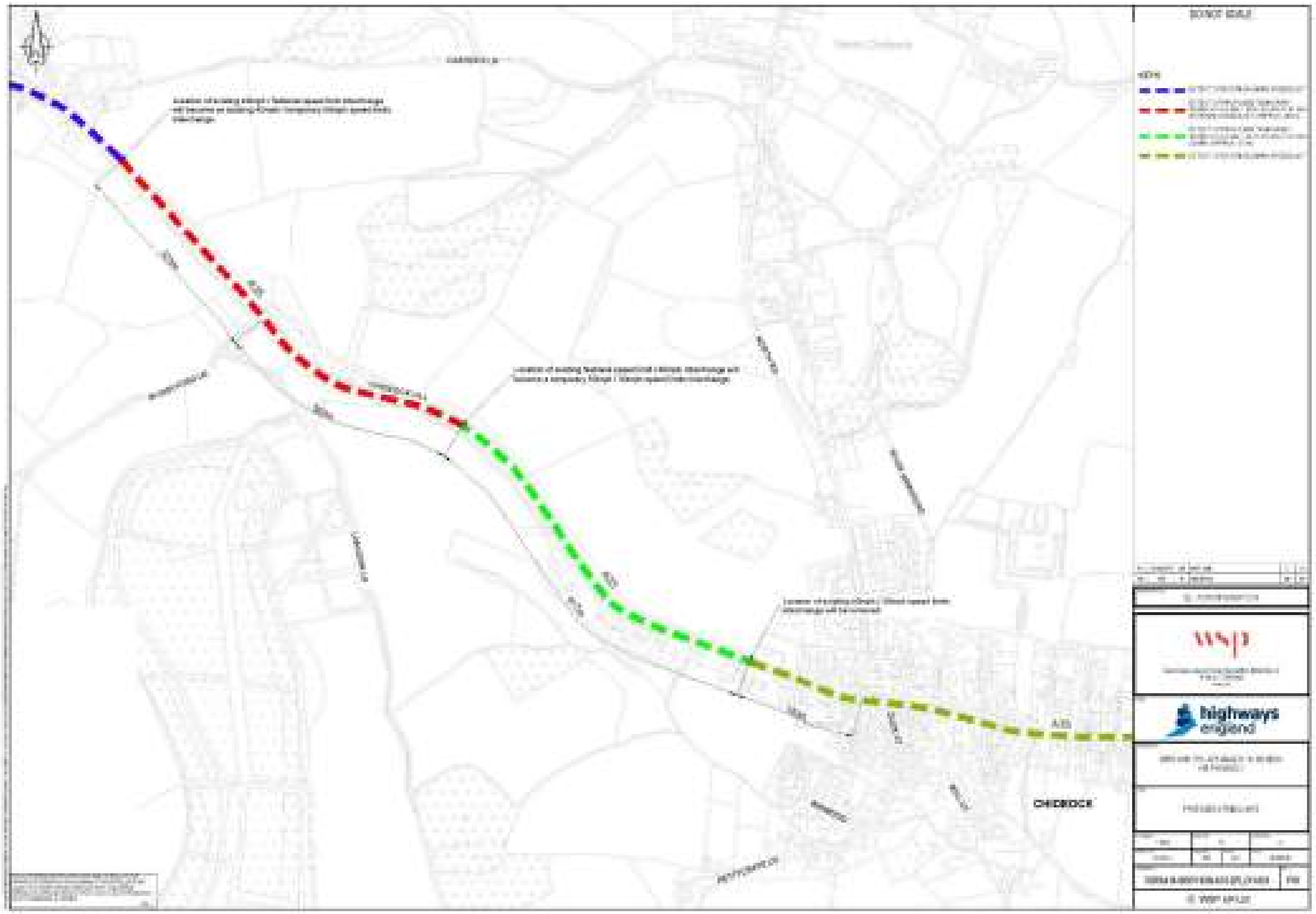

Figure 14: Temporary Traffic Order

6. Enviro Technology Services 'Smogmobile' Air Quality Surveys

6.1 Implementation

When investigating the exceedances of the NO_2 annual mean objective of 40µg/m^3 within the Chideock AQMA, and the potential impact of a speed management intervention to help to improve local air quality, consideration was given to the most appropriate instrumentation to be utilised.

The Enviro Technology 'Smogmobile' is a mobile air quality laboratory in an all-electric van, fitted with a range of sensors and monitors. It is capable of measuring key pollutants and greenhouse gases, either parked at a static location next to the road, or sampling traffic related emissions whilst being driven on the road. It therefore has the capability of measuring air pollution within the moving traffic stream, and over a predetermined section of highway of interest, at a high temporal resolution.

Surveys were undertaken in Chideock in two phases, before and after the implementation of the temporary traffic order changing the speed limits from 40mph to 30mph:

- Phase 1 surveys - Over three days, Tuesday 30th July to Thursday 1st August 2019 inclusive, generally from 0900 to 1700.
- Phase 2 surveys - Over three days, Tuesday 8th October to Thursday 10th October 2019 inclusive, again generally from 0900 to 1700.

Air quality data were collected by the 'Smogmobile' at 1Hz (*one measurement per second*), utilising air intakes on the roof of the vehicle only. Pollutants measured were NO_2 (2 x sensors), $PM_{2.5,}$ and PM_{10}. In the Phase 2 surveys only, CH_4 and CO_2 concentrations were also monitored by the Smogmobile, in addition to meteorological parameters (wind speed, wind direction, temperature, relative humidity, and atmospheric pressure).

The focus of interest for the surveys was the section of westbound carriageway within the AQMA where exceedances of the NO_2 annual mean objective value are observed. The vehicle was driven on a repeated loop from the Central Stores car park at Foss Orchard in Chideock at the eastern extremity, to 'Felicity's Farm Shop', Morcombelake at the western extremity, these being the most suitable turning points for the vehicle. A total of 104 repetitions were driven over the three days in Phase 1, and 108 repetitions over three days in Phase 2. The survey method was to follow vehicles westbound, selected at random, driven through the area of interest, measuring near instantaneous air quality every second via the air inlets on the roof of the vehicle. Instrumentation was not switched off between runs, so air quality data were also collected in an eastbound direction.

It should be noted that during the Phase 1 surveys (July/August), significant congestion due to high volumes of seasonal holiday traffic was occasionally encountered. This particularly influenced traffic speeds eastbound (down the hill) into Chideock, but westbound traffic also encountered some congestion. The survey vehicle was occasionally caught in eastbound queues down the hill, and any interpretation of the air quality data collected in an eastbound direction should take this issue into account.

In addition to the air quality measurements, the 'Smogmobile' recorded GPS location at 1Hz. This was supplemented by an additional 10Hz VBOX GPS data logger. Data from the 10Hz (*ten measurements per second*) GPS logger has been used to characterise both Smogmobile survey vehicle speed (kph) and acceleration (m/s^2) in this analysis. The measured speed and acceleration data may be considered broadly representative of the wider vehicle fleet within the Chideock urban area (where traffic speeds at any particular point in time are broadly homogenous), but this will not necessarily be the case on the westbound two lane section up the hill, where overtaking can occur. It should be noted that the Smogmobile survey vehicle always complied with the posted speed limit, whereas the general traffic flow did not always comply with speed limits, particularly during the Phase 2 surveys when the 30mph speed limit was in operation.

6.2 Smogmobile survey results

Smogmobile NO_2 survey results have initially been presented in two forms:

1. Graphically, with data aggregated into 50 meter 'bins' over the A35 road network of interest (from the eastern extremity of the AQMA in Chideock, to the western extremity of the national speed limit, a distance of just under approximately 1650 meters), and;

2. In tabular form, data within the AQMA being aggregated to spatial sections 100 meters in length. Mean values for NO_2, survey vehicle speed and acceleration are then calculated and presented by section, together with highway gradient, in tabular and graphical form.

- Figure 15 presents the A35 westbound mean NO_2 concentrations for each day of the Phase 1 surveys (July 30th to August 1st 2019). The error bars presented indicate the 95% confidence interval about the mean NO_2 value.
- Figure 16 presents the corresponding A35 westbound mean NO_2 concentrations for each day of the Phase 2 surveys (October 8th to 10th 2019). Again, the error bars presented indicate the 95% confidence interval about the mean NO_2 value.
- Figure 17 compares the A35 westbound overall mean NO_2 values (aggregated over all three survey days) for the Phase 1 and Phase 2 surveys, where Phase 2 includes the temporary speed limit regime.
- Figure 18 presents the difference between the A35 westbound Phase 1 and Phase 2 mean NO_2 values in absolute terms.

A number of observations can be made. Firstly, in both the Phase 1 and Phase 2 surveys, significant variation in day to day NO_2 concentrations can be observed. For example, in Phase 1 westbound, observed NO_2 concentrations are significantly higher on July 31st and August 1st, relative to July 30th. Similarly, in Phase 2 westbound, NO_2 concentrations within the AQMA are observed to be higher on Oct 9th, relative to the other two survey days. However, in the latter case, there appears to be a spatial dimension to the differences, with the Oct 10th concentrations being as high as the Oct 9th values about 200 meters beyond the new 50mph speed limit sign.

Secondly, with reference to Figure 17, the observed levels of mean NO_2 concentrations are significantly lower in the Phase 2 survey data (October 8th, 9th, and 10th), in comparison to the Phase 1 survey data (July 30th, 31st, and August 1st). In the westbound direction, there is a difference of approximately 20 µg/m^3 in the vicinity of the 'old' 40mph speed limit sign (which is removed in Phase 2); this could indicate that the removal of acceleration behaviour in this location in Phase 2 has resulted in a reduction of NO_x and NO_2 emissions, and consequent NO_2 atmospheric concentrations. However, the difference between the Phase 2 and Phase 1 data increases westbound from the point where the climbing lane commences (at approximately 500 meters), to the end of the AQMA and beyond, which may be due to differences in traffic speed and acceleration behaviour, but may also be due to differences in traffic volumes and weather conditions. The significance of variation in traffic volumes will be discussed in the next section.

