Scottish Air Quality Database

Annual Report 2018

Report for Scottish Government

RICARDO
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Energy & Environment

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Executive summary

In April 2007, Ricardo Energy & Environment were commissioned by the Scottish Government to undertake a 3-year project (Apr 2007 – Apr 2010) to develop an Air Quality Database and Website for Scotland. This contract has been renewed in recent years, with the latest contract running from 2016-2019.

This report brings together all the Scottish Air Quality Database data for calendar year 2017 and associated work relating to project deliverables including: data management; QA/QC services; liaison with stakeholders; website development; spatial analysis of air quality data; trend analysis. In addition, the report presents the additional activities and further developments undertaken during the eleventh year of the project, July 2018 – June 2019.

Legislation and Policy

The "Cleaner Air for Scotland – The Road to a Healthier Future" (CAFS) strategy was published by the Scottish Government in November 2015. The purpose of CAFS is to provide a national framework which sets out how the Scottish Government and its partner organisations propose to achieve further reductions in air pollution and fulfil their legal responsibilities as soon as possible. CAFS outlines the contribution that better air quality can make to sustainable development whilst improving health and the natural environment and reducing health inequalities for the citizens of Scotland.

In addition to the six main objectives, CAFS outlines new initiatives to be implemented to compliment the objectives set; these initiatives include a National Modelling Framework and National Low Emissions Framework. CAFS outlines further changes such as the adoption of the WHO guideline value for $PM_{2.5}$; this was transposed by the Air Quality Scotland Amendment Regulations 2016 when the annual mean objective for $PM_{2.5}$ was set at 10ug m^{-3} in April 2016.

The Scottish Government published the NLEF framework in January 2019. The framework provides a methodology for local authorities to undertake air quality assessment to inform decisions on transport related actions.

During the first half of 2019, the Scottish Government carried out an indepth independent review of CAFS and the resulting documents were published in July 2019. The Scottish Government intend to use the information and recommendations made from this review to update CAFS in 2020.

Air Quality Monitoring in Scotland

Air pollution data for 97 automatic monitoring sites throughout Scotland are available in the database for all or part of 2018. All automatic data maintained within the Scottish database are subject to the same QA/QC procedures as at the national network air quality monitoring stations within the UK Automatic Urban and Rural Network. This ensures that all data in the database are quality assured and traceable to UK national calibration standards for the various pollutants.

Analysis shows that data capture rates since 2008 have continued to improve, year on year, for both nitrogen dioxide (NO_2) and Particulate Matter (PM_{10}). A significant improvement in PM_{10} data capture seen between 2016 and 2017 has been attributed to a change in analyser used within the network.

In 2018 six automatic monitoring sites exceeded the annual mean objective for NO_2. However, in 2018, 74 NO_2 diffusion tube monitoring sites exceeded the annual mean objective. The majority of these exceedances were located in and around the 4 cities of Glasgow, Edinburgh, Dundee and Aberdeen.

In 2018, two sites exceeded the PM_{10} annual objective for PM_{10}.

The pattern of measured concentrations is similar to previous years in that where exceedances of the Scottish air quality objectives occur, these are in areas where the relevant local authority has already declared or is in the process of declaring an Air Quality Management Area (AQMA).

In 2018, the Air Quality Strategy Objective the ozone objective was exceeded at 9 out of the 11 sites measuring the pollutant in Scotland. In the same year, no exceedances were observed for the pollutants $PM_{2.5}$, SO_2, CO, benzene, 1,3-butadiene and benzo(a)pyrene.

Air Quality Mapping of Scotland

Ricardo Energy & Environment provide mapped concentrations of modelled background air pollutant concentrations on a 1 km x 1 km basis for the whole of Scotland. Modelled roadside air pollutant concentrations are provided for road links in Scotland. The air pollution maps are derived from a combination of (1) measurements from Scotland's network of air quality monitoring stations, and (2) spatially disaggregated emissions information from the UK National Atmospheric Emissions Inventory (NAEI). This report provides maps modelled using 2017 data, the most recent year for which inventory data is available.

For NO_2, there were no modelled exceedances of the Scottish annual mean objective of 40 µg m^{-3} at background locations. Exceedances of the annual mean NO_2 objective at roadside locations were modelled at 38 road links (57.5 km of road) in the Glasgow Urban Area and at 11 road links (21.7 km of road) in Central Scotland. In the Edinburgh Urban Area and the North East Scotland zone there were fewer than five road links where exceedances of the Scottish annual mean NO_2 air quality objective were modelled, affecting 4-6 km of roads.

There were no modelled exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} at background locations. Two road links (3.9 km of road) were identified as exceeding the Scottish annual mean PM_{10} air quality objective. Exceedances of the Scottish annual mean PM_{10} objective were modelled in the Glasgow Urban Area only.

Air Quality Trends for Scotland

Data held within the database covering many years have been used to assess possible trends in air pollution throughout Scotland. Air quality trends have been examined on the basis of individual monitoring sites, and subsets of long-running sites, rather than the composite dataset.

NO_2

Trend Analysis of nitrogen dioxide concentrations at Scotland's five long-running urban non-roadside sites suggests that NO_2 concentrations are in general decreasing however not all at the same rate. It also indicates that NO_2 concentrations are decreasing at a greater rate in the larger urban areas.

Nitrogen dioxide concentrations at Scotland's three long-running rural sites showed decreasing trends. Bush Estate and Eskdalemuir showed small but highly significant downward trends. However, this was not the case for Glasgow Waukmillglen Reservoir, where concentrations were decreasing very slightly year-on-year.

Scotland has a large number of urban traffic monitoring sites monitoring NO_2, of which 30 have now been operating for at least 10 years. This trend analysis therefore focussed on eight of these sites that have operated for 10 years and have reported exceedances of the AQS objective in recent years. All these sites showed significant downward trends, with seven of the eight site trends significant at the 0.001 level.

Examination of trends at the same nine sites over the most recent five complete years (2018 to 2018) indicates that the patterns are mostly very similar to the 10-year trends. The exception being N. Lanarkshire Chapelhall where the trend switches from a downwards to an upward trend (though not statistically significant).

PM_{10}

PM_{10} at Scotland's eight long-running urban non-roadside sites showed a significant or highly significant downward trend. PM_{10} at Scotland's nine long-running urban traffic (roadside and kerbside) sites showed statistically significant downward trends at all sites (at the 0.001 level in all but one case).

Examination of trends in PM_{10} at the same nine sites over the most recent five complete years (2014 to 2018) indicates that, at some of these, the decreasing trends have continued but at others they have weakened, levelled off or switched to an increasing trend (Glasgow Byres Road). For Edinburgh Queensferry Road analysis indicates a highly significant increasing trend. However, this may have been influenced by ongoing construction works close to the monitor location.

Only four sites in Scotland have 10 years or more particulate matter 2.5 ($PM_{2.5}$) data. Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth sites show slight but highly statistically significant downward trends. Contrary to this, the rural site Auchencorth Moss shows a slight upward trend however not statistically significant.

$PM_{2.5}$

At the time of writing this report there are 63 sites monitoring $PM_{2.5}$ in Scotland. However, the vast majority of these sites started monitoring in the last 3 years with the introduction of the $PM_{2.5}$ objective and the requirement for local authorities to measure the pollutant. By the end of 2018 there were four sites with 10 consecutive years of $PM_{2.5}$ data. Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth sites show slight but highly statistically significant (at the 0.001 level) downward trends for $PM_{2.5}$. Contrary to this, the rural site Auchencorth Moss shows a slight upward trend however not statistically significant.

Ozone

Ozone has been measured at three rural sites in Scotland for thirty years. All three sites showed small positive trends over this very long period, highly statistically significant at two of the three sites. Ozone has been measured for the past 10 years at six rural sites. Over this more recent period only one site (Lerwick) showed a significant trend (positive)– so trends over this more recent period are less consistent. Ozone concentrations showed no significant trends at one of the two urban background sites which have monitored this pollutant for the past 10 years, while the other site showed a slightly positive trend.

Emissions of Pollution Species

Scotland NOx emissions have declined by 73% since 1990 and were estimated to be 93kt in 2017 representing 11% of the UK total. This decline is driven by the continued introduction of tighter vehicle emissions standards over the last decade. Since 2008, emissions from passenger cars have further decreased. This has been mainly driven by improvements in catalyst repair rates resulting from the introduction of regulations controlling the sale and installation of replacement catalytic converters and particle filters for light duty vehicles. However, the increasing number of diesel cars partly offsets these emissions reductions, because diesel cars emit higher NO_x relative to their petrol counterparts (88% of 2017 passenger car emissions is due to diesel cars).

Emissions of PM_{10} have declined by 63% since 1990 and in 2017 and were estimated to be 15kt (9% of the UK total). PM_{10} exhaust emissions from diesel vehicles have been decreasing due to the successive introduction of tighter emission standards over time. The decline in PM_{10} emissions has basically stopped across all sectors over the past few years with some, such as Industrial Processes increasing. This has been attributed to an increased quantity of wood fuel use. In addition, almost all other emissions sources have remained stable since 2011. Though PM_{10} emissions have reduced since 1990, overall there has been no significant reduction in PM_{10} emissions since 2013.

Emissions of $PM_{2.5}$ have declined by 68% since 1990 and in 2017 were estimated to be 8kt (8% of the UK total). For $PM_{2.5}$, the residential, commercial and public sector combustion category accounts for 42% of 2017 emissions. The decline in emissions has significantly reduced over the past few years with no significant decrease since 2013. One of the reasons for this slowing has been attributed to the increase in emissions from the residential sector and in particular the combustion of wood.

SAQD Developments and Websites Updates

Expansion of the $PM_{2.5}$ Network

The $PM_{2.5}$ network continues to expand with 14 new sites added to the network by the end of 2018. At the time of writing this report there were 63 sites.

Air Quality in Scotland App

In October 2018 Scottish Government commissioned Ricardo to update the Air Quality in Scotland App. As well as update the app, Scottish Government took this opportunity to increase the capabilities of the App by adding new functionality. These functionalities included:

- App Notification Alert Function for elevated site data
- App Notification Alert Function for Local Authority areas with forecast elevated pollution
- App Notification Alert Function when entering an AQMA
- Interactive AQMA map and Summary page which provides the location, area covered by the AQMA and supporting information on each AQMA in Scotland.

In June 2019 the newest version of the Air Quality in Scotland App was released.

Development of NO_2 Diffusion Tube Map

In October 2018 Scottish Government commissioned Ricardo to develop a NO_2 diffusion tube database and Map similar to what is already provided for the automated site data. The map was release live on the Air Quality in Scotland website in June 2019. The Map provides bias corrected annual mean data previously published in the local authorities' annual progress report and has the following features:

- Due to the large number of diffusion tube sites compared to automatic sites, a cluster format will be applied (i.e. when the user is zoomed out and can see the full map of Scotland each local authority will display the number of diffusion tube sites available rather than individual sites. When selected the map zooms in to display the individual sites) enabling the user to easily select specific sites whilst at the same time having a map easy to use, isn't overly busy and is visually aesthetic.
- The colour of each site markers will be related to the NO_2 annual mean concentration (i.e. displayed red when the annual mean exceeds 40 $\mu g\ m^{-3}$).
- A Year Selector will enable the user to view historical data from current and closed sites.
- A Local Authority drop down list will provide the user an alternative way to specify which local authority and site they wish to obtain data from rather than using the map.
- When the user selects a site, specific site details will appear giving information such as, site type, location coordinates, historical data, graphing capabilities.

Interactive Pollution Plots

Scottish Government commissioned Ricardo to update pollution graphs to a more interactive, visually more attractive plotting format and they were release on the website in June 2019. The new graphing format allows the user to obtain actual concentrations, zoom in on certain dates and times, print and download (to various formats) individual graphs. In addition, a new site comparison functionality has been included enabling the user to compare their site data to any other site in Scotland on the same plot.

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1 Introduction

The Scottish Government undertakes considerable monitoring of a wide range of air pollutant species as part of a joint UK programme run in conjunction with Defra, the Welsh Government and the Department of the Environment in Northern Ireland. In addition, a large number of local authorities in Scotland monitor air quality within their geographical boundaries as part of the requirements of the Local Air Quality Management system. Prior to 2006, air quality data in Scotland outside of the nationally operated sites were collected by a wide range of organisations for many purposes and were widely dispersed. Consequently, and following experience gained across the rest of the UK it was recognised that a comprehensive centralised resource providing air quality information for Scotland would serve to improve the quality of research and data analysis required to support Scottish air quality policy. Hence, in 2006, the Scottish Government contracted AEA, now Ricardo Energy & Environment, to undertake a pilot programme to develop an air quality database for Scotland.

The pilot study developed the initial Scottish Air Quality Database (SAQD) and Website, undertook stakeholder feedback and assessed the air quality data available across Scotland. The key recommendations that were developed from this initial study were based around the methodology for successful harmonisation of existing air quality monitoring data. It was suggested that a programme for Scotland should include the following components:

- Independent audits of every site - to include checks on both the analysers and the site calibration cylinders.
- Regular data checks.
- Longer term data checking and adjustment where necessary.

Following this pilot study, Ricardo Energy & Environment were commissioned to undertake the next stage which was to further develop and extend the SAQD and website incorporating all stakeholder comments and to bring selected Local Authority sites in line with the national QA/QC requirements. Reports relating to earlier years of the project are available on the Air Quality Scotland website (www.scottishairquality.co.uk).

This annual report summarises the progress made during 2018 in the on-going project tasks and also highlights the new work undertaken during 2018. **Section 2** of this report provides a breakdown of the legislation and policy that drives local air quality management within Scotland.
Section 3 provides a summary of the latest annual Air Quality in Scotland Seminar.

The network of sites within the Scottish Air Quality Database is dynamic and forever changing to address the requirements of the local authorities to deal with air pollution issues. **Section 4** describes in detail the structure of the database in terms of number and type of sites as well as pollutants measured, and how it has changed over the past year.

Quality Assurance and Quality Control (QA/QC) is an integral part of the SAQD project. Since conception of the SAQD project, the QA/QC programme has expanded and adapted to encompass the dynamicity of the database and the changing best practice guidance and regulations. **Section 5** of this report provides detailed information on the QA/QC process and how this was applied to the Scottish Air Quality Database during 2018.

A statistical summary of all the available Scottish air quality data is provided in **Section 6**. This includes all pollutants covered under the Air Quality Strategy as well as other monitoring networks.

In 2009, a pilot mapping exercise specific to Scotland was undertaken including future year projections for 2010, 2015 and 2020. This pilot exercise has been subject to further development in subsequent years and an improved methodology has been used to deliver pollution climate mapping of NO_x, NO_2 and PM_{10} including projections. As the number of monitoring sites in Scotland has significantly increased since 2006, it has become feasible to undertake pollution climate mapping of NO_x, NO_2 and PM_{10} using solely Scottish measurement data. As part of the Scottish Air Quality Database **project**, Ricardo Energy & Environment provide mapped concentrations of modelled background air pollutant concentrations on a 1 km x 1 km basis for the whole of Scotland. The Scottish pollution climate mapping work carried out in 2018 is described in **Section 7**.

The SAQD has accumulated a substantial body of air quality data since its establishment which in turn allows for robust statistical trend analysis to be undertaken. **Section 8** of this report provides a discussion of trends in pollutant concentrations across Scotland, based on the latest available data. The trend analysis focuses on roadside and urban background locations across Scotland and pollutants nitrogen dioxide (NO_2) and particulate matter (PM_{10} and $PM_{2.5}$).

Section 9 provides most up to date and historical data on emissions of pollutants into the atmosphere in Scotland. The data is obtained from the UK National Atmospheric Emissions Inventory (NAEI) and the Scottish Pollution Release Inventory (SPRI)

Throughout 2018 there were a number of developments and projects carried out as part of and in relation to the SAQD project. Section 10 of this report provides information on these.

2 Legislation and Policy

Air quality management is shaped by legislation and policy set at Scottish, UK and EU levels. The foundations of Scotland's air quality management system are based on the following air quality directives adopted by all Member States of the European Union:

- Directive 2008/50/EC - on ambient air quality and cleaner air for Europe (the Air Quality Directive).
- Industrial Emissions Directive 2010/75/EC – Controls emissions from industrial activities.
- National Emission Ceilings Directive 2016/2284/EU – sets emission limits for five important air pollutants
- Clean Air Policy Package and Clean Air Programme for Europe-new air quality objectives to 2030, to improve air quality within cities.

Domestic air quality legislation is largely derived from the requirements of the Environment Act 1995.

In the UK, air quality is a devolved matter, with the Scottish Government having responsibility for the development of air quality policy and legislation for Scotland. The Scottish Government has duly transposed these Directives into national law through the Air Quality Strategy and Air Quality Standards (Scotland) Regulations 2010, and the Pollution Prevention and Control (Scotland) Regulations 2012. The National Emission Ceilings Directive was transposed on a UK basis by the National Emission Ceilings Regulations 2018. The 2010 Regulations also incorporates the 4th air quality daughter directive (2004/107/EC), which sets targets for ambient concentrations of specific heavy metals and polycyclic aromatic hydrocarbons. Equivalent regulations exist in England, Wales and Northern Ireland.

A substantial review of the EU's air quality policy, including the Air Quality Directive was undertaken in 2013 with the Commission adopting a new Clean Air package, including a new Clean Air programme for Europe with measures to ensure that existing targets are met in the short term, and new air quality objectives for the period up to 2030. The package also includes support measures to help cut air pollution, with a focus on improving air quality in cities, supporting research and innovation, and promoting international cooperation.

2.1 Air Quality Standards and Objectives

A set of air quality standards and objectives has been developed for several pollutants of concern for human health. The objectives are derived from the standards and are a compromise between what is desirable purely on health grounds and what is practical in terms of feasibility and costs. Each objective has a date by when it must be achieved. The objectives adopted in Scotland for the purpose of Local Air Quality Management are set out in the Air Quality (Scotland) Regulations 2000, the Air Quality (Scotland) Amendment Regulations 2002 and the Air Quality (Scotland) Amendment Regulations 2016. Similar targets are set at EU level, where there are called limit or target values. These limit values are set out in the European 2008 Ambient Air Quality Directive (2008/50/EC) and transposed into Scottish legislation. It is the responsibility of EU Member States to achieve the limit and target values. A summary of the current Scottish air quality objectives is provided in the table below.

Table 2.1 Summary of Scotland's Air Quality Objectives

AQ Objective-Pollutant	Concentration	Measured as	Date to be achieved by
Nitrogen Dioxide (NO_2)	200 µg m^{-3} not to be exceeded more than 18 times a year	1-hour mean	31.12.2005
	40 µg m^{-3}	Annual mean	31.12.2005
Particulate Matter (PM_{10})	50 µg m^{-3}, not to be exceeded more than 7 times a year	24-hour mean	31.12.2010
	18 µg m^{-3}	Annual mean	31.12.2010

AQ Objective-Pollutant	Concentration	Measured as	Date to be achieved by
Particulate Matter ($PM_{2.5}$)	10 µg m^{-3}	Annual mean	31.12.2020
Sulphur Dioxide (SO_2)	350 µg m^{-3}, not to be exceeded more than 24 times a year	1-hour mean	31.12.2004
	125 µg m^{-3}, not to be exceeded more than 3 times a year	24-hour mean	31.12.2004
	266 µg m^{-3}, not to be exceeded more than 35 times a year	15-minute mean	31.12.2005
Benzene	3.25 µg m^{-3}	Running annual mean	31.12.2010
1,3 Butadiene	2.25 µg m^{-3}	Running annual mean	31.12.2003
Carbon Monoxide	10.0 mg m^{-3}	Running 8-Hour mean	31.12.2003
Lead	0.25 µg m^{-3}	Annual Mean	31.12.2008
Poly Aromatic Hydrocarbons*	0.25 ng m^{-3}	Annual Mean	31.12.2010
Ozone*	100 µg m^{-3} not to be exceeded more than 10 times a year	8 hourly running or hourly mean	31.12.2005

* not required to be monitored or assessed by local authorities under LAQM, however is a UK requirement under EU directive (Directives 2004/107/EC and 2008/50/EC)

2.2 Cleaner Air for Scotland-The Road to a Healthier Future

The "Cleaner Air for Scotland – The Road to a Healthier Future" (CAFS) strategy was published by Scottish Government in November 2015. The purpose of CAFS is to provide a national framework which sets out how the Scottish Government and its partner organisations propose to achieve further reductions in air pollution and fulfil their legal responsibilities to achieve the air quality objectives. It recognises that although progress has been made through Scotland, areas of poorer air quality still exist within towns and cities.