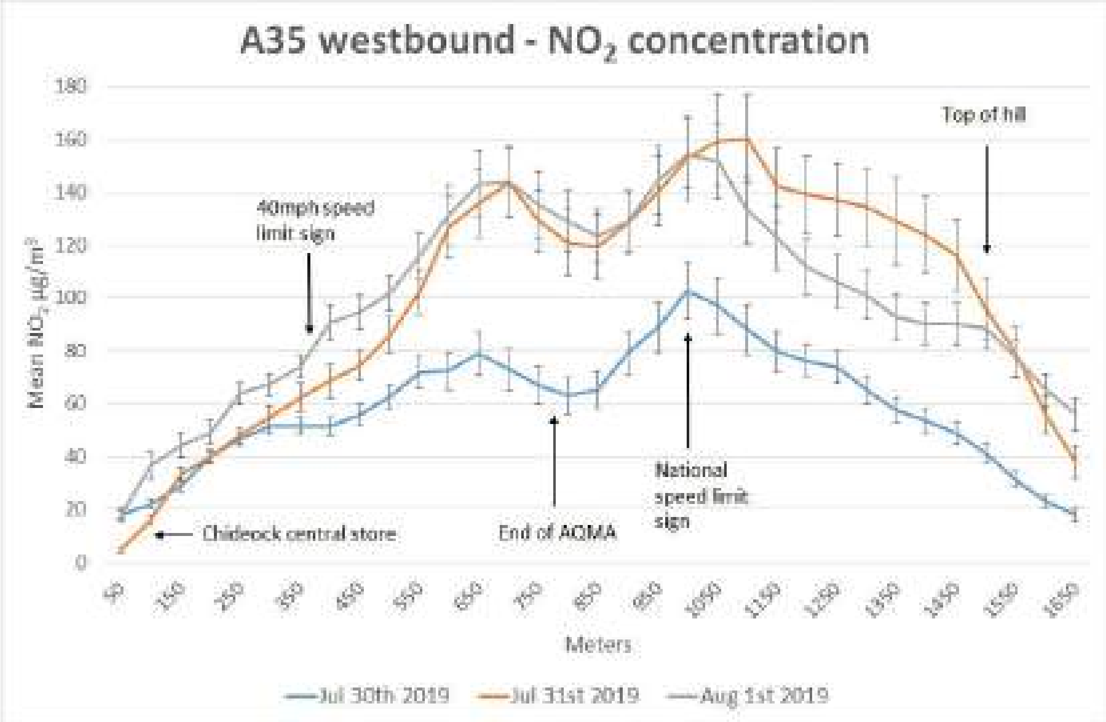

Figure 15: A35 westbound - NO_2 concentration – Phase 1 (July/August 2019)

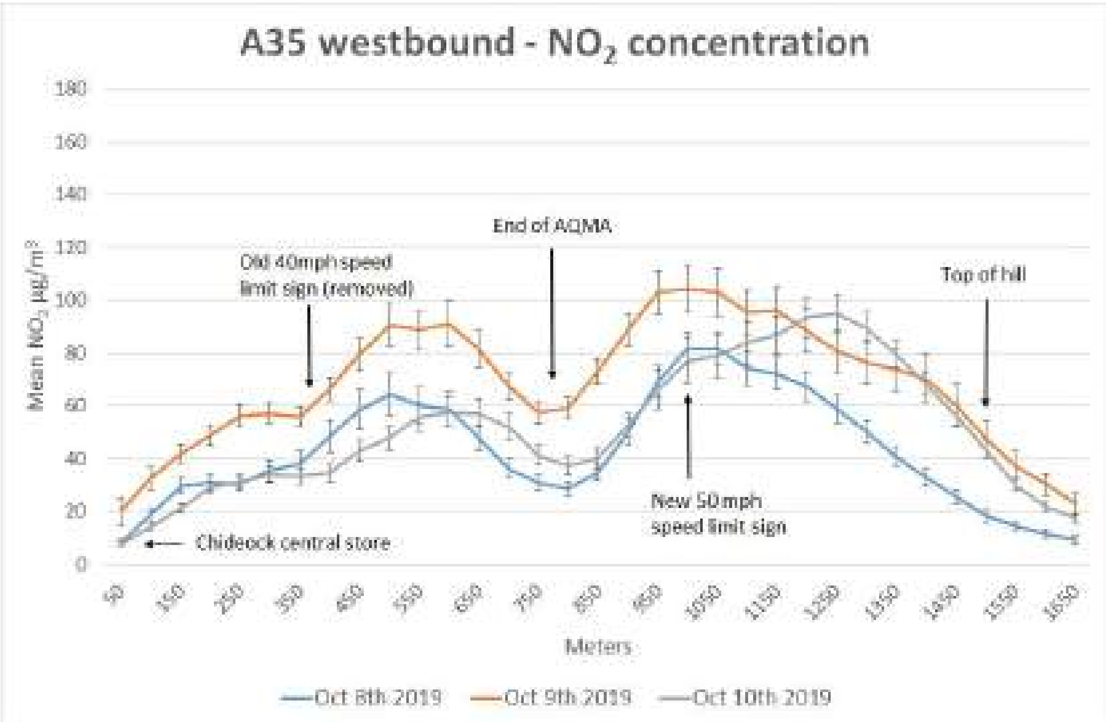

Figure 16: A35 westbound - NO_2 concentration – Phase 2 (October 2019)

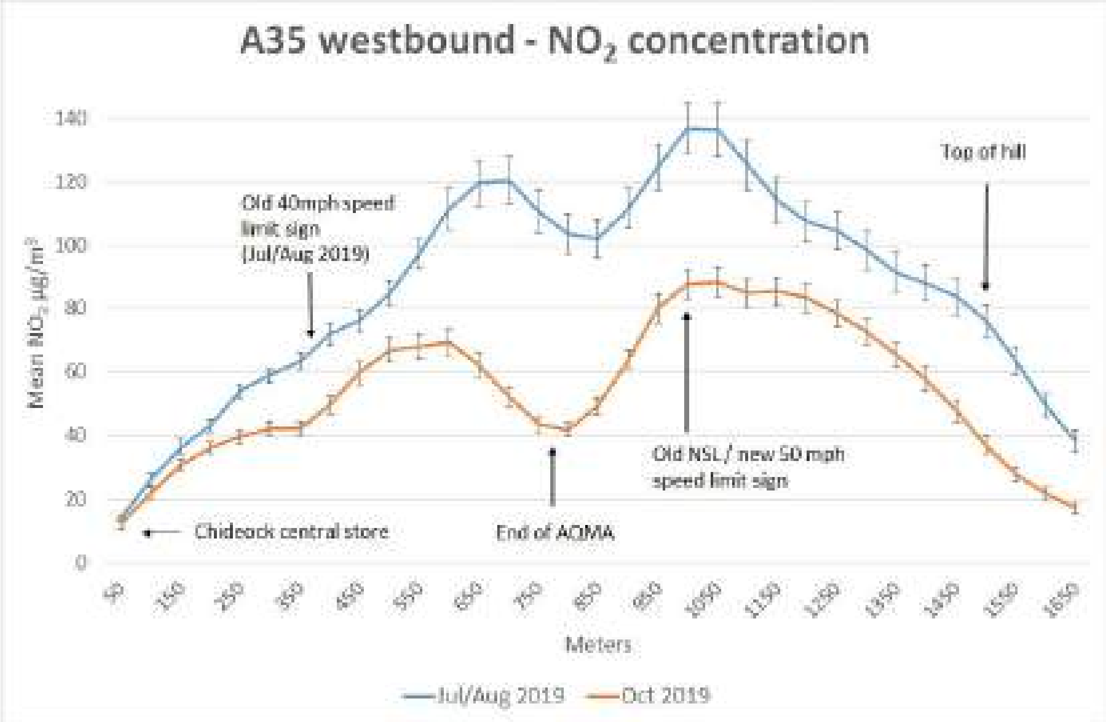

Figure 17: A35 westbound - NO_2 concentration – Phase 1 vs Phase 2

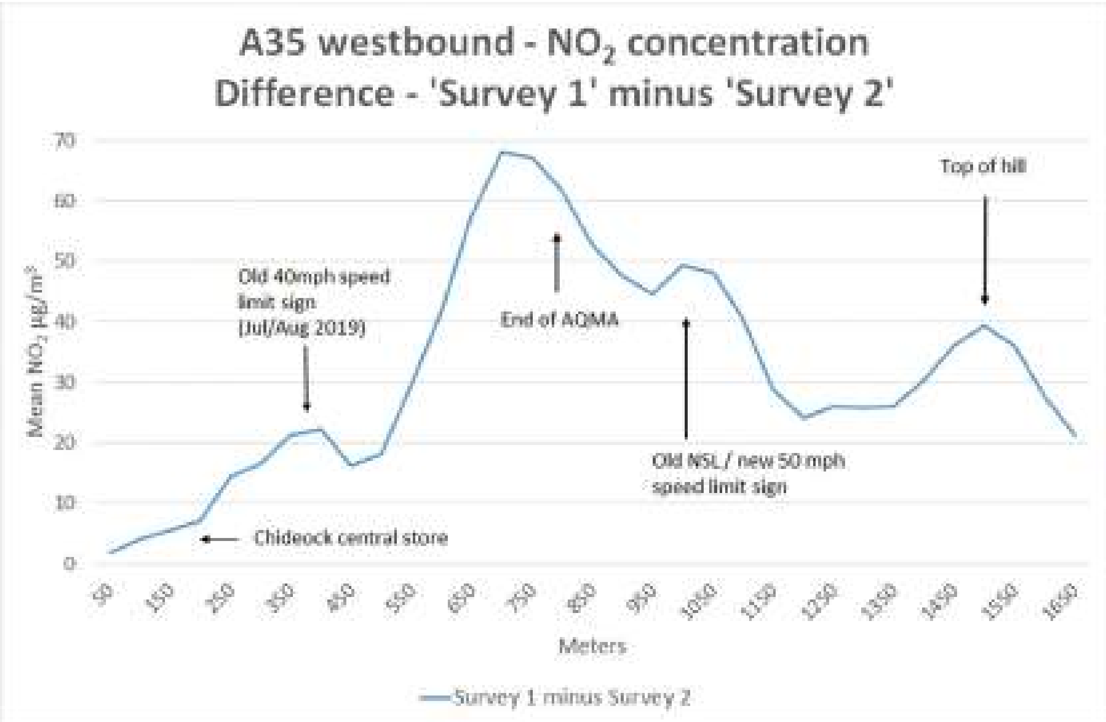

Figure 18: A35 westbound - NO_2 concentration – Phase 1 minus Phase 2

An alternative data processing approach aggregates the data within the AQMA to spatial sections 100 meters in length. Mean values for NO_2, Smogmobile speed, and acceleration are then calculated and presented by section, together with road gradient.

Figures 19, 20, and 21 illustrate the 100 meter sections corresponding with the extent of the Chideock AQMA. Note that the original westbound 40mph speed limit sign is in the centre of section 'D', and that the westbound climbing lane commences approximately at the boundary between sections 'E' and 'F'. Diffusion tube locations are also illustrated in the figures for reference.

- Diffusion tube 723 Section 'B' eastbound
- Diffusion tube 724 Section 'B' westbound
- Diffusion tube 726 Section 'C' westbound
- Diffusion tube 727 Section 'D' westbound
- Diffusion tube 728 Section 'C' eastbound
- Diffusion tube 738 Section 'G' westbound (N.B. 738 is located 17 meters back from the kerb)

Table 8 presents the summary results by 100 meter section for July 30th, July 31st, and August 1st individually, and for all Phase 1 survey days combined.

Table 9 presents the summary results by 100 meter section for October 8th, 9th, and 10th individually, and for all Phase 2 survey days combined.

Focusing on the westbound results (up the hill) for all Phase 1 survey days combined in Table 8, it can be seen that the calculated mean NO_2 concentrations display a similar pattern to Figure 17. There are a number of significant issues to note.