CAFS considers the impact of air quality on health and looks at the estimated costs as well as the premature deaths associated with poor air quality. It has been estimated that around 1,700 premature deaths across the Scottish population are associated with fine particulate air pollution[1].

During the first half of 2019 the Scottish Government carried out an indepth independent review of CAFS and the documents were published in July 2019. The Scottish Government plan to use the information and recommendations made from this review to update CAFS in 2020. More information can be found on the Air Quality in Scotland website (http://www.scottishairquality.scot/lez/cafs-review-documents).

2.2.1 Cleaner Air for Scotland- Objectives

The Strategy outlines six main objectives. The document sets out the main objectives and actions required to achieve improvements in air quality. A summary of the six main objectives and the 40 actions stated in CAFS are set out below.

[1] https://www.hps.scot.nhs.uk/web-resources-container/air-pollution-and-health-briefing-note-mortality-associated-with-exposure-to-fine-particulate-matter-pm25-attributable-mortality-in-scotland/

i. TRANSPORT

A Scotland that reduces transport emissions by supporting the uptake of low and zero emission fuels and technologies, promoting a modal shift away from the car, through active travel (walking and cycling) and reducing the need to travel.

This will be achieved by:

- Ensuring that all local authorities have a corporate travel plan which is consistent with any local air quality action plan.
- Delivering National Walking Strategy & Cycling Action Plan.
- Working collaboratively with delivery partners to deliver our shared vision in the cycling Action Plan for Scotland.
- Review supporting green buses including scope for supporting retrofitting existing vehicles, taking account of Technology and market developments, and climate change.
- Evaluating the Bus Investment Fund.
- Reviewing Bus Operators Grant to incentivise the use of low emission buses.
- Reviewing guidance & legislation on the powers of local transport authorities regarding bus services.
- Delivering Switched On Scotland: A Roadmap to widespread Adoption of Plug in Vehicles.
- Review the Roadmap and develop a post 2015 plug in vehicle action plan.
- With key partners investigate the use of hydrogen as a transport fuel and energy applications.
- Review the role less carbon intensive fuels such as LPG, CNG and biofuels can play towards a near zero emission road transport sector by 2050.
- Encourage Freight Quality Partnerships to consider their Environmental impact.
- Encourage LAs with AQMAs to establish a Freight Quality Partnership to achieve improved air quality.
- Review Ministerial guidance on regional and local transport strategies considering air quality management and to support a modal shift towards sustainable and active travel.
- Review the impacts of trunk roads on AQMAs and implement mitigation where trunk roads are the primary contributor.

ii. HEALTH

A Scotland which protects its citizens from the harmful effects of air pollution and reducing health inequalities

This will be achieved by:

- NHS boards and their local authority partners to include reference to air quality and health in joint health protection plans.
- Include in legislation as Scottish objectives, World Health Organization (WHO) guideline values for PM_{10} and $PM_{2.5}$.

iii. LEGISLATION and POLICY

A Scotland where all European and Scottish legal requirements relating to air quality are as a minimum complied with.

This will be achieved by:

- Refocus the Local Air Quality Management system.
- Establish a $PM_{2.5}$ monitoring network.
- Produce revised and updated Scottish action plans to demonstrate how compliance with the EU ambient air quality Directives will be achieved.
- Design develop and implement a two-level modelling system for regional and local scales to support potential transport and planning solutions to air quality issues.
- Develop guidance and promote s support network for all practitioners in review and assessing air quality.
- Undertake detailed modelling of all four major cities in Scotland (National Modelling Framework).

- Identify requirements and undertake data collection for additional urban areas within three years.
- Implement the national databases for traffic data collection and local modelling outputs associated with CAFS.
- Ensure the NLEF criteria, test, and processes are developed agreed and finalised.
- Design and implement a standard appraisal process for assessing local air quality measures.
- Develop software tools and guidance for the NLEF including funding options and technical reports.

iv. PLACEMAKING

A Scotland where air quality is not compromised by new or existing development and where places are designed to minimise air pollution and its effects.

This will be achieved by:

- Ensuring Scottish Planning Policy and the National Planning Framework take account of CAFS.
- Ensuring Local Development Plans policies are consistent with CAFS objectives and any local authority air quality action plans.
- Work with Environmental Protection Scotland to produce updated guidance on air quality and planning.
- Work with SEPA to introduce air quality training for local authority planners.
- Support SEPA in revising its guidance on Strategic Environmental Assessment to bring it into line with CAFS.

v. COMMUNICATION

A Scotland where all are well informed engaged and empowered to improve our air quality.

This will be achieved by:

- Develop a Scottish Air Quality Indicator to assist in assessing compliance with air quality legislation and delivery of CAFS objectives;
- Developing a national air quality public awareness campaign
- Support the ongoing Greener Scotland communication campaigns, encouraging individuals to use the car less to improve their health and their local environment.

vi. CLIMATE CHANGE

Reducing greenhouse gas emissions and achieving renewable energy targets whilst delivering co-benefits for air quality.

This will be achieved by:

- Ensuring ‘Low Carbon Scotland: Meeting Our Emissions Reduction Targets’ publication takes into account air quality impacts.
- Expecting Scottish local authorities to ensure a Sustainable Energy Action Plan includes air quality considerations.
- Working with Forestry Commission Scotland to publish updated guidance on the impact of biomass on air quality to help local authorities fulfil their statutory responsibilities.

2.2.2 Cleaner Air for Scotland- $PM_{2.5}$

In addition to the six main objectives, CAFS outlines new initiatives to be implemented to compliment the objectives set; these initiatives include a National Modelling Framework and National Low Emissions Framework. CAFS outlines further changes such as the adoption of the WHO guideline value for $PM_{2.5}$; this was transposed by the Air Quality Scotland Amendment Regulations 2016 when the annual mean objective for $PM_{2.5}$ was set at 10µg m^{-3}. Scotland was the first country in Europe to adopt the guideline value in legislation.

2.3 National Modelling Framework

The National Modelling Framework (NMF) will provide a two-tiered standardised approach to modelling air quality in Scotland. Detailed models for the first four cities covering Glasgow, Edinburgh, Aberdeen and Dundee will provide evidence for taking direct actions at the city scale to reduce street-level emissions. The regional model will provide a tool for screening and assessing the potential air quality impacts associated with large-scale planned developments across local authority areas. The NMF will help with providing evidence for actions developed through the National Low Emission Framework.

2.4 National Low Emission Framework

The National Low Emission Framework (NLEF) has been developed to assist in the appraisal of air quality improvement options related to transport. Together with the National Modelling Framework, it provides guidance on the appraisal of such measures to help facilitate consistent assessment and implementation across Scotland.

The Scottish Government published the NLEF framework in January 2019 and it is available at http://www.scottishairquality.scot/news/reports?view=technical. The framework provides a methodology for local authorities to undertake air quality assessment to inform decisions on transport related actions.

2.5 Low Emission Zones

In September 2017, the Scottish Government in their Programme for Government, committed to the introduction of Low Emission Zones (LEZs) into Scotland's four biggest cities (Glasgow, Edinburgh, Aberdeen and Dundee) by 2020 and into all other Air Quality Management Areas (AQMAs) by 2023 where the National Low Emissions Framework appraisal advocates such mitigation. The first LEZ was introduced in Glasgow at the end of 2018.

The Scottish Government will work in partnership with local authorities and Regional Transport Partnerships to introduce LEZs. Engagement with transport organisations, businesses and members of the public will help support the design of LEZs. Further information is available at http://www.scottishairquality.scot/lez/ and https://www.lowemissionzones.scot/.

2.6 Local Air Quality Management

The LAQM process places an obligation on all local authorities to regularly review and assess air quality in their areas, and to determine whether or not the air quality objectives are likely to be achieved. Where an exceedance is considered likely the local authority must:

- Declare an Air Quality Management Area (AQMA)
- Assess and identify the reasons for the problem, quantifying the sources of emissions
- Develop an Air Quality Action Plan (AQAP) to help address the problem.

In 2016 the Scottish Government produced and updated Technical Guidance and Policy Guidance for the LAQM regime in UK. One of the main changes was to the LAQM reporting process. An Annual Progress Report (APR) has replaced the previous three-year cyclical process. The LAQM Policy and Technical Guidance are available at http://www.scottishairquality.scot/air-quality/legislation.

3 Air Quality Seminar

As part of the Scottish Air Quality Database project, Ricardo Energy & Environment organise, on behalf of the Scottish Government, organise an annual air quality seminar. The most recent Scottish Government Annual Air Quality Seminar was held at the COSLA building, Verity House, 19 Haymarket Yards, Edinburgh, on Tuesday 12th February 2019. The event was attended by over 80 air quality experts representing the Scottish Government, local authorities, Health Protection Scotland, SEPA, consultancy, academia and students. The objective of the seminar was to discuss some of the most recent work carried out under the Scottish Air Quality Database and Website project and consider a number of other topical air quality issues that affect Scotland.

The seminar covered a number of interesting topics in the field of air quality. These subjects included amongst others; “A trend analysis approach to air quality network data” by Polly Lang (University of York); “Exploring synergies for air pollution and carbon reduction through citizen engagement” by Enda Hayes (University of the West of England); “Air Quality and Health” by Dr Jackie Hyland (NHS Tayside); “Three Decades of Real World Driving Emission – Remote Sensing” by Niranjan Vescio (Opus Inspection); “Application of Real-World Driving Emissions for Air Quality Modelling and Impact Assessments” by Dr Nicola Masey (Ricardo); “Low cost sensors for the measurement of atmospheric composition” by Prof Alastair Lewis (University of York); “Engaging Schools in AQ through an EU Wide Citizen Science Programme” by Colin Gillespie (SEPA); “Transport Bill and Low Emission Zones” by Dr Stephen Thomson (Transport Scotland); “Effects of Vegetation on Urban Air Pollution” by David Fowler (CEH), and “Clean Air Day 2019” by John Bynorth (Environmental Protection Scotland). All presentations can be found on the Scottish air Quality website (www.scottishairquality.co.uk). The full agenda for the day is shown in Figure 3.1.

3.1 Annual Newsletter

In addition to this report, an annual newsletter (Air Pollution in Scotland) is also produced as part of this project. This sets out the legislative and policy background to air quality in Scotland and briefly reviews the latest available air quality monitoring and key results. Trends and mapping of air quality are also summarised along with recent developments and information on how to stay informed with regards to air quality matters (i.e. forecasts, health alerts and social media)

Figure 3.1 Agenda for the Scottish Air Quality Seminar on 12th January 2019

SCOTTISH AIR QUALITY DATABASE AND WEBSITE ANNUAL SEMINAR

Tuesday 12th January 2018

COSLA, Verity House, 19 Haymarket Yards, Edinburgh, EH12 5BH

Agenda

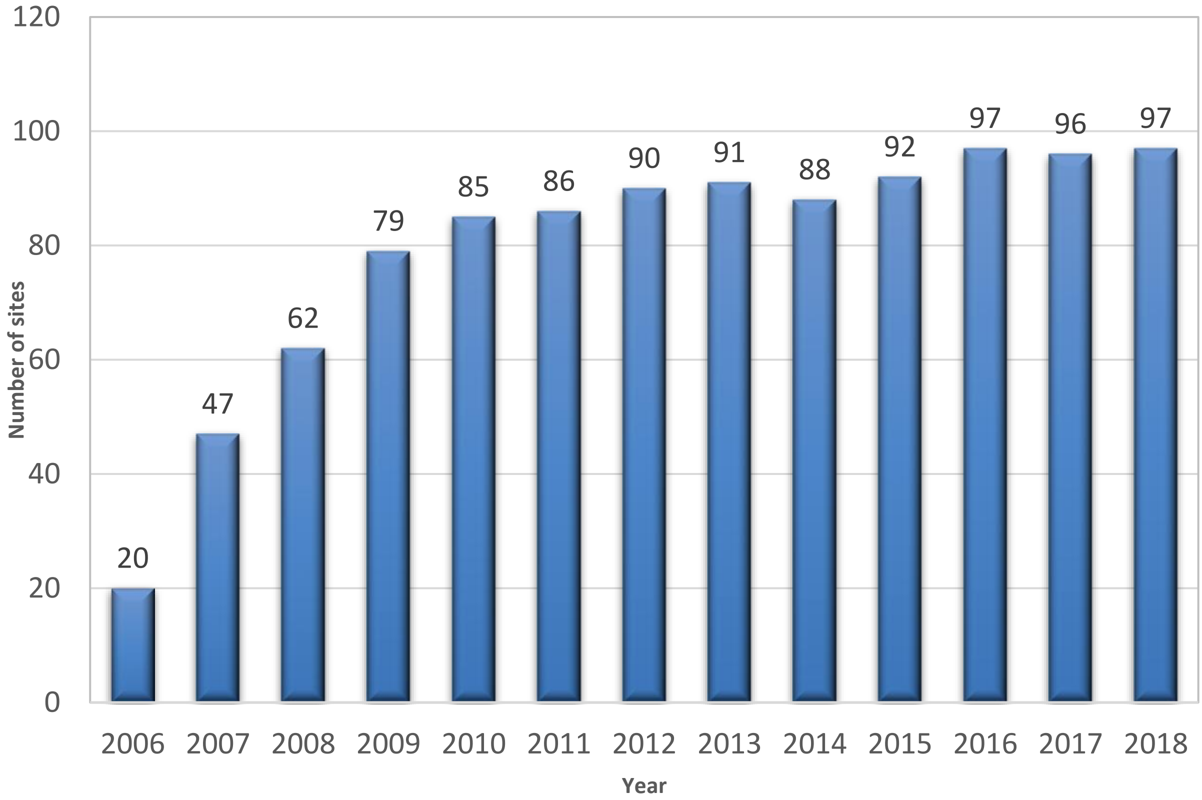
09:15	Registration	
10:00	Welcome and Introduction	Andrew Taylor – Scottish Government
10:10	Brief overview of project and the aims of the day	Stuart Sneddon, Ricardo Energy & Environment
10:20	Trend Analysis of Ambient Air Quality (Scotland)	Polly Lang, University of York
10:40	Exploring Synergies for Air Pollution and Carbon Reduction through Citizen Engagement	Irene Johnston, British Lung Foundation
11:05	Air Quality / Health	Dr Jackie Hyland, NHS Tayside
11:30	Tea/Coffee Break	
11:45	Real World Driving Emissions	Niranjan Vescio – Opus Inspection
12:10	Application of Real-World Driving Emissions for Air Quality Modelling and Impacts Assessments	Dr Colin Gillespie, SEPA
12:35	Approaches to Measurement	Prof Ally Lewis, University of York
13:00	Lunch	
13:45	The impacts of Vegetation on Urban Air Pollution	Dr Stephen Thomson, Transport Scotland
14:10	The Transport Bill and Scotland's Low Emission Zones	Dr Stephen Thomson, Transport Scotland
14:35	Comparison of PM Measurements from Different Instrument Types	Brian Stacey, Ricardo Energy & Environment
15:00	Tea/Coffee Break	
15:10	Engaging Schools in AQ through an EU Wide Citizen Science Programme	Dr Colin Gillespie, SEPA
15:35	Air Quality in Scotland Project Developments	David Hector, Ricardo Energy & Environment
15:45	Clean Air Day 2019	John Bynorth, Environmental Protection Scotland
15:55	Questions/Answers Session - Close	

4 Data Availability 2018

4.1 Hourly Data for Nitrogen Dioxide, Carbon Monoxide, Sulphur Dioxide, Ozone, PM_{10} and $PM_{2.5}$

At the end of 2018 the Scottish Air Quality Database contained data for of 97 automatic monitoring sites. In total, two new monitoring sites were incorporated into the database during 2018: Edinburgh Tower Street and N Lanarkshire Motherwell Civic Centre. One monitoring site, Falkirk Graham's Road, was decommissioned during 2018. Figure 4.1 shows the growth of the SAQD from 20 sites in 2006 pilot study to 97 sites during 2018.

Figure 4.1 Number of Monitoring Sites within the Scottish Air Quality Database Network 2006 – 2018



For the 22 National Network AURN monitoring stations in the Scottish Database, the data are available from the commencement of these stations, which in some cases is as long ago as 1986. However, for local authority monitoring stations, data are only available from when the station joined the database project. In many cases the stations commenced monitoring much earlier and these earlier data may be available from the relevant local authority.

Data availability for 2018, in terms of site, pollutants and months available, is summarised in Table 4.1. The full 12-figure OS grid reference and the site location classification are also provided for each site and the monitoring network the site is affiliated to; either the Scottish Air Quality Database Network (SAQD) or the Automatic Urban and Rural Network (AURN).

Table 4.1 also provides the start date for each site. However, not all pollutants are measured over the same period at all sites – measurements of some pollutants may commence or cease during the lifetime of monitoring at a particular site. The dates of availability of data for each pollutant measured at each site can be found by selecting the site on the 'Latest Data' page of the SAQD website (http://www.scottishairquality.scot/latest/) and then selecting the "site details" tab.

In addition, some sites may join a network or change network during their lifetime and hence, earlier data from a site may be available elsewhere. At a small number of sites, different pollutants are in different networks. This is due to the differing requirements of specific networks. The data from closed sites are available in the database for their period of operation.

Table 4.1 Scottish Air Quality Database Data Availability in 2018

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2018
Aberdeen Anderson Dr	RS	392506	804186	NO_2 PM_{10}	SAQD	2004	Jan – Dec
Aberdeen Errol Place	UB	394416	807408	NO_2 O_3 PM_{10} $PM_{2.5}$	AURN	1999	Jan – Dec
Aberdeen King Street	RS	394333	808770	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
Aberdeen Market Street 2	RS	394535	805687	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
Aberdeen Union St~	RS	393655	805984	PM_{10}, $PM_{2.5}$	SAQD	2005	Jan – Dec
Aberdeen Union Street Roadside~	RS	393655	805984	NO_2	AURN	2008	Jan – Dec
Aberdeen Wellington Road	RS	394395	804779	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
Alloa A907	RS	288689	693068	NO_2 PM_{10} $PM_{2.5}$	SAQD	2016	Jan – Dec
Angus Forfar Glamis Road	RS	345248	750385	PM_{10}	SAQD	2016	Jan – Dec
Auchencorth Moss	R	322167	656123	13BD BENZ O_3 PM_{10} $PM_{2.5}$ TOL XYL	AURN	2006	Jan – Dec
Bush Estate	R	324626	663880	NO_2 O_3	AURN	1986	Jan – Dec
Dumbarton Roadside	RS	240234	675193	NO_2	AURN	2010	Jan – Dec
Dumfries	RS	297012	576278	NO_2	AURN	2001	Jan – Dec
Dundee Broughty Ferry Road	UI	341970	730997	PM_{10} SO_2	SAQD	2006	Jan – Dec
Dundee Lochee Road	KS	330773	738861	NO_2 PM_{10} $PM_{2.5}$	SAQD	2006	Jan – Dec
Dundee Mains Loan	UB	340972	731893	NO_2 PM_{10} $PM_{2.5}$	SAQD / AURN	2006	Jan – Dec
Dundee Meadowside	RS	340241	730654	NO_2 PM_{10}	SAQD	2011	Jan – Dec
Dundee Seagate	KS	340487	730446	NO_2 PM_{10}	SAQD	2006	Jan – Dec
Dundee Whitehall Street	KS	330155	740279	NO_2	SAQD	2006	Jan – Dec
East Ayrshire Kilmarnock St Marnock St	RS	242742	637705	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec
East Dunbartonshire Bearsden	RS	254269	672067	NO_2 PM_{10}	SAQD	2005	Jan – Dec
East Dunbartonshire Bishopbriggs	RS	260995	670130	NO_2 PM_{10}	SAQD	2003	Jan – Dec
East Dunbartonshire Kirkintilloch	RS	265700	673500	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
East Dunbartonshire Milngavie	RS	255325	674115	NO_2 PM_{10}	SAQD	2011	Jan – Dec
East Lothian Musselburgh N High St	RS	333941	672836	NO_2 PM_{10}	SAQD	2008	Jan – Dec
Edinburgh Currie	UB	317575	667874	NO_2 PM_{10}	SAQD	2013	Jan – Dec
Edinburgh Glasgow Road	RS	313101	672651	NO_2 PM_{10}	SAQD	2012	Jan – Dec