- Firstly, from section 'C' to section 'H', the gradient of the A35 increases, from +6.39% (+3.66 degrees) in section 'C', to +11.35% (+6.48 degrees) in section 'H'.
- Secondly, a localised peak in survey vehicle acceleration is observed in section 'D' as the Smogmobile accelerates in the transition from the 30mph speed limit to the 40mph speed limit.
- Thirdly, the transition from section 'E' to section 'F' has the largest absolute change in NO_2 concentration, from 80.3µg/m^3 to 104.1 µg/m^3 (+23.9 µg/m^3), coinciding with the start of the climbing lane.
- Fourthly, the lower NO_2 concentration in section 'A' corresponds with a lower gradient value of 3.72% (2.13 degrees).

The Phase 2 survey results presented in Table 9, incorporating the speed limit changes, show key differences in terms of both NO_2 concentrations and Smogmobile vehicle dynamics. Smogmobile survey vehicle speeds in sections A, B, and C are generally slightly higher than in Phase 1 (July/August), although still within the 30mph speed limit, presumably due to lower levels of congestion. However, the Smogmobile complies with the temporary 30mph speed limit in sections D to H, resulting in lower mean speeds in these sections than in Phase 1. The peaks in Smogmobile acceleration observed in sections D and E in the Phase 1 surveys have been removed in the Phase 2 surveys, due to the extension of the 30mph speed limit throughout the AQMA. This may suggest reduced 'acceleration related' NO_x emissions in sections D and E, if drivers were to comply with the 30mph speed limit. However, it should be noted that the survey notes for the Phase 2 surveys indicate that 52% of observed vehicles (56 out of 108 observations) were judged to be exceeding the 30mph speed limit westbound up the hill. A speed survey was implemented westbound within the AQMA during the Phase 2 (October 2019) surveys which highlights the speed limit non-compliance problem. Traffic speed is discussed further in a later section.

Figure 19: A35 100 meter spatial sections A to H (Chideock AQMA). (Base map © Google Earth)

Figure 20: A35 100 meter spatial sections A to D (Chideock AQMA eastern end). (Base map © Google Earth)

Figure 21: A35 100 meter spatial sections D to H (Chideock AQMA western end). (Base map © Google Earth)

Table 8: Survey results by 100 meter section within AQMA (July/August 2019)

Survey days: All

Smogmobile Mean			Uphill Westbound		Downhill Eastbound	Smogmobile Mean		
NO_2	Speed	Acceln	Gradient	Section	Gradient	Acceln	Speed	NO_2
$\mu g/m^3$	kph	m/s^2	%		%	m/s^2	kph	$\mu g/m^3$
19.9	35.7	0.17	3.72	A	-3.72	-0.18	30.3	41.0
39.3	35.8	0.07	7.33	B	-7.33	0.09	28.1	42.4
56.2	39.3	0.10	6.39	C	-6.39	0.01	27.1	46.0
67.7	46.7	0.30	7.58	D	-7.58	-0.18	26.5	40.0
80.3	52.5	0.15	9.04	E	-9.04	-0.16	33.1	47.7
104.1	56.1	0.08	10.20	F	-10.20	-0.14	34.2	50.8
118.6	56.4	0.01	10.84	G	-10.84	-0.12	36.3	52.4
106.1	56.9	-0.02	11.35	H	-11.35	-0.07	36.0	56.3

Survey days: July 30th 2019

Smogmobile Mean			Uphill Westbound		Downhill Eastbound	Smogmobile Mean		
NO_2	Speed	Acceln	Gradient	Section	Gradient	Acceln	Speed	NO_2
$\mu g/m^3$	kph	m/s^2	%		%	m/s^2	kph	$\mu g/m^3$
19.9	36.2	0.27	3.72	A	-3.72	-0.18	31.6	36.1
34.1	34.5	0.09	7.33	B	-7.33	0.06	29.9	37.1
48.9	42.4	0.11	6.39	C	-6.39	-0.05	31.5	40.2
51.4	47.1	0.21	7.58	D	-7.58	-0.29	36.2	31.9
59.0	50.7	0.10	9.04	E	-9.04	-0.17	39.8	24.9
71.9	52.4	-0.02	10.20	F	-10.20	-0.16	48.0	35.2
74.5	50.5	-0.01	10.84	G	-10.84	-0.18	50.1	45.9
64.1	50.2	-0.04	11.35	H	-11.35	-0.05	55.8	47.5

Survey days: July 31st 2019

Smogmobile Mean			Uphill Westbound		Downhill Eastbound	Smogmobile Mean		
NO_2	Speed	Acceln	Gradient	Section	Gradient	Acceln	Speed	NO_2
$\mu g/m^3$	kph	m/s^2	%		%	m/s^2	kph	$\mu g/m^3$
9.9	36.3	0.09	3.72	A	-3.72	-0.19	30.6	29.0
36.5	35.3	0.04	7.33	B	-7.33	0.13	26.3	30.1
51.3	38.3	0.13	6.39	C	-6.39	0.06	22.3	37.4
65.5	47.0	0.40	7.58	D	-7.58	-0.11	20.7	36.7
79.8	54.3	0.16	9.04	E	-9.04	-0.12	26.1	45.9
113.8	60.4	0.22	10.20	F	-10.20	-0.11	23.5	43.5
136.6	63.7	0.06	10.84	G	-10.84	-0.08	25.0	39.6
124.5	64.7	0.04	11.35	H	-11.35	-0.06	24.7	50.2

Survey days: August 1st 2019

Smogmobile Mean			Uphill Westbound		Downhill Eastbound	Smogmobile Mean		
NO_2	Speed	Acceln	Gradient	Section	Gradient	Acceln	Speed	NO_2
$\mu g/m^3$	kph	m/s^2	%		%	m/s^2	kph	$\mu g/m^3$
27.8	34.7	0.16	3.72	A	-3.72	-0.17	29.1	53.9
46.1	37.3	0.10	7.33	B	-7.33	0.07	28.5	57.5
65.1	37.9	0.07	6.39	C	-6.39	0.00	29.4	59.8
82.3	46.2	0.29	7.58	D	-7.58	-0.19	27.3	48.4
98.0	52.5	0.19	9.04	E	-9.04	-0.20	36.8	66.3
123.9	55.7	0.07	10.20	F	-10.20	-0.17	41.0	72.3
143.7	55.9	0.00	10.84	G	-10.84	-0.15	44.2	76.5
130.1	56.6	-0.05	11.35	H	-11.35	-0.11	44.7	70.5

Table 9: Survey results by 100 meter section within AQMA (October 2019)

Survey days: All

Smogmobile Mean			Uphill Westbound		Downhill Eastbound	Smogmobile Mean		
NO_2	Speed	Acceln	Gradient	Section	Gradient	Acceln	Speed	NO_2
μg/m³	kph	m/s²	%		%	m/s²	kph	μg/m³
17.0	40.0	0.15	3.72	A	-3.72	-0.29	36.4	22.1
33.2	40.8	0.07	7.33	B	-7.33	0.08	37.1	22.4
40.9	43.2	0.07	6.39	C	-6.39	-0.05	36.4	28.3
45.7	46.2	0.08	7.58	D	-7.58	-0.12	39.9	26.3
63.5	46.3	0.01	9.04	E	-9.04	-0.08	42.8	23.0
68.7	47.8	0.05	10.20	F	-10.20	-0.08	46.6	17.7
56.3	48.1	-0.03	10.84	G	-10.84	-0.02	47.8	24.3
41.9	47.1	-0.06	11.35	H	-11.35	-0.05	48.1	36.0

Survey days: October 8th 2019

Smogmobile Mean			Uphill Westbound		Downhill Eastbound	Smogmobile Mean		
NO_2	Speed	Acceln	Gradient	Section	Gradient	Acceln	Speed	NO_2
μg/m³	kph	m/s²	%		%	m/s²	kph	μg/m³
13.3	41.7	0.19	3.72	A	-3.72	-0.30	38.8	17.3
30.0	40.4	0.07	7.33	B	-7.33	0.12	35.9	17.4
32.9	44.5	0.08	6.39	C	-6.39	-0.07	35.1	20.3
43.5	47.0	0.05	7.58	D	-7.58	-0.16	40.8	16.1
61.4	46.8	0.00	9.04	E	-9.04	-0.08	45.5	15.6
59.2	48.4	0.08	10.20	F	-10.20	-0.07	47.7	13.6
41.5	49.1	-0.04	10.84	G	-10.84	0.00	48.4	16.9
28.8	47.4	-0.08	11.35	H	-11.35	-0.07	48.6	28.9

Survey days: October 9th 2019

Smogmobile Mean			Uphill Westbound		Downhill Eastbound	Smogmobile Mean		
NO_2	Speed	Acceln	Gradient	Section	Gradient	Acceln	Speed	NO_2
μg/m³	kph	m/s²	%		%	m/s²	kph	μg/m³
26.5	38.9	0.17	3.72	A	-3.72	-0.26	35.7	27.8
45.2	41.2	0.04	7.33	B	-7.33	0.06	36.7	28.6
56.8	43.1	0.10	6.39	C	-6.39	-0.05	36.4	38.2
61.1	46.6	0.08	7.58	D	-7.58	-0.11	40.6	34.0
84.7	46.9	-0.01	9.04	E	-9.04	-0.08	43.5	27.2
90.2	47.9	0.03	10.20	F	-10.20	-0.08	46.3	21.9
73.4	47.8	-0.02	10.84	G	-10.84	-0.05	47.8	28.9
57.1	47.1	-0.04	11.35	H	-11.35	-0.03	48.4	38.0

Survey days: October 10th 2019

Smogmobile Mean			Uphill Westbound		Downhill Eastbound	Smogmobile Mean		
NO_2	Speed	Acceln	Gradient	Section	Gradient	Acceln	Speed	NO_2
μg/m³	kph	m/s²	%		%	m/s²	kph	μg/m³
11.0	39.7	0.10	3.72	A	-3.72	-0.31	35.1	20.6
25.0	40.7	0.11	7.33	B	-7.33	0.05	38.7	20.9
32.6	42.1	0.02	6.39	C	-6.39	-0.02	37.6	26.2
33.9	45.1	0.10	7.58	D	-7.58	-0.10	38.6	28.0
45.7	45.2	0.03	9.04	E	-9.04	-0.07	40.2	25.2
56.6	47.2	0.05	10.20	F	-10.20	-0.08	45.9	17.3
53.5	47.6	-0.04	10.84	G	-10.84	-0.01	47.3	26.6
38.8	46.7	-0.07	11.35	H	-11.35	-0.04	47.2	40.3

6.3 Significance of variation in traffic flow

The measured NO_2 concentrations within the AQMA are significantly lower during the October 2019 (Phase 2) Smogmobile surveys, relative to the July/August 2019 (Phase 1) surveys. However, not all of this reduction can be attributed to the introduction of the temporary speed limit regime. The correlation between traffic flow volume and concentrations of air pollution was highlighted in Section 4.