Site Name	Type	East	North	Pollutants	Network	Start Year[#]	Data in 2018
Edinburgh Gorgie Road	RS	323121	672314	NO_2	SAQD	2005	Jan – Dec
Edinburgh Nicolson Street	RS	326145	673038	NO2	AURN	2017	Jan – Dec
Edinburgh Queensferry Road	RS	318734	674931	NO_2 PM_{10}	SAQD	2011	Jan – Dec
Edinburgh Salamander St	RS	327621	676342	NO_2 PM_{10}	SAQD	2009	Jan – Dec
Edinburgh St John's Road	KS	320100	672890	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Edinburgh St Leonards	UB	326250	673132	CO NO_2 O_3 PM_{10} $PM_{2.5}$ SO_2	AURN	2003	Jan – Dec
Edinburgh Tower Street	RS	327460	676531	PM_{10} $PM_{2.5}$	SAQD	2018	Oct - Dec
Eskdalemuir	R	323552	603018	NO_2 O3	AURN	1986	Jan – Dec
Falkirk Banknock	RS	277247	679026	PM_{10} $PM_{2.5}$	SAQD	2013	Jan – Dec
Falkirk Bo'ness	UI	299827	681462	SO2	SAQD	2016	Jan – Dec
Falkirk Graham's Road	RS	288814	680232	PM_{10}	SAQD	2011	Jan – Oct
Falkirk Grangemouth MC	UB	292816	682009	NO_2 PM_{10} SO_2	SAQD	2003	Jan – Dec
Falkirk Grangemouth Zetland Park	UI	292969	681106	SO_2	SAQD	2016	Jan – Dec
Falkirk Haggs	RS	278977	679271	NO_2	SAQD	2009	Jan – Dec
Falkirk Hope St	RS	288688	680218	NO_2 PM_{10} $PM_{2.5}$ SO_2	SAQD	2007	Jan – Dec
Falkirk Main St Bainsford	RS	288569	681519	NO_2 PM_{10}	SAQD	2015	Jan – Dec
Falkirk West Bridge Street	RS	288457	680064	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Fife Cupar	RS	337401	714572	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
Fife Dunfermline	RS	309912	687738	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Fife Kirkcaldy	RS	329143	692986	NO_2 PM_{10} $PM_{2.5}$	SAQD	2011	Jan – Dec
Fife Rosyth	RS	311752	683515	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
Fort William	S	210849	774421	NO_2 O_3	AURN	2006	Jan – Dec
Glasgow Abercromby Street	RS	260420	664175	PM_{10}	SAQD	2007	Jan – Dec
Glasgow Anderston	UB	257925	665487	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
Glasgow Broomhill	RS	255030	667195	PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Glasgow Burgher Street	RS	262548	664168	NO_2 PM_{10}	SAQD	2011	Jan – Dec
Glasgow Byres Road	RS	256553	665487	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
Glasgow Dumbarton Road	RS	255030	666608	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec
Glasgow Kerbside	KS	258708	665200	NO_2	AURN	1997	Jan – Dec
Glasgow Great Western Road	RS	258007	666650	NO_2	AURN	2016	Jan – Dec
Glasgow High Street	RS	260014	665348	NO_2 PM_{10} $PM_{2.5}$	AURN	2016	Jan – Dec

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2018
Glasgow Nithsdale Road	RS	257883	662673	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Glasgow Townhead	UB	259692	665899	NO_2 O_3 PM_{10} $PM_{2.5}$	AURN	2013	Jan – Dec
Glasgow Waulkmillglen Reservoir	R	252520	658095	NO_2 O_3 PM_{10} $PM_{2.6}$	SAQD	2005	Jan – Dec
Grangemouth	UI	293837	681035	NO_2 PM_{10} $PM_{2.5}$ SO_2	AURN	2001	Jan – Dec
Grangemouth Moray~	UB	293469	681321	NO_2	AURN	2009	Jan – Dec
Grangemouth Moray Scot Gov~	UB	293469	681321	SO_2	SAQD	2007	Jan – Dec
Inverclyde Greenock A8	RS	229335	675710	NO_2 PM_{10} $PM_{2.5}$	SAQD	2016	Jan – Dec
Inverness*	RS	265720	845680	NO_2 PM_{10} $PM_{2.5}$	AURN	2001	Jan – Dec
Inverness Academy Street	RS	266644	845440	NO_2	SAQD	2016	Jan – Dec
Lerwick~	R	445337	1139683	O_3	AURN	2005	Jan – Dec
N Lanarkshire Chapelhall	RS	278174	663124	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
N Lanarkshire Coatbridge Whifflet	UB	273668	663938	NO_2 PM_{10}	SAQD	2007	Jan – Dec
N Lanarkshire Croy	RS	272775	675738	CO NO_2 PM_{10} $PM_{2.5}$ SO_2	SAQD	2006	Jan – Dec
N Lanarkshire Kirkshaws	RS	272522	663029	NO_2 PM_{10}	SAQD	2016	Jan – Dec
N Lanarkshire Motherwell	RS	275460	656785	PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
N Lanarkshire Motherwell Civic Centre	UB	275814	656235	PM_{10} $PM_{2.5}$	SAQD	2018	Jul - Dec
N Lanarkshire Shawhead Coatbridge	RS	273411	662997	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
North Ayrshire Irvine High Street	KS	232142	638892	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
Paisley Gordon Street	RS	248316	663611	NO_2 PM_{10}	SAQD	2004	Jan – Dec
Paisley St James St	RS	248175	664311	PM_{10}	SAQD	2010	Jan – Dec
Peebles	S	324812	641083	NO_2 O_3	AURN	2009	Jan – Dec
Perth Atholl Street	RS	311582	723931	NO_2 PM_{10} $PM_{2.5}$	SAQD	2004	Jan – Dec
Perth Crieff	RS	286363	721614	NO_2 PM_{10} $PM_{2.5}$	SAQD	2010	Jan – Dec
Perth High Street	RS	311688	723625	NO_2 $PM_{2.5}$	SAQD	2003	Jan – Dec
Perth Muirton	UB	311688	723625	PM_{10}	SAQD	2012	Jan – Dec
Renfrew Cockels Loan	RS	250467	665943	NO_2 PM_{10}	SAQD	2013	Jan – Dec
Renfrewshire Johnston	RS	243002	663183	PM_{10} $PM_{2.5}$	SAQD	2017	Jan – Dec
Shetland Lerwick~	R	445337	1139683	NO_2 SO_2	SAQD	2012	Jan – Dec
South Ayrshire Ayr Harbour	RS	233617	622749	NO_2 $PM_{2.5}$	SAQD	2012	Jan – Dec
South Ayrshire Ayr High St	RS	233725	622120	NO_2 $PM_{2.5}$	SAQD	2007	Jan – Dec
South Lanarkshire Cambuslang	KS	264340	660496	NO_2 PM_{10} $PM_{2.5}$	SAQD	2015	Jan – Dec

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2018
South Lanarkshire East Kilbride	RS	264390	655658	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
South Lanarkshire Hamilton	RS	272298	655289	NO_2 PM_{10} $PM_{2.5}$	SAQD	2013	Jan – Dec
South Lanarkshire Lanark	RS	288427	643701	NO_2 PM_{10}, $PM_{2.5}$	SAQD	2012	Jan – Dec
South Lanarkshire Raith Interchange 2	KS	271065	658087	NO_2 PM_{10}, $PM_{2.6}$	SAQD	2016	Jan – Dec
South Lanarkshire Rutherglen	RS	261113	661690	NO_2 PM_{10}, $PM_{2.5}$	SAQD	2012	Jan – Dec
South Lanarkshire Uddingston	RS	269657	660305	NO_2 PM_{10}, $PM_{2.5}$	SAQD	2013	Jan – Dec
Stirling Craig's Roundabout	RS	279955	693012	NO_2 PM_{10}	SAQD	2009	Jan – Dec
Strath Vaich	RS	234829	874785	O_3	AURN	1987	Jan – Dec
West Dunbartonshire Clydebank	RS	249724	672042	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
West Lothian Broxburn	RS	308364	672248	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
West Lothian Linlithgow High St 2	RS	300419	677120	NO_2 PM_{10} $PM_{2.5}$	SAQD	2013	Jan – Dec
West Lothian Newton	RS	309258	677728	NO_2 PM_{10}	SAQD	2012	Jan – Dec

+ Sites added to database in 2018
* Sites changed monitoring
^Changes in number of measured pollutants or monitoring method during 2018
This is the date of the site joining the network. Data for some pollutants may not be available from this date. Also, data for some pollutants may be available from earlier dates from the Local Authority other networks. The period of availability for data for each pollutant measured at each site can be seen on www.scottishairquality.scot by selecting the site and the "site details" tab.
~ At these sites, some pollutants are affiliated to the AURN network and some pollutants are affiliated the SAQD Network.
KS – Kerbside
R – Rural
RS – Roadside
S – Suburban
UB – Urban Background
UI – Urban Industrial

4.1.1 Summary of Changes to Monitoring Sites within the Database During 2018

Details of changes to monitoring sites included within the SAQD are summarised below.

Sites opened during 2018:

- Edinburgh Tower Street PM_{10}, $PM_{2.5}$ from 16/10/2018
- N Lanarkshire Motherwell Civic Centre PM_{10}, $PM_{2.5}$ from 05/07/2018

Sites closed during 2018:

- Falkirk Graham's Road NO_2, PM_{10} on 10/10/2018

Sites changes during 2018:

Monitoring of $PM_{2.5}$ in addition to PM_{10} using a FIDAS analyser at the following sites:

- Glasgow Anderston on 29/11/2018
- Glasgow Broomhill on 27/11/2018
- Glasgow Nithsdale Road on 12/02/2018
- N Lanarkshire Croy on 05/07/2018
- N Lanarkshire Kirkshaw on 03/07/2018
- N Lanarkshire Motherwell on 04/07/2018
- N Lanarkshire Shawhead Coatbridge on 02/07/2018
- South Lanarkshire Raith Interchange 2 on 14/08/218

Monitoring of PM_{10} using a TEOM analyser at the following sites:

- Falkirk Hope St on 18/10/2018

4.2 NO_2 and PM_{10} Data Capture Rates

Figures 5.2 and 5.3 show the average data capture rates achieved between 2008 and 2018 for NO_2 and PM_{10} sites, respectively. Note that 2006 and 2007 data capture rates have not been included due to the rapid change in site numbers.

With the introduction of a harmonised QA/QC regime, the data capture rates for NO_2 and PM_{10} monitoring continue to improve. The sudden increase in PM_{10} data captures in 2017 has been attributed to the change in analyser type measuring Particulate Matter (PM) at a significant number of local authority sites, coinciding with the requirement for local authorities to measure $PM_{2.5.}$ Likewise, a number of new PM sites were introduced half way through 2018 resulting in a decrease in the average data capture rate during 2018.