Figure 22 presents the observed westbound traffic flows during the two Smogmobile surveys. Traffic flow data has been obtained from the permanent traffic count site (TMU site 5080/1) which is located to the west of Chideock. Table 10 presents the aggregate 12 hour and 24 hour traffic flows, together with the calculated mean values and factors.

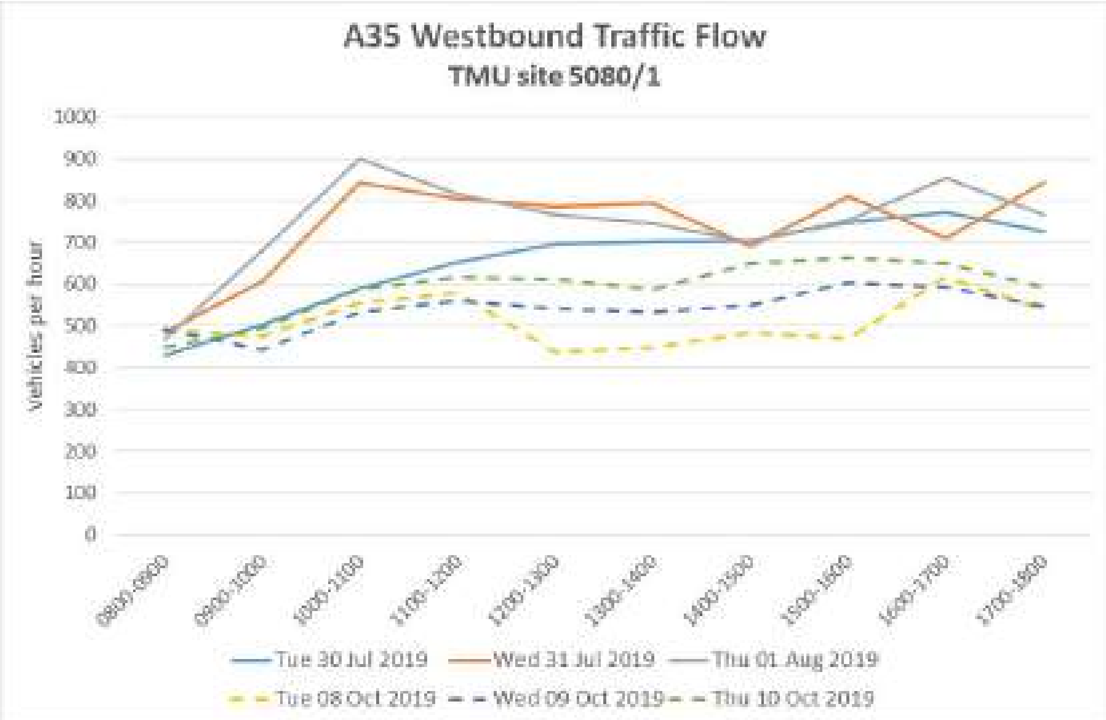

Figure 22: Observed variation in A35 westbound hourly traffic flow during the Smogmobile surveys

Table 10: A35 westbound traffic flows (TMU site 5080/1)

	12 hour (0700-1900)	24 hour flow
Tue 30 Jul 2019	7275	8459
Wed 31 Jul 2019	8241	9600
Thu 01 Aug 2019	8494	10095
Average	***8003***	***9385***
Tue 08 Oct 2019	5792	6644
Wed 09 Oct 2019	6087	6994
Thu 10 Oct 2019	6589	7625
Average	***6156***	***7088***
Factor	***0.77***	***0.76***

It can be seen that average westbound 12 hour traffic flows during the July/August 2019 surveys were approximately 30% higher than during the October 2019 surveys. This reflects the significance of seasonality for variation in traffic flow at different times of year.

Figures 23 and 24 present scatter plots of measured mean Smogmobile NO_2 µg/m^3 within the AQMA, against hourly traffic flow during the surveys. In these plots, all survey data are combined, with Figure 23 presenting data where a 'diesel vehicle is in front' and Figure 24 presenting data where a 'petrol vehicle is in front'. A simple linear trend line is fitted through each set of data. Whilst variability in measured NO_2 between individual runs is obviously very significant, the trend lines suggest that for an increase in traffic flow of 100 vehicles per hour, the NO_2 µg/m^3 behind diesel cars increases by 12.7 µg/m^3, whilst behind petrol cars the value increases by 4.8 µg/m^3, all other things being equal. It therefore appears clear that higher traffic flows will result in higher levels of NO_2 pollution.

Figures 25 and 26 present a simple adjustment of the NO_2 µg/m^3 values, factoring the NO_2 value pro rata based on the difference in 12 hour traffic flows observed between the July/August 2019 survey and the October 2019 survey (a factor of 0.77 from Table 10). A cubic smoothing spline has been fitted through each data set using the 'R' function 'smooth.spline' (R Core Team, 2019). 95% confidence intervals have been calculated using a bootstrap re-sampling technique.

It can be seen that adjusting the measured NO_2 values to take account of the difference in traffic volume causes the July/August 2019 survey data to converge more closely with the October 2019 survey data for a significant part of the survey route. Within the AQMA, it can be seen that there is little difference (at 95% confidence) between the two data sets for the first 250 meters (measured from the eastern extremity of the AQMA) until the approach to the old 40mph speed limit sign (at circa 350 meters), when the October 2019 NO_2 values drop below the July/August 2019 NO_2 values, possibly due to reduction of acceleration events. The two data sets then re-converge between 450 meters and 500 meters (section 'E' in Figure 21), before diverging again at circa 550 meters (section 'F' in Figure 21) where the climbing lane commences. This divergence may be due to differences in vehicle speed up the hill with the new 30mph speed limit introduced in September 2019, but this is speculation in the absence of detailed traffic speed survey data for the July/August 2019 Smogmobile survey.

The October 2019 NO_2 values remain lower than the July/August 2019 values until re-converging between 1150 meters and 1350 meters (beyond the old NSL / new 50mph speed limit sign). The values then diverge again near the top of the hill.

Figure 27 presents a further comparison of the July/August 2019 survey results (NO_2 values factored by 0.77) and the October 2019 survey results. Figure 28 presents a difference graph, July/August 2019 survey values (NO_2 values factored by 0.77) minus the October 2019 survey values. Towards the western end of the AQMA, the maximum difference in NO_2 concentration is around 40 µg/m^3.

Figure 29 presents the same data as Figure 27, but magnifying the first 600 meters of the AQMA westbound from Chideock central store to the start of the climbing lane. It can be seen that the NO_2 values are similar for the first 250 meters, but then diverge from 250 meters to approximately 400 meters, before re-converging at around 450 meters. The two data sets then diverge again at the start of the climbing lane (around 550 meters). The data suggests that, including a simple adjustment to account for differences in traffic volume, there is a reduction in measured NO_2 of about 3 to 6 $\mu g/m^3$ (6 to 12%) in the vicinity of diffusion tubes 726 and 727 with the introduction of the extended temporary 30 mph speed limit in October 2019. It can be hypothesised that this is due to a localised reduction in acceleration events in this location. However, detailed speed and acceleration data for the fleet is not available at this location to confirm this hypothesis.

The seasonal variation in NO_2 concentrations associated with seasonal variation in traffic flows is to be expected, as discussed in Section 5. Figure 30 presents the monthly diffusion tube results for sites 724, 726, and 727 in 2018 and 2019. These three diffusion tube sites are adjacent to the westbound traffic flow. It can be seen that the measured October NO_2 concentrations historically tend to be lower on average than the corresponding July and August values. This difference is largely due to higher levels of seasonal traffic flow and congestion during the summer months on the A35 in Chideock, an assertion which is supported by local traffic data. Figure 31 presents westbound traffic flow data from the traffic count site to the west of Chideock, in Morcombelake for 2019 (the most recent full year of data). It can be seen that traffic flows in July and August 2019 were, on average, about 24% higher than in October 2019.

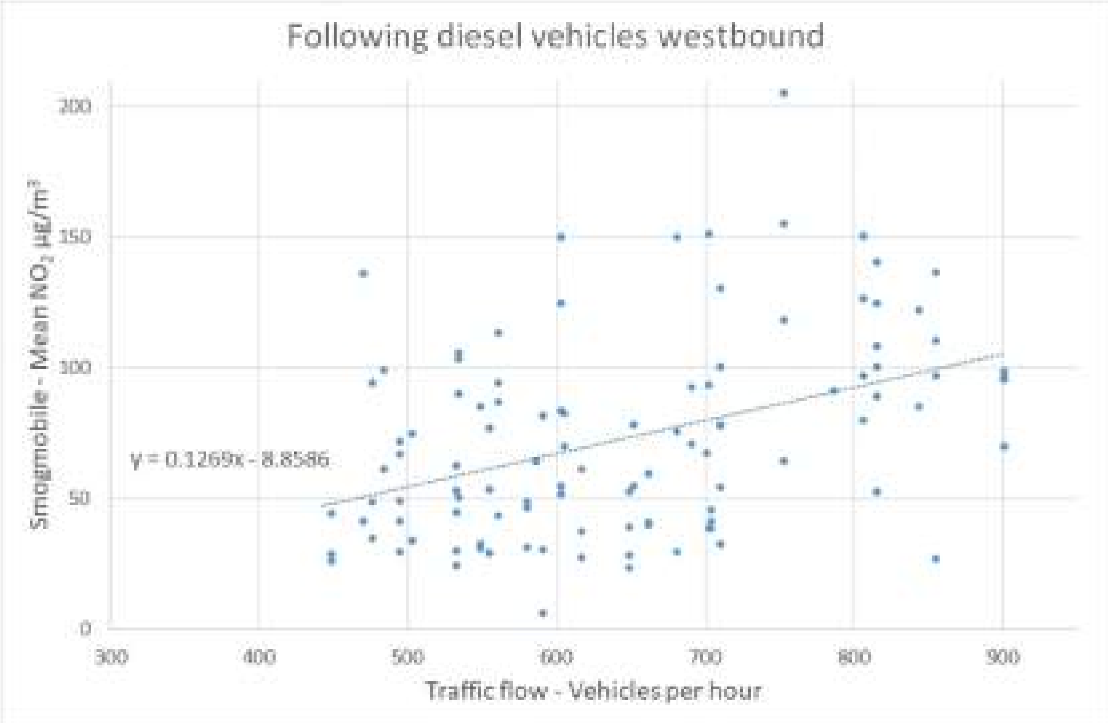

Figure 23: Scatterplot of measured mean Smogmobile NO_2 µg/m^3 within the AQMA against hourly traffic flow. All survey data, diesel vehicle in front.