Figure 5.2 Network data capture rate for NO_2 monitoring, 2008 – 2018

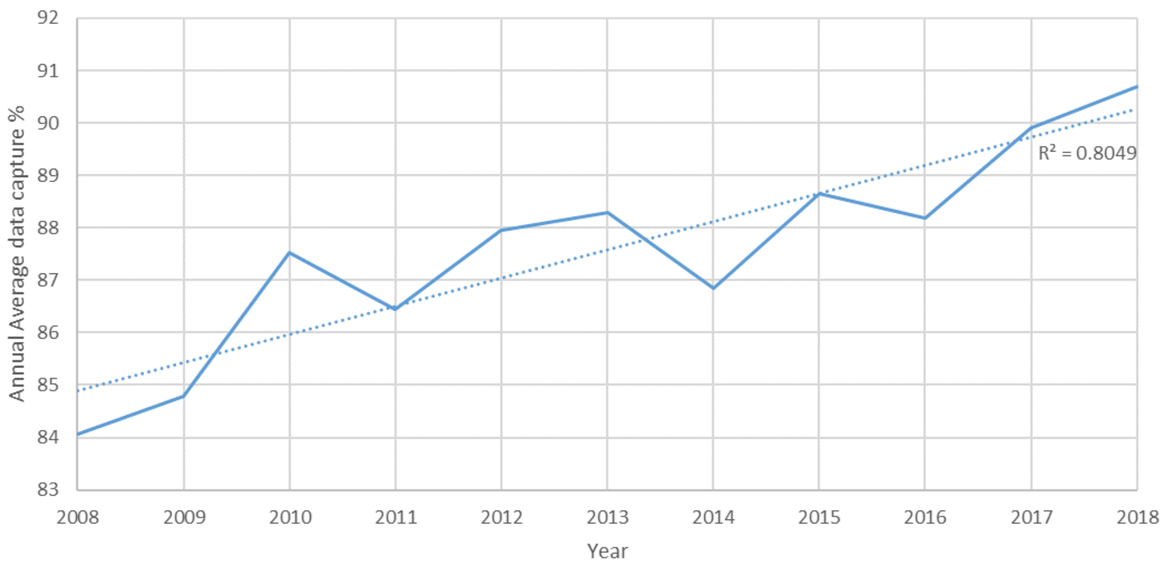
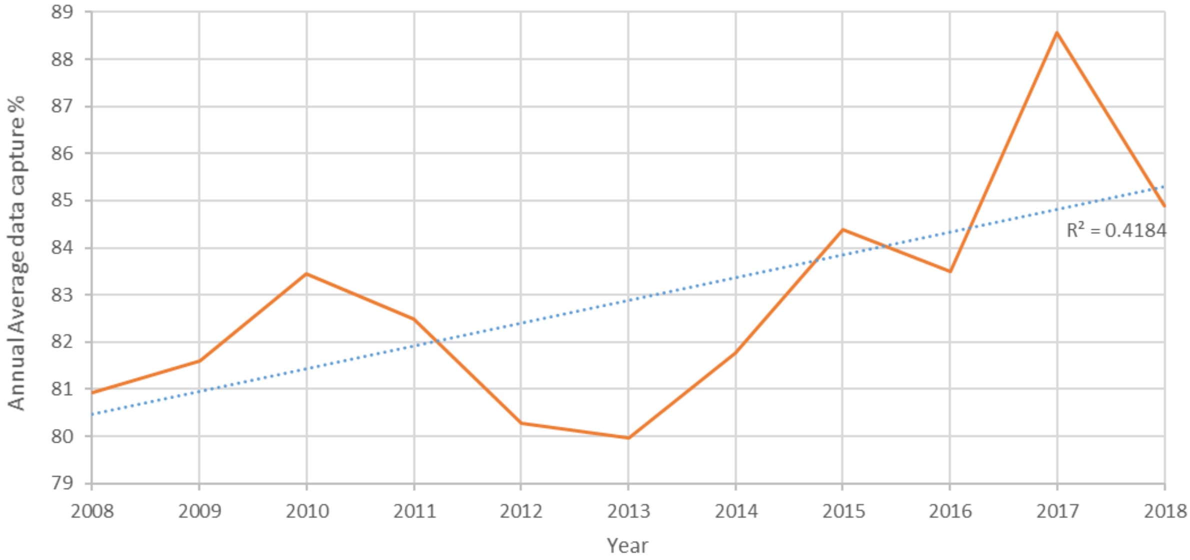


Figure 5.3 Network data capture rate for PM_{10} monitoring, 2008 – 2018



5 QA/QC of the Scottish Database

In order that all data within the Scottish Air Quality Database are harmonised to the same quality standard, the QA/QC procedures adopted within the UK Automatic and Rural Network (AURN) are provided for all Local Authority sites within the database.

The main elements of the QA/QC programme are on-site analyser and calibration gas inter-calibrations every 6-months, daily automatic data collection and validation and data ratification in 3-monthly blocks.

5.1 On-Site Analyser and Calibration Gas Audits

The automatic air quality monitoring stations located throughout Scotland employ a wide variety of different analyser types and site infrastructure. Intercalibration of the stations provides essential input to the data management process, to ensure that data across Scotland are harmonised, consistent in quality and traceable to a recognised gas calibration standard.

Monitoring station audits evaluate analysers to obtain an assessment of their performance level on the date of test. This information, in conjunction with the full analyser data set and additional calibration and service records, helps ensure data quality specifications have been met during the preceding data period.

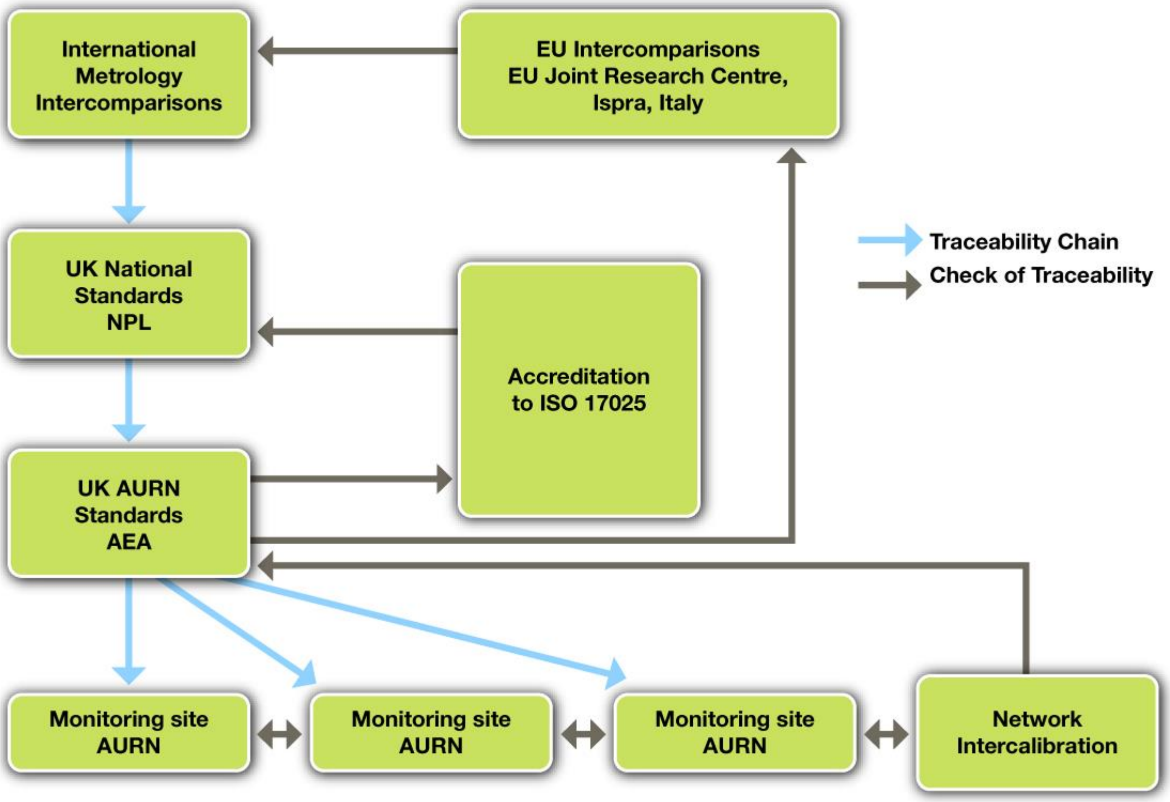
The assessment of the on-site calibration cylinder concentrations against accredited and traceable Ricardo Energy & Environment gas standard cylinders provides the essential final link in the measurement traceability chain (Fig 5.1). This process ensures that all monitoring stations in Scotland are traceable to reference gas standards held at Ricardo Energy & Environment. These in turn are traceable to UK national reference standard gases held by the National Physical Laboratory who, in turn regularly inter-compare these standards internationally. Ricardo Energy & Environment also participate in EU level inter-comparisons at the EU Joint Research Centre at Ispra, Italy. Hence, there is an unbroken traceability chain from each monitoring site in Scotland to internationally agreed gas calibration standards. This check also identifies any unstable gas cylinders which may need to be recertified or discarded.

The aims and objectives of the audit and intercalibration exercise can be summarised as follows:

- Ensure the correct operation of analysers at each monitoring station
- Ensure harmonisation of data throughout the network (i.e. that a NO_X analyser at one station measuring 40 $\mu g\ m^{-3}$ of NO_2 would also measure 40 $\mu g\ m^{-3}$ of NO_2 at any other site)
- Ensure traceability of all stations in the network to national and international standards
- Provide information on any necessary adjustments to data into the ratification process
- Report any faults found to the site operator.

Detailed audit procedures are provided in Appendix 2.

Figure 5.1 Traceability chain for the SAQD monitoring stations



5.2 Data Management

The following sections describe the data management package applied to the data from the Scottish local authority monitoring stations. This is the same data management package, using the same data ratification procedures, that is applied to the AURN network stations across the UK.

The process includes the following tasks:

- Data acquisition
- Data validation
- Ratification

The data acquisition and management system consist of a central computer and telemetry facility that has been developed by Ricardo Energy & Environment specifically for the UK's air quality monitoring programmes. The database used in this system is backed-up on a 24-hour basis to independent network servers to ensure data security.