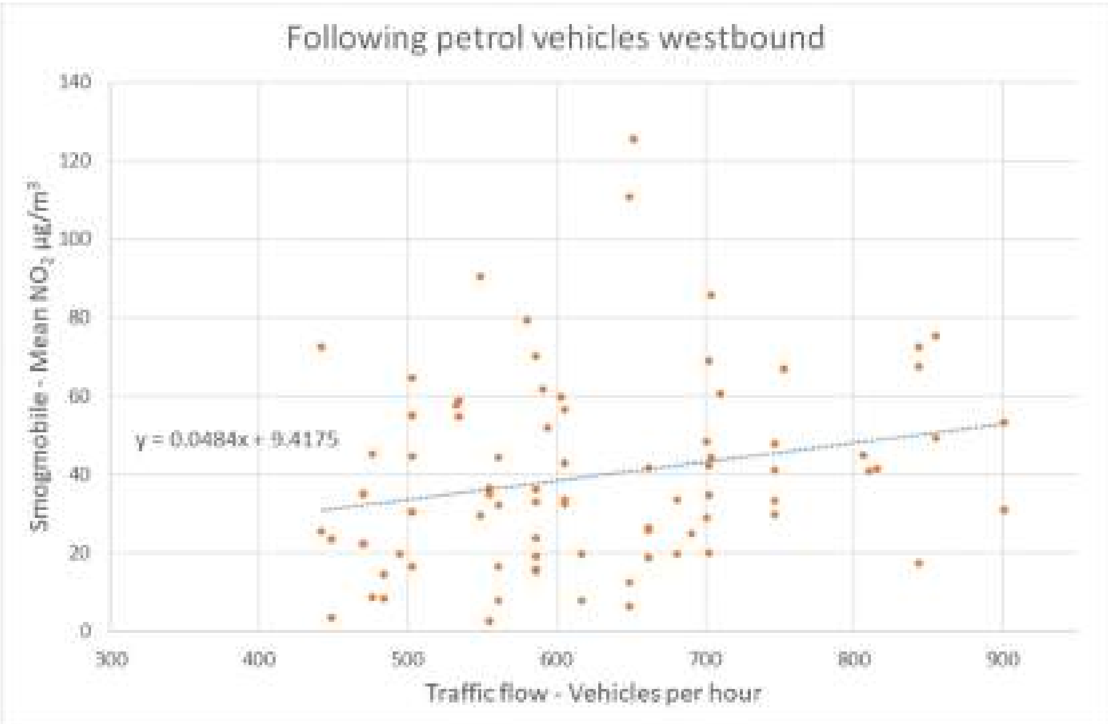

Figure 24: Scatterplot of measured mean Smogmobile NO_2 µg/m^3 within the AQMA against hourly traffic flow. All survey data, petrol vehicle in front.

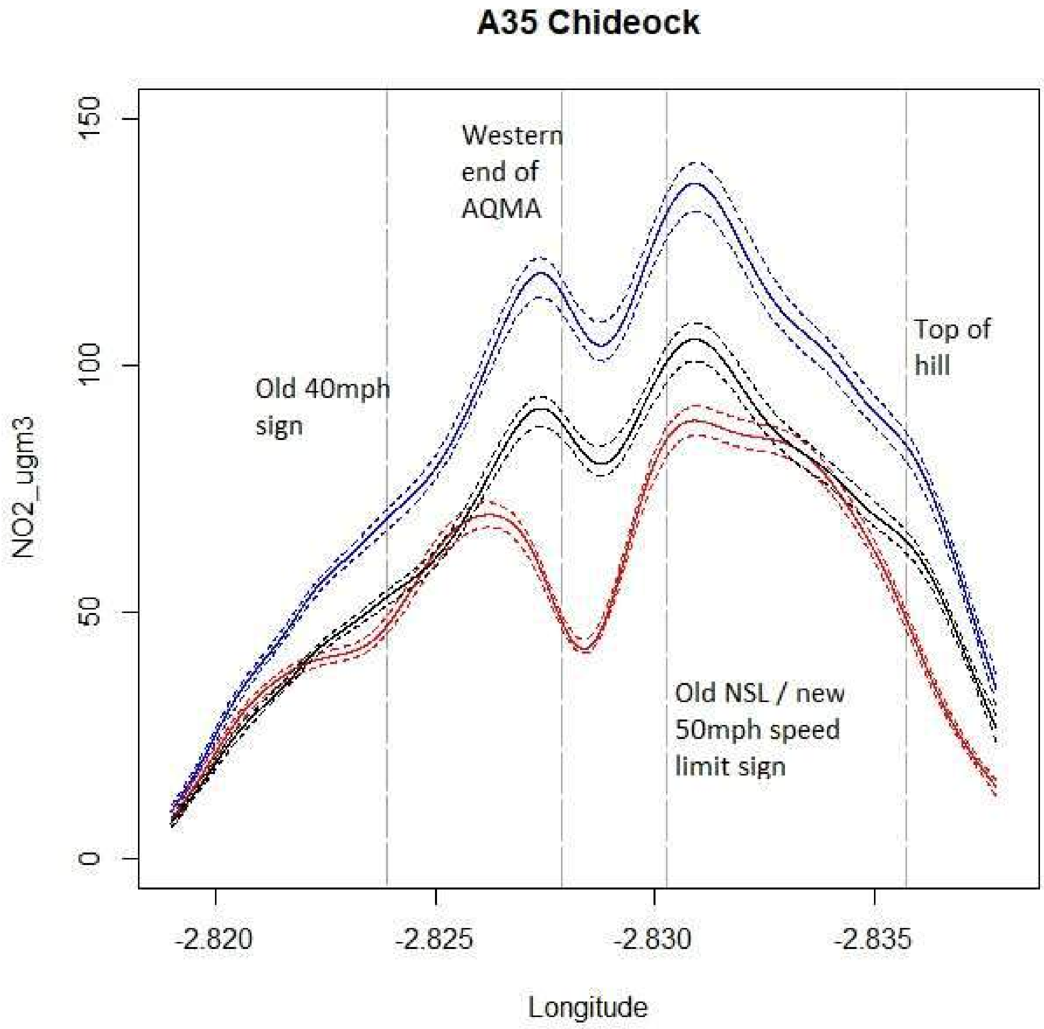

Figure 25: Spline plot of (a) July/August 2019 survey (coloured blue); (b) October 2019 survey (coloured red), and; (c) July/August 2019 survey factored by 0.77 (coloured black). Dashed lines indicate 95% confidence intervals.

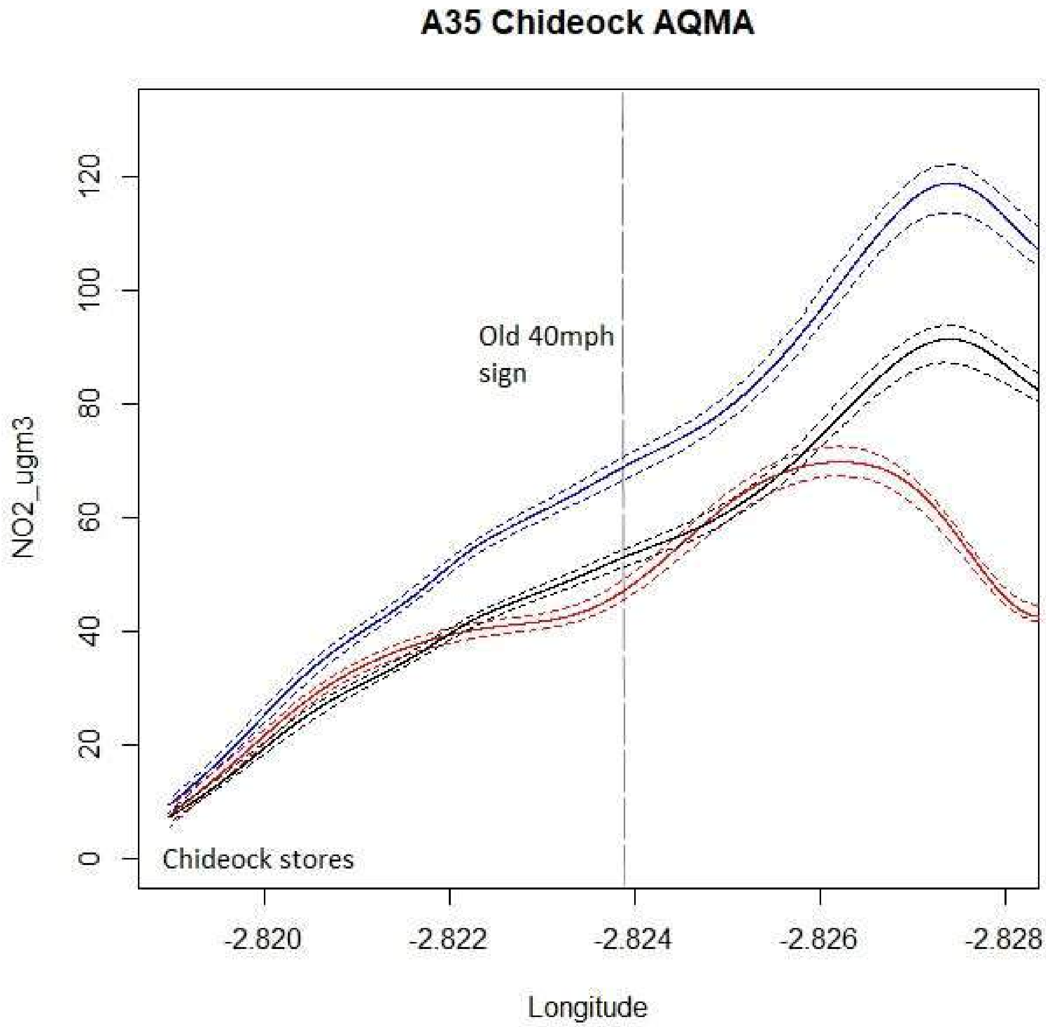

Figure 26: Spline plot of (a) July/August 2019 survey (coloured blue); (b) October 2019 survey (coloured red), and; (c) July/August 2019 survey factored by 0.77 (coloured black). Dashed lines indicate 95% confidence intervals. Physical extent of AQMA only.

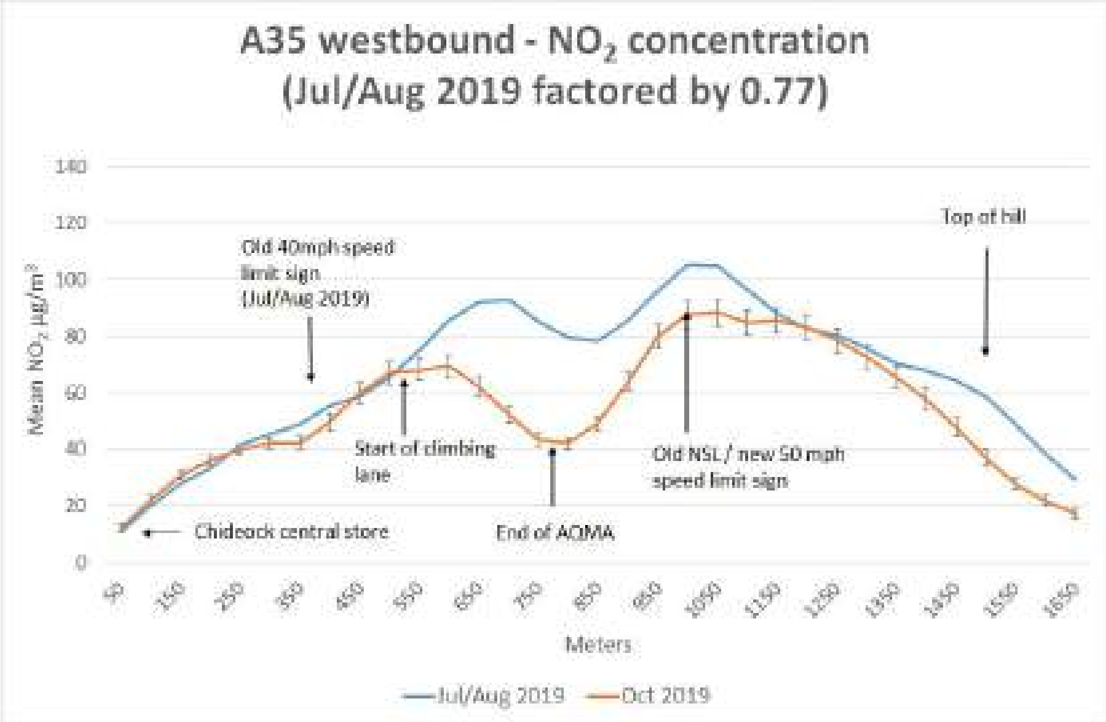

Figure 27: Comparison of July/August 2019 survey (NO_2 values factored by 0.77) and the October 2019 survey

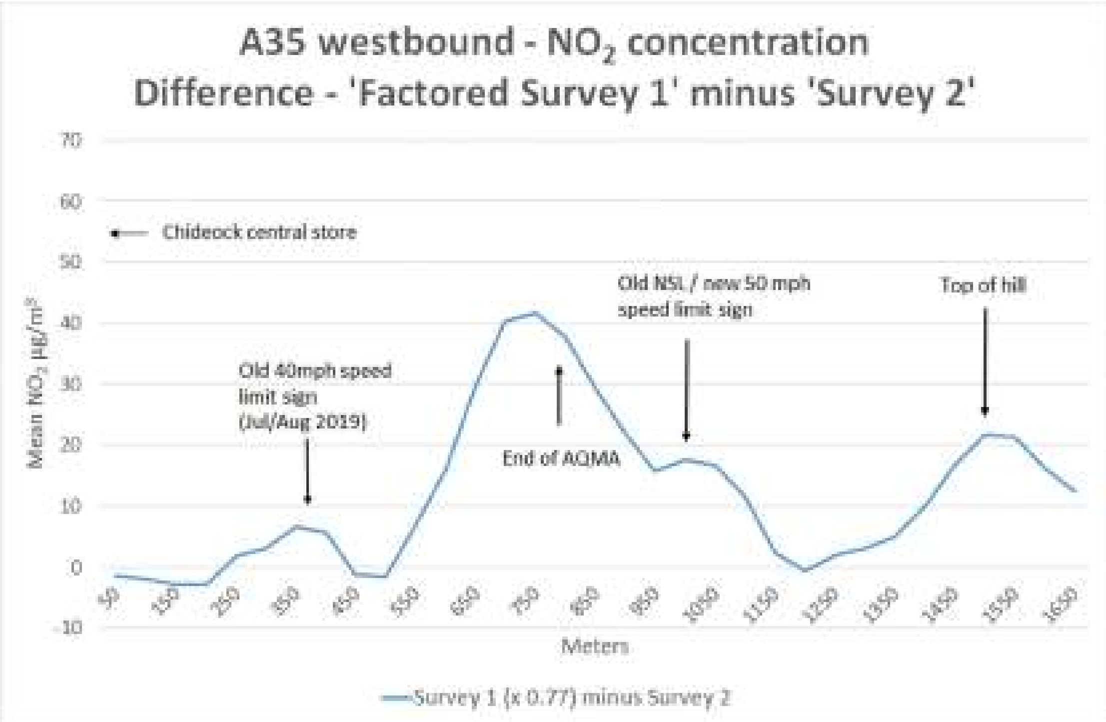

Figure 28: Difference graph: July/August 2019 survey (NO_2 values factored by 0.77) minus the October 2019 survey values

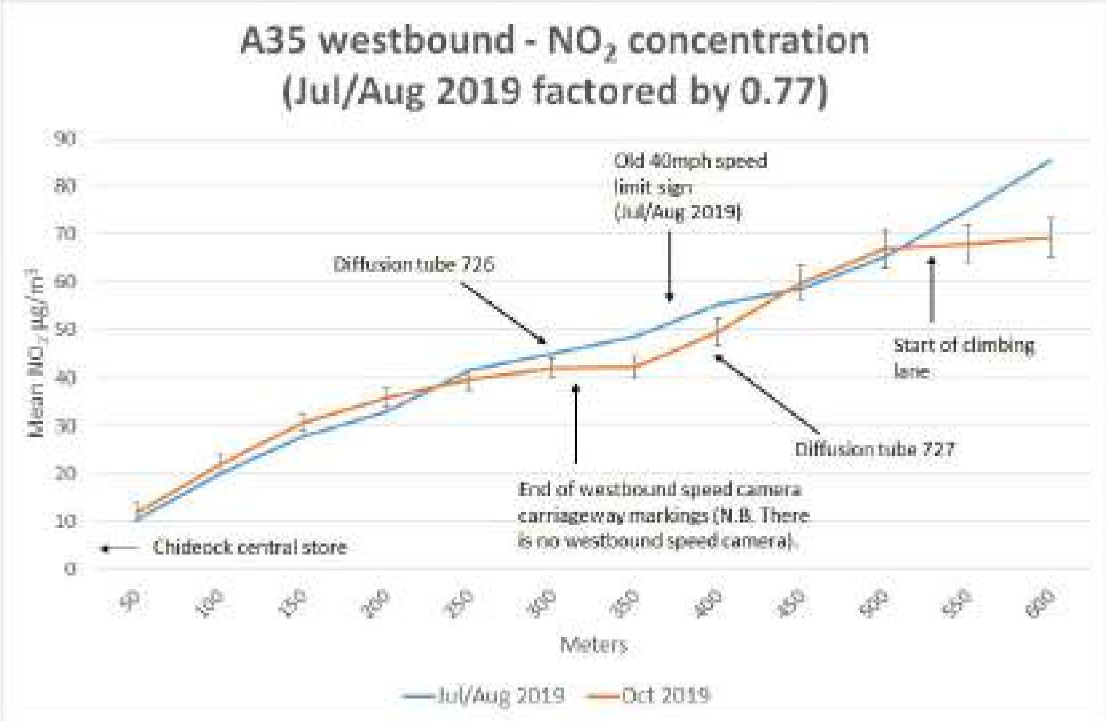

Figure 29: Comparison of July/August 2019 survey (NO_2 values factored by 0.77) and the October 2019 survey (first 600 meters of AQMA westbound from Chideock central store to start of climbing lane)

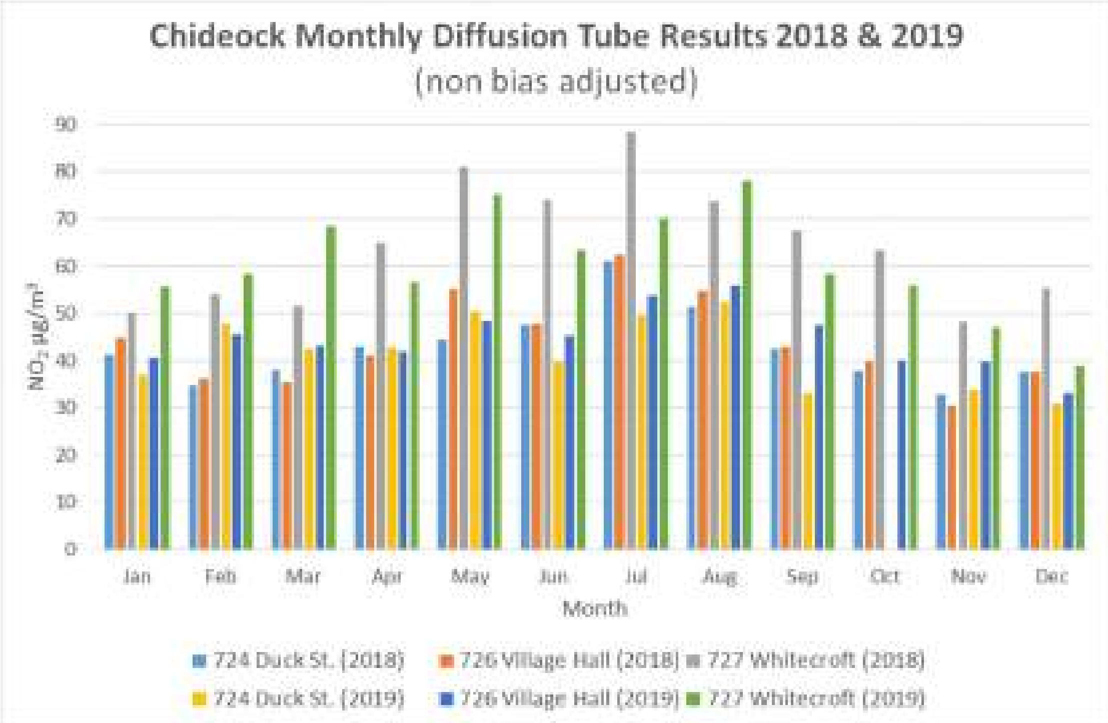

Figure 30: Chideock monthly diffusion tube results 2018 & 2019

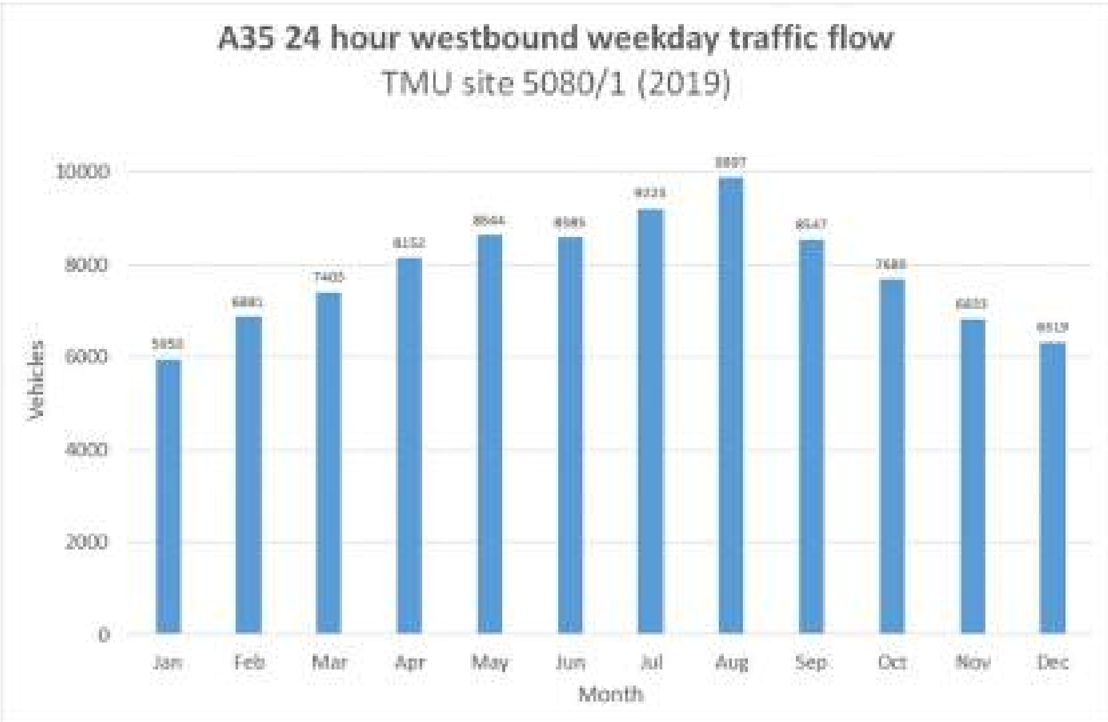

Figure 31: A35 Morcombelake 24 hour weekday westbound traffic flow (2019)

7. Speed surveys

7.1 October 2019 speed survey

A speed survey was carried out in Chideock from October 7th to 20th 2019 inclusive. The speed survey location is illustrated in Figure 32. Table 11 presents the summary statistical results for October 8th, 9th and 10th westbound up the hill, coincident with the October Smogmobile survey dates. It can be seen that between 35.1% and 45.3% of traffic exceeded 36mph, and between 18.0% and 21.6% of traffic exceeded 41mph. The speed survey location was within the new temporary 30mph speed limit.