A wide range of data management activities are routinely performed, and these are integrated into the streamlined automatic data management system. Data are retrieved automatically from the Scottish air quality monitoring stations (*data acquisition*). The data are then rapidly processed by applying the latest available calibration factors (*data scaling*) and carefully screened using specifically developed computer algorithms to identify suspect data or equipment faults (*data validation*). These validated data are then appended to the site database and uploaded to the Scottish Database and Website. These operations are carried out automatically by computer systems, with all output manually checked by data management experts.

The validated data are then updated to the Scottish Air Quality Database – and accessible via the web - as provisional data. These data are therefore available to all users on a day-to-day basis. This gives the local authority the opportunity to easily view both their own data and data from other stations throughout Scotland. This will assist in dealing with day-to-day requests for information on specific data or the overall pollution situation either locally or throughout Scotland. In particular the automatic data summary bulletin, available by email from the website, and the plotting package incorporated into this, will be useful to authorities to rapidly evaluate their data against that from other stations.

5.3 Data Ratification

The validated data, which have been screened and scaled, are fit for day-to-day use and provide a good indication of pollution levels. However, the final stage of data management is a comprehensive and detailed critical review of the data and is generally termed 'ratification'. Note that ratification necessarily includes the results from the site audits and inter-calibrations – ratified data must be shown to be traceable to national gas standards.

The aim of data ratification is to make use of all of the available information to identify and remove any faulty data, ensuring that remaining measurement data meet the accuracy and precision specifications of the Scottish Government for detailed Review and Assessment (LAQM.TG(16)).

The policy on data rejection opted by Ricardo Energy & Environment is that all data are assumed to be correct unless there is good evidence to suggest otherwise. This prevents the ratification process from erroneously removing any important air pollution episode data. The ratification process is comprehensive and is outlined step-by-step in Appendix 2.

Data ratification of the Scottish local authority station data is undertaken on a 3-monthly basis, based on calendar year timetables (January through to December). The process of ratification can take up to six weeks - we therefore aim to have the finalised datasets from all network sites ready by 31st March of the following year. This fits well with the timetable for local authority reporting under the Review and Assessment process.

The ratified data are uploaded to the Scottish Database and overwrite the provisional data. Summary statistics of these ratified data are available from the website to assist local authorities complete their Air Quality Review and Assessment reports.

5.4 QA/QC During 2018

As discussed above, site inter-calibrations and audit visits are undertaken at 6-monthly intervals. However, where a site joins the database part way through a year then it is possible that only one audit will be conducted during the year. Table 5.2 shows the full list of inter-calibrations and audits undertaken on air quality sites in the Scottish Database during 2018.

The majority of analysers and sites were found to be operating satisfactorily during the audits. However, inevitably some problems were identified at some sites, these are summarised in Table 5.1.

Table 5.1 Monitoring site faults identified during the 2018 audits

Fault	Number of Monitoring Sites Winter 2017/18	Number of Monitoring Sites Summer 2018
TEOM** and TEOM FDMS k_0 out by > 2.5%	2	0
Particulate Analyser*** flow out by >10%	15	3
NO_x analyser converter <97% efficiency	6	5
NO cylinder out by >10%	7	5

Fault	Number of Monitoring Sites Winter 2017/18	Number of Monitoring Sites Summer 2018
SO_2 cylinder out by >10%	1	4
CO cylinder out by >10%	0	0
O3 Analyser out by >5%	0	0

* Filter Dynamics Measurement System
** Tapered Element Oscillating Microbalance
*** These include TEOM, FDMS and Beta Attenuation Monitors (BAM)

These are all typical faults that are found during audit and intercalibration exercises and as can be seen from the 2018 figures.

In many cases, the results from the audit and intercalibration visits provide the information necessary to correct for these issues at the data ratification stage so that the data can be corrected and retained, rather than being deleted as erroneous data. Table 5.2 summarises the site inter-calibrations and audits undertaken during 2018, where the period Winter 2017/18 corresponds to Dec-17 to Mar-18 and Summer 2018 corresponds to Jun-18 to Aug-18.

5.4.1 Data Ratification

With the renewal of the Scottish Air Quality Database and Website contract in 2013, data ratification was brought in line with the AURN schedule and is now undertaken at 3-monthly intervals. Hence, as with the inter-calibrations and audits, if the site joins the database part way through a year then data can only be ratified from the date of the site joining the database.

All ratified data for 2018 have now been uploaded to the Scottish Air Quality website and Table 5.3 summarises the ratification undertaken during 2018. The column headings labelled Q1 – Q4 refer to the quarter periods of the calendar year:

- Q1 = January to March;
- Q2 = April to June;
- Q3 = July to September;
- Q4 = October to December.

Table 5.2 Air quality site intercalibration and audits conducted during 2018

Site Name	Winter 2017/18	Summer 2018	Site Name	Winter 2017/18	Summer 2018
Aberdeen Anderson Dr	✓	✓	Glasgow Broomhill	✓	✓
Aberdeen Errol Place	✓	✓	Glasgow Burgher Street	✓	✓
Aberdeen King Street	✓	✓	Glasgow Byres Road	✓	✓
Aberdeen Market Street 2	✓	✓	Glasgow Dumbarton Road	✓	✓
Aberdeen Union St	✓	✓	Glasgow Kerbside	✓	✓
Aberdeen Union Street Roadside	✓	✓	Glasgow Great Western Road	✓	✓
Aberdeen Wellington Road	✓	✓	Glasgow High Street+	✓	✓
Alloa A907	✓	✓	Glasgow Nithsdale Road	✓	✓
Angus Forfar Glamis Road	✓	✓	Glasgow Townhead	✓	✓
Auchencorth Moss	✓	✓	Glasgow Waulkmillglen Reservoir	✓	✓
Bush Estate	✓	✓	Grangemouth	✓	✓
Dumbarton Roadside	✓	✓	Grangemouth Moray	✓	✓
Dumfries	✓	✓	Grangemouth Moray Scot Gov	✓	✓
Dundee Broughty Ferry Road	✓	✓	Inverclyde Greenock A8	✓	✓

Site Name	Winter 2017/18	Summer 2018	Site Name	Winter 2017/18	Summer 2018
Dundee Lochee Road	✓	✓	Inverness	✓	✓
Dundee Mains Loan	✓	✓	Inverness Academy Street	✓	✓
Dundee Meadowside	✓	✓	Lerwick	✓	✓
Dundee Seagate	✓	✓	N Lanarkshire Chapelhall	✓	✓
Dundee Whitehall Street	✓	✓	N Lanarkshire Coatbridge Whifflet	✓	✓
East Ayrshire Kilmarnock St Marnock St	✓	✓	N Lanarkshire Croy	✓	✓
East Dunbartonshire Bearsden	✓	✓	N Lanarkshire Kirkshaws	✓	✓
East Dunbartonshire Bishopbriggs	✓	✓	N Lanarkshire Motherwell	✓	✓
East Dunbartonshire Kirkintilloch	✓	✓	N Lanarkshire Motherwell Civic Centre	-	✓
East Dunbartonshire Milngavie	✓	✓	N Lanarkshire Shawhead Coatbridge	✓	✓
East Lothian Musselburgh N High St	✓	✓	North Ayrshire Irvine High St	✓	✓
Edinburgh Currie	✓	✓	Paisley Glasgow Airport	✓	✓
Edinburgh Glasgow Road	✓	✓	Paisley Gordon Street	✓	✓
Edinburgh Nicolson	✓	✓	Paisley St James St	✓	✓
Edinburgh Gorgie Road	✓	✓	Peebles	✓	✓
Edinburgh Queensferry Road	✓	✓	Perth Atholl Street	✓	✓
Edinburgh Salamander St	✓	✓	Perth Crieff	✓	✓
Edinburgh St John's Road	✓	✓	Perth High Street	✓	✓
Edinburgh St Leonards	✓	✓	Perth Muirton	✓	✓
Edinburgh Tower Street	-	✓	Renfrew Cockels Loan	✓	✓
Eskdalemuir	✓	✓	Renfrewshire Johnstone	✓	✓
Falkirk Main Street Bainsford	✓	✓	Shetland Lerwick	✓	✓
Falkirk Banknock	✓	✓	South Ayrshire Ayr Harbour	✓	✓
Falkirk Bo'ness	✓	✓	South Ayrshire Ayr High St	✓	✓
Falkirk Grahams Road	✓	-	South Lanarkshire East Kilbride	✓	✓
Falkirk Grangemouth MC	✓	✓	South Lanarkshire Hamilton	✓	✓
Falkirk Grangemouth Zetland Park	✓	✓	South Lanarkshire Lanark	✓	✓
Falkirk Haggs	✓	✓	South Lanarkshire Raith Interchange	✓	✓
Falkirk Hope St	✓	✓	South Lanarkshire Rutherglen	✓	✓
Falkirk West Bridge Street	✓	✓	South Lanarkshire Uddingston	✓	✓
Fife Cupar	✓	✓	Stirling Craig's Roundabout	✓	✓
Fife Dunfermline	✓	✓	Strath Vaich	✓	✓
Fife Kirkcaldy	✓	✓	West Dunbartonshire Clydebank	✓	✓
Fife Rosyth	✓	✓	West Lothian Broxburn	✓	✓
Fort William	✓	✓	West Lothian Linlithgow High St 2	✓	✓
Glasgow Abercromby Street	✓	✓	West Lothian Newton	✓	✓
Glasgow Anderston	✓	✓			

Table 5.3 Data ratification undertaken during 2018

Site Name	Q1	Q2	Q3	Q4	Site Name	Q1	Q2	Q3	Q4
Aberdeen Anderson Dr	✓	✓	✓	✓	**Glasgow Broomhill**	✓	✓	✓	✓
Aberdeen Errol Place	✓	✓	✓	✓	**Glasgow Burgher Street**	✓	✓	✓	✓
Aberdeen King Street	✓	✓	✓	✓	**Glasgow Byres Road**	✓	✓	✓	✓