Comparable speed survey data is not available for the July / August 2019 Smogmobile survey dates. However, it is clear from Table 11 that some form of ongoing enforcement will be required if the extended temporary 30mph speed limit is to be observed by drivers. The results of the October 2019 Smogmobile surveys should be interpreted in the knowledge that the majority of drivers were exceeding the temporary 30mph speed limit.

Figure 32: Speed survey location – October 2019 (base map © Google Earth)

Table 11: Speed survey summary statistics (westbound 0900 hours to 1800 hours)

	85th percentile	Mean	% 31+ mph	% 36+ mph	% 41+ mph
Tues 8th Oct 19	42.2 mph	34.4 mph	62.7%	35.1%	18.0%
Weds 9th Oct 19	42.2 mph	34.7 mph	70.0%	40.4%	18.8%
Thurs 10th Oct 19	42.5 mph	35.1 mph	77.9%	45.3%	21.6%

7.2 October & December 2020 speed surveys

Two further local speed surveys were undertaken in 2020:

- Friday 16th October to Wednesday 4th November 2020, and;
- Friday 11th December to Tuesday 22nd December 2020

The first survey in October / November 2020 was conducted whilst traffic management was in place to facilitate highway and embankment works due to a local landslip. The traffic management would have had an influence on traffic speeds in the vicinity.

The second survey in December 2020 was implemented after the traffic management (cones) had been removed, but before the Christmas holiday period. Intuitively, it would be expected that the removal of the traffic management and cones would lead to an increase in observed traffic speed, relative to the October / November 2020 situation.

Surveys were carried out at three locations (Sites 1, 2, & 3) as illustrated in Figure 33. Unfortunately, the data from Site 2 in December 2020 was found to be corrupted, and is therefore not available.

Figure 33: Speed survey locations – October & December 2020 (base map © Google Earth)

It can be seen from Tables 12, 13 and 14 that with the traffic management in place during October 2020, the average speed at the easternmost location (Site 1) was circa 26 mph, with the 85th percentile value circa 29.9 mph. At the westernmost location (Site 3), the average speed increased to around 29.1 mph, with the 85th percentile value circa 37.6 mph.

With reference to Tables 15 and 16, when the traffic management was removed in December 2020, the average speed increased to circa 28.3 mph at Site 1 (85th percentile circa 35.0 mph), whilst at Site 3 the average speed increased to circa 37.7 mph (85th percentile 47.1 mph). All three survey sites are within the 30mph speed limit, highlighting the importance of giving appropriate consideration to measures to encourage compliance with the speed limit for air quality management purposes.

*Table 12: Speed survey summary statistics (**Site 1** westbound 24 hour)*

	85th percentile mph	Mean mph	% 31+ mph	% 41+ mph
Sat 17th Oct 2020	30.0	26.1	5.9%	0.1%
Sun 18th Oct 2020	30.1	26.4	6.5%	0.0%
Mon 19th Oct 2020	29.9	25.9	4.9%	0.1%
Tues 20th Oct 2020	29.9	26.1	5.4%	0.1%
Weds 21st Oct 2020				
Thurs 22nd Oct 2020	29.8	25.9	4.4%	0.0%
Fri 23rd Oct 2020	30.0	26.1	5.8%	0.1%
Sat 24th Oct 2020	30.0	26.3	5.9%	0.2%
Sun 25th Oct 2020	30.0	26.3	6.1%	0.1%
Mon 26th Oct 2020	29.8	25.7	4.5%	0.0%
Tues 27th Oct 2020	29.8	25.7	4.4%	0.0%
Weds 28th Oct 2020	29.8	25.7	4.4%	0.1%
Thurs 29th Oct 2020	29.8	25.7	4.2%	0.0%
Fri 30th Oct 2020	29.7	25.2	4.4%	0.0%
Sat 31st Oct 2020	30.1	26.4	6.9%	0.2%
Sun 1st Nov 2020	30.2	26.6	7.7%	0.2%
Mon 2nd Nov 2020	30.0	26.2	5.5%	0.1%
Tues 3rd Nov 2020	29.9	26.2	5.4%	0.1%

*Table 13: Speed survey summary statistics (**Site 2** westbound 24 hour)*

	85th percentile mph	Mean mph	% 31+ mph	% 41+ mph
Sat 17th Oct 2020	30.8	26.7	13.3%	0.2%
Sun 18th Oct 2020	31.9	27.3	16.4%	0.2%
Mon 19th Oct 2020	30.6	26.0	11.6%	0.1%
Tues 20th Oct 2020	30.6	26.4	11.7%	0.1%
Weds 21st Oct 2020				
Thurs 22nd Oct 2020	30.6	26.4	12.0%	0.2%
Fri 23rd Oct 2020	30.9	26.7	14.4%	0.2%
Sat 24th Oct 2020	30.9	27.0	13.8%	0.1%
Sun 25th Oct 2020	32.3	27.5	17.2%	0.2%
Mon 26th Oct 2020	30.7	26.3	12.3%	0.1%
Tues 27th Oct 2020	30.6	26.2	11.9%	0.1%
Weds 28th Oct 2020	30.6	26.2	11.5%	0.0%
Thurs 29th Oct 2020	30.5	26.2	10.8%	0.1%
Fri 30th Oct 2020	30.4	25.9	10.2%	0.1%
Sat 31st Oct 2020	32.1	27.4	16.8%	0.3%

*Table 14: Speed survey summary statistics (**Site 3** westbound 24 hour)*

	85th percentile mph	Mean mph	% 31+ mph	% 41+ mph
Sat 17th Oct 2020	37.7	29.3	39.5%	3.1%
Sun 18th Oct 2020	38.3	30.5	45.7%	3.9%
Mon 19th Oct 2020	37.3	28.2	36.7%	2.5%
Tues 20th Oct 2020	37.3	28.7	35.7%	2.7%
Weds 21st Oct 2020				
Thurs 22nd Oct 2020	37.3	28.6	36.1%	2.4%
Fri 23rd Oct 2020	37.7	29.0	39.2%	2.9%
Sat 24th Oct 2020	37.9	30.1	41.8%	2.7%
Sun 25th Oct 2020	38.4	30.9	47.6%	3.5%
Mon 26th Oct 2020	37.1	28.3	34.7%	2.3%
Tues 27th Oct 2020	36.5	27.5	30.4%	2.4%

*Table 15: Speed survey summary statistics (**Site 1** westbound 24 hour)*

	85th percentile mph	Mean mph	% 31+ mph	% 41+ mph
Sat 12th Dec 2020	35.0	28.3	24.4%	0.6%
Sun 13th Dec 2020	36.0	29.0	29.3%	1.0%
Mon 14th Dec 2020	34.5	28.0	22.9%	0.5%
Tues 15th Dec 2020	34.9	28.2	24.4%	0.5%
Weds 16th Dec 2020				
Thurs 17th Dec 2020	35.0	28.2	24.6%	0.4%
Fri 18th Dec 2020	34.6	28.1	23.0%	0.7%
Sat 19th Dec 2020	35.3	28.5	25.8%	0.8%
Sun 20th Dec 2020	35.5	28.6	26.8%	0.8%
Mon 21st Dec 2020	34.0	27.9	21.3%	0.4%

*Table 16: Speed survey summary statistics (**Site 3** westbound 24 hour)*

	85th percentile mph	Mean mph	% 31+ mph	% 41+ mph
Sat 12th Dec 2020	47.0	37.9	83.9%	30.6%
Sun 13th Dec 2020	48.0	38.7	85.2%	36.4%
Mon 14th Dec 2020	46.7	37.0	79.1%	29.1%
Tues 15th Dec 2020	46.5	37.0	79.0%	28.2%
Weds 16th Dec 2020				
Thurs 17th Dec 2020	47.2	37.7	81.9%	30.5%
Fri 18th Dec 2020	47.1	37.7	81.9%	31.5%
Sat 19th Dec 2020	47.2	37.9	83.8%	31.0%
Sun 20th Dec 2020	48.0	38.7	85.2%	35.1%
Mon 21st Dec 2020	46.1	36.4	78.4%	26.6%

8. Theoretical calculation of NO_x exhaust emissions

8.1 Calculation of emission rates westbound assuming different speed limits

A comparison was made of the westbound speed profile of the Smogmobile survey vehicle with the 30mph speed limit and the 40 mph speed limit. For reasons of safety and legality, the Smogmobile survey vehicle complied with the prevailing speed limits. A 'representative' journey or 'run' was used for each case, selected from the multiple survey runs.

The comparison was made over the westbound section from Chideock Village Hall to the western extremity of the AQMA (consistent with sections D to H inclusive in Figure 21), a distance of around 500 metres. The speed profile comparison is presented in Figure 34.