Site Name	Q1	Q2	Q3	Q4	Site Name	Q1	Q2	Q3	Q4
Aberdeen Market Street 2	✓	✓	✓	✓	Glasgow Dumbarton Road	✓	✓	✓	✓
Aberdeen Union St	✓	✓	✓	✓	Glasgow Kerbside	✓	✓	✓	✓
Aberdeen Union Street Roadside	✓	✓	✓	✓	Glasgow Great Western Road	✓	✓	✓	✓
Aberdeen Wellington Road	✓	✓	✓	✓	Glasgow High Street+	✓	✓	✓	✓
Alloa A907	✓	✓	✓	✓	Glasgow Nithsdale Road	✓	✓	✓	✓
Angus Forfar Glamis Road	✓	✓	✓	✓	Glasgow Townhead	✓	✓	✓	✓
Auchencorth Moss	✓	✓	✓	✓	Glasgow Waulkmillglen Reservoir	✓	✓	✓	✓
Bush Estate	✓	✓	✓	✓	Grangemouth	✓	✓	✓	✓
Dumbarton Roadside	✓	✓	✓	✓	Grangemouth Moray	✓	✓	✓	✓
Dumfries	✓	✓	✓	✓	Grangemouth Moray Scot Gov	✓	✓	✓	✓
Dundee Broughty Ferry Road	✓	✓	✓	✓	Inverclyde Greenock A8	✓	✓	✓	✓
Dundee Lochee Road	✓	✓	✓	✓	Inverness	✓	✓	✓	✓
Dundee Mains Loan	✓	✓	✓	✓	Inverness Academy Street	✓	✓	✓	✓
Dundee Meadowside	✓	✓	✓	✓	Lerwick	✓	✓	✓	✓
Dundee Seagate	✓	✓	✓	✓	N Lanarkshire Chapelhall	✓	✓	✓	✓
Dundee Whitehall Street	✓	✓	✓	✓	N Lanarkshire Coatbridge Whifflet	✓	✓	✓	✓
East Ayrshire Kilmarnock St Marnock St	✓	✓	✓	✓	N Lanarkshire Croy	✓	✓	✓	✓
East Dunbartonshire Bearsden	✓	✓	✓	✓	N Lanarkshire Kirkshaws	✓	✓	✓	✓
East Dunbartonshire Bishopbriggs	✓	✓	✓	✓	N Lanarkshire Motherwell	✓	✓	✓	✓
East Dunbartonshire Kirkintilloch	✓	✓	✓	✓	N Lanarkshire Motherwell Civic Centre	-	-	✓	✓
East Dunbartonshire Milngavie	✓	✓	✓	✓	N Lanarkshire Shawhead Coatbridge	✓	✓	✓	✓
East Lothian Musselburgh N High St	✓	✓	✓	✓	North Ayrshire Irvine High St	✓	✓	✓	✓
Edinburgh Currie	✓	✓	✓	✓	Paisley Glasgow Airport	✓	✓	✓	✓
Edinburgh Glasgow Road	✓	✓	✓	✓	Paisley Gordon Street	✓	✓	✓	✓
Edinburgh Gorgie Road	✓	✓	✓	✓	Paisley St James St	✓	✓	✓	✓
Edinburgh Nicolson Street	✓	✓	✓	✓	Peebles	✓	✓	✓	✓
Edinburgh Queensferry Road	✓	✓	✓	✓	Perth Atholl Street	✓	✓	✓	✓
Edinburgh Salamander St	✓	✓	✓	✓	Perth Crieff	✓	✓	✓	✓
Edinburgh St John's Road	✓	✓	✓	✓	Perth High Street	✓	✓	✓	✓
Edinburgh St Leonards	✓	✓	✓	✓	Perth Muirton	✓	✓	✓	✓
Edinburgh Tower Street	-	-	-	✓	Renfrew Cockels Loan	✓	✓	✓	✓
Eskdalemuir	✓	✓	✓	✓	Renfrew Johnston	✓	✓	✓	✓
Falkirk Main Street Bainsford	✓	✓	✓	✓	Shetland Lerwick	✓	✓	✓	✓
Falkirk Banknock	✓	✓	✓	✓	South Ayrshire Ayr Harbour	✓	✓	✓	✓
Falkirk Bo'ness	✓	✓	✓	✓	South Ayrshire Ayr High St	✓	✓	✓	✓
Falkirk Grahams Road	✓	✓	✓	✓	South Lanarkshire East Kilbride	✓	✓	✓	✓
Falkirk Grangemouth MC	✓	✓	✓	✓	South Lanarkshire Hamilton	✓	✓	✓	✓
Falkirk Grangemouth Zetland Park	✓	✓	✓	✓	South Lanarkshire Lanark	✓	✓	✓	✓
Falkirk Haggs	✓	✓	✓	✓	South Lanarkshire Raith Interchange	✓	✓	✓	✓
Falkirk Hope St	✓	✓	✓	✓	South Lanarkshire Rutherglen	✓	✓	✓	✓
Falkirk West Bridge Street	✓	✓	✓	✓	South Lanarkshire Uddingston	✓	✓	✓	✓
Fife Cupar	✓	✓	✓	✓	Stirling Craig's Roundabout	✓	✓	✓	✓
Fife Dunfermline	✓	✓	✓	✓	Strath Vaich	✓	✓	✓	✓
Fife Kirkcaldy	✓	✓	✓	✓	West Dunbartonshire Clydebank	✓	✓	✓	✓

Site Name	Q1	Q2	Q3	Q4	Site Name	Q1	Q2	Q3	Q4
Fife Rosyth	✓	✓	✓	✓	West Lothian Broxburn	✓	✓	✓	✓
Fort William	✓	✓	✓	✓	West Lothian Linlithgow High St 2	✓	✓	✓	✓
Glasgow Abercromby Street	✓	✓	✓	✓	West Lothian Newton	✓	✓	✓	✓
Glasgow Anderston	✓	✓	✓	✓		□	□	□	□

5.5 Volatile Correction Model

5.5.1 Background

The EU Directive on Ambient Air Quality[2] and the UK Air Quality Strategy[3] set target values and objectives respectively for PM_{10} concentrations in terms of gravimetric measurements referenced to the EU reference method of measurement (EN 12341). It has long been recognised that PM_{10} measurements made with many automatic PM_{10} monitors are not equivalent to the EU reference method. However, these analysers are widely used since they provide hourly resolved data and have many operational advantages over the manual reference method. Hence, correction factors, most noticeably the 1.3 correction factor for the TEOM analyser, have been widely used for many years. In setting the value of 1.3 as a correction factor, it was recognized that this was a conservative factor and that TEOMx1.3 data were likely to overestimate PM_{10} concentrations. In Scotland, a lower correction factor of 1.14, which was based on intercomparison data obtained in Edinburgh, has also been widely used.

The results of the formal UK PM_{10} Equivalence Study[4] carried out in 2006, showed that data from the TEOM could not be considered as equivalent to the EU reference method, whether or not a correction factor was used. The reason for this is that the TEOM heats the filter used to collect PM_{10} to 50°C in order to eliminate the possible interference from water vapour – this heating also removes some of the more volatile components of the particulate matter.

In the new modification to the TEOM – the FDMS TEOM, the volatile fraction of PM_{10} is measured separately and used to correct the data in order to obtain results that are equivalent to the EU reference method. The equivalence of the FDMS TEOM analyser to the EU reference method was confirmed in the UK Equivalence study. Note that this study also showed that a number of other PM_{10} analysers could also provide data equivalent to the EU reference method - Partisol 2025, FDMS Model B, Opsis SM200 Beta Attenuation Monitor (BAM), Opsis SM200 sampler (with slope and intercept correction) and the Met One BAM (with slope correction).

King's College London (KCL) developed a relationship utilising FDMS purge (volatile PM_{10}) measurements to correct data from nearby TEOM analysers. These corrected data were tested for equivalence with the EU reference method and shown to pass the appropriate criteria. Since then, as additional FDMS data have become available throughout the UK, the geographic range of the model has been extended and on-going tests have shown that any TEOM located within 130 km of an FDMS TEOM can be corrected with data from that analyser.

For additional information regarding this visit http://www.scottishairquality.co.uk/data.

5.5.2 Use of the VCM in Scotland

The VCM correction of Scottish PM_{10} data was first undertaken for the 2008 dataset. As the VCM method was relatively new and, hourly meteorological data for pressure were not readily available, the corrections were undertaken on a daily, rather than hourly basis. These corrected data were provided to the local authorities and made available on the Scottish Air Quality website as a separate data spreadsheet.

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[2] *Directive 2008/50/EC Of The European Parliament and of The Council of 21 May 2008 on ambient air quality and cleaner air for Europe* *http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:152:0001:0044:EN:PDF*

[3] *The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007. CM 7169* *http://www.scotland.gov.uk/Topics/Environment/Pollution/16215/6116*

[4] *UK Equivalence Programme for Monitoring of Particulate Matter. David Harrison Bureau Veritas UK Ltd. June 2006 (BV/AQ/AD202209/DH/2396)* *http://www.airquality.co.uk/archive/reports/cat05/0606130952_UKPMEquivalence.pdf*

However, additional refinement of the VCM model has been undertaken and hourly meteorological data for all parameters has been sourced. As a result, VCM correction of the 2009 to 2018 datasets has been undertaken on an hourly basis. This also brings into line the processing of the Scottish local authority data with that of the AURN.

The TEOM measurements are recorded with an inbuilt correction factors of 1.03x+3 (where x is the raw TEOM measurement) as mandated by the US Environmental Protection Agency. This is first removed and the data are then corrected to ambient pressure and temperature (as required by the EU Directive) using meteorological data from met monitoring sites within 260 km of the TEOM.

Data from FDMS analysers within 130 km of the TEOM are then used to provide an estimate of the volatile particle concentration at the TEOM location. This estimated volatile fraction is then added back onto the TEOM measurements to give Gravimetric Equivalent mass concentrations. The following data were used as inputs to the VCM:

- Hourly average temperatures (°C)
- Hourly average pressures (mbar)
- Hourly average TEOM concentrations (μg m^{-3})
- Hourly average FDMS purge concentrations (μg m^{-3})

For the 2018 corrections, temperature and pressure data from Edinburgh Airport meteorological monitoring stations were utilised. This site was selected as a good representation of weather conditions in the central belt of Scotland.

Hourly average purge measurements from all Scottish FDMS monitoring sites within the Scottish Government-run network (SAQD) and the UK national network (AURN) were used for the correction. A total of 20 FDMS sites were used for correcting hourly average TEOM data at 19 sites across Scotland. A list of sites used for correction is provided in appendix 3 of this report. Table 5.4 provides the names of the sites where data was corrected using VCM.

Any outliers in the FDMS purge measurements were identified using Grubbs' Test[5] on daily average data. All hourly data within a day identified as an outlier were then removed from the data set and the average of each hourly purge