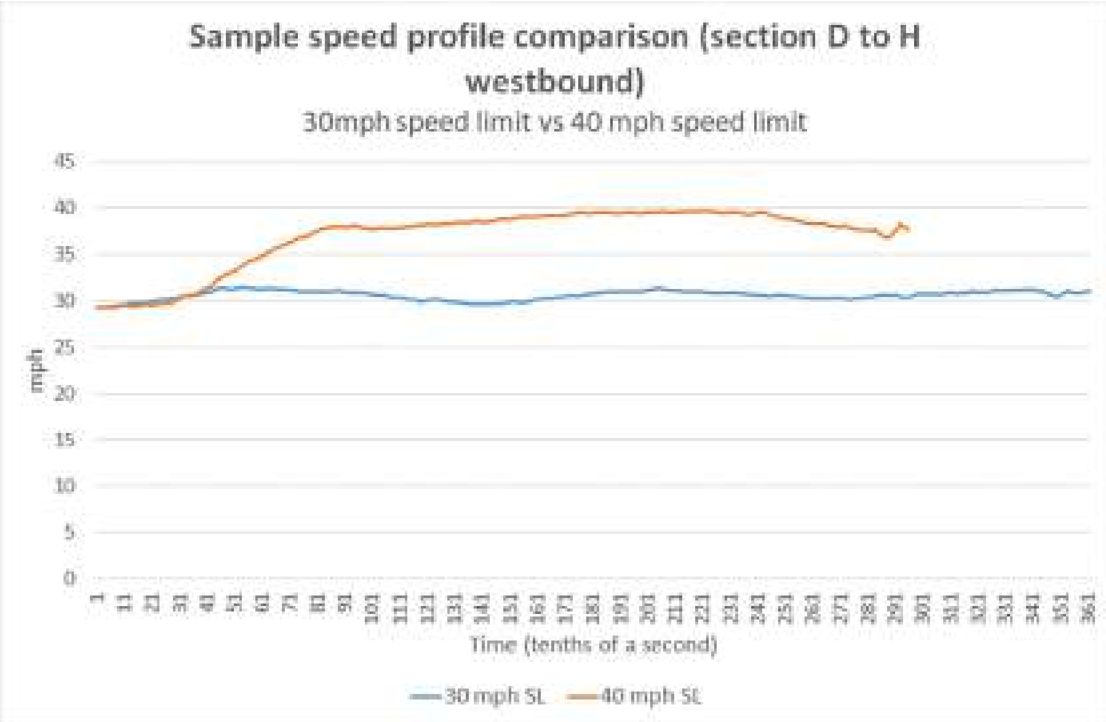

Figure 34: Sample speed profile comparison – 30mph speed limit vs 40mph speed limit

Obviously, over the fixed distance, the travel time with the 30mph speed limit (36.2 seconds) is greater than the travel time with the 40mph speed limit (29.6 seconds), with this sample of speed data.

As previously reported, the highway gradient increases as one travels westbound from Chideock Village Hall to the western extremity of the AQMA, as detailed in Table 17.

PEMS (Portable Emissions Monitoring System) tailpipe exhaust emissions monitoring data is not available in the UK public domain for such steep highway gradients. PEMS data currently available includes NO_x mg/sec matrices derived from DfT 2016 PEMS ('Dieselgate') surveys and DVSA 2017 PEMS (Vehicle Market Surveillance) surveys for Euro 5 and Euro 6 diesel cars (NO_x mg/sec by vehicle speed and acceleration). Newer DVSA 2018 PEMS (Vehicle Market

Surveillance) data has been recently released, but was not available in a comparable format to the other surveys at the time of writing this report.

Table 17: Westbound highway gradient (sections D to H inclusive)

Section	Gradient (degrees)
D	4.33
E	5.17
F	5.82
G	6.19
H	6.48

The effect of highway gradient on NO_x emissions from diesel cars was estimated by calculating the power (kW) required to overcome the gradients in sections D to H at these speeds, and then calculating the acceleration value which corresponds to the same power requirement (kW) for a 'typical' passenger car, i.e. using additional acceleration as a proxy for gradient (because the existing emissions matrices are presented in terms of vehicle speed and acceleration only). Adopting this approach, the 'additional' acceleration value as a proxy for gradient was found to be in the range 0.75 to 1.1 m/s^2 for sections D to H. It should be noted that adding this level of additional acceleration means that the NO_x emission values being utilised from the emissions matrices are at the outer boundary of the data set in terms of sample size (because in 'normal' driving, such high acceleration rates are encountered less frequently).

Table 18: Estimated NO_x mg/km results

	Euro 5 diesel car			**Euro 6 diesel car**		
Section	**40mph SL**	**30mph SL**	**Change**	**40mph SL**	**30mph SL**	**Change**
D	3381	3245	96.0%	2268	2092	92.2%
E	3684	3297	89.5%	3015	2053	68.1%
F	3598	3606	100.2%	2962	2395	80.9%
G	3555	3824	107.5%	2945	2654	90.1%
H	3573	3796	106.2%	2870	2550	88.8%
Total	**3558**	**3553**	**99.9%**	**2812**	**2349**	**83.5%**

Table 18 presents the estimated results from this analysis in terms of NO_x mg/km. The following observations can be made.

- NO_x emission rates from a Euro 6 diesel car are generally lower than from a Euro 5 diesel car, but in addition, the Euro 6 diesel car NO_x emissions are more sensitive to changes in speed and acceleration;
- For both Euro 5 and Euro 6 diesel cars, the removal of the acceleration phase by implementing the 30mph speed limit (i.e. not accelerating to 40 mph), reduces NO_x emissions in section D and particularly E (immediately after the old 40mph speed limit sign);
- However, for Euro 5 diesel cars, the combination of relatively lower sensitivity to changes in speed and acceleration (relative to Euro 6), together with the increased journey time (36.2 seconds vs 29.6 seconds), results in little change overall in total NO_x emissions (mg/km) over the 500 metre section between the two speed limit scenarios. These results should be interpreted with knowledge of the limitations of

the available NO_x emissions matrices in terms of sample size, particularly for higher acceleration rates; there is inherent uncertainty in NO_x emission rates for particular combinations of speed and higher acceleration due to limited data availability;

- For Euro 6 diesel cars, the introduction of the 30 mph speed limit does result in an overall reduction in NO_x emissions of about 16.5%, with a particularly notable reduction due to the removal of the acceleration phase in section E (32% reduction);
- Extrapolating these broad brush results to the wider fleet is challenging, but some simple assumptions could be made. According to NAEI (National Atmospheric Emissions Inventory) UK fleet data for 2020, diesel cars and vans comprise 51.2% of rural vehicle kilometres at 2020. In addition, approximately 55% of these light diesel vehicles are Euro 6 standard at 2020. So a 16.5% reduction in NO_x emissions from Euro 6 light diesel vehicles might result in a 4.6% reduction in NO_x fleet emissions overall (excluding additional potential NO_x increases / decreases from other vehicle types);
- Due consideration should be given to the uncertainties inherent in these broad brush calculations, particularly relating to assumptions regarding NO_x emissions under high acceleration rates (small sample sizes). Primary PEMS exhaust emissions data does not exist in the UK public domain for such steep highway gradients as found on Chideock Hill; acceleration power was used in this calculation as a proxy for gradient power. The calculations also assume compliance with the 30mph speed limit.

9. Summary observations and conclusions

The high nitrogen dioxide concentrations observed on the A35 at Chideock are primarily a consequence of the levels of traffic flow in combination with the steep uphill gradient westbound. The steep gradient increases vehicle engine load, especially when accelerating up the hill, leading to increased emissions. The problem is exacerbated by the peaks in seasonal tourist traffic in the summer months.

Monitoring of NO_2 concentrations using diffusion tubes indicates that some monitoring sites (such as sites 724 Duck Street, and 726 Village Hall) which historically have exceeded the 40µg/m^3 annual mean limit value have now fallen below the 40µg/m^3 threshold, presumably due to the evolution of the vehicle fleet and the introduction of newer, cleaner vehicles. However, there are still some local authority monitoring locations (such as 727 Whitecroft, and N14 Hill House) which continue to record very high, albeit reduced in recent years, NO_2 concentrations. The additional diffusion tubes deployed by Highways England since the beginning of 2019 indicate that a number of physical locations continue to be in breach of the annual mean limit value.

The analysis of monthly diffusion tube data in combination with traffic flow and traffic speed data has confirmed the strong correlation between monthly traffic volumes and NO_2 concentrations, over the period January 2017 to September 2020. The correlation between NO_2 concentrations and traffic speed is relatively weak. However, the analysis did indicate that NO_2 concentrations were better explained by a combination of traffic flow and traffic speed, than by traffic flow alone, i.e. traffic speed does have some influence. The analysis of the monthly traffic speed data also identified the impact of the recent temporary extension of the 30mph speed limit up Chideock Hill on mean westbound speeds, and the analysis of the traffic flow data confirmed the impact of the Covid-19 lockdown on traffic flows in 2020.

The 'Smogmobile' surveys provided a snap shot of NO_2 concentrations on the A35 up Chideock Hill, both before and after the introduction of the temporary extended 30mph speed limit. The analysis was complicated significantly by the differences in prevailing traffic volumes during the two phases of the surveys. The first survey (before the temporary traffic order was implemented) was carried out in July/August 2019 during the tourist season, whereas the second survey was carried out in October 2019 when traffic flows were approximately 30% lower. However, after making adjustments for the differences in traffic flow, the analysis did indicate that there was some modest and localised air quality benefit in retaining the extended 30mph zone, due to the discouragement of westbound vehicle acceleration (where previously vehicles would accelerate from 30mph to 40mph). This served to reduce NO_2 concentrations within this 'acceleration zone', particularly if the 30mph speed limit on Chideock Hill included appropriate measures for compliance. It was noted during the second Smogmobile survey that significant numbers of drivers were ignoring the extended 30mph speed limit.

The potential benefits of influencing vehicle speed and vehicle acceleration were confirmed by the (limited) theoretical calculations of NO_x exhaust emission rates from different westbound speed profiles, assuming either 30mph or 40mph speed limits. This indicated a reduction in NO_x emissions from Euro 6 diesel passenger cars assuming a 30mph speed limit (compared to a 40mph speed limit), with especially notable localised benefits as a consequence of removing the acceleration phase. Again, this assumes that appropriate speed limit compliance measures are implemented.

In summary, based on the balance of available evidence at the present time, it is recommended that the temporary 30mph traffic order on Chideock Hill be made permanent, combined with appropriate speed limit compliance measures, in order to retain the NO_2 reduction benefits set out in this report.

Annex A

A35 Chideock NO_2 diffusion tube locations (Source: LAQM Annual Status Report 2018)

Site ID	Site name	Site type	X OS Grid ref	Y OS Grid ref	Pollutants monitored	In AQMA?	Distance to relevant exposure (m)	Distance to kerb of nearest road (m)	Height (m)
722	Chideock Main St.	Roadside	342364	92814	NO_2	N	Y (2m)	1.5m	2
723	Chideock St Giles Church	Roadside	342151	92869	NO_2	N	Y – Representative of public exposure	2m	2
724	Chideock Duck St.	Roadside	342190	92840	NO_2	Y	Y – on façade	1m	2.5
725	Chideock George Inn	Kerbside	342486	92791	NO_2	N	Y – Representative of public exposure	0m	2
726	Chideock Village Hall	Roadside	342015	92887	NO_2	Y	Y – Representative of public exposure	2m	2.5
727	Chideock Main St.	Roadside	341946	92908	NO_2	Y	Y – on façade	1m	2
728	Chideock Main St.	Roadside	342025	92894	NO_2	N	Y – Representative of public exposure	1.5m	2
738	Greenhills	Roadside	341678	93040	NO_2	Y	3.5m	17m	2.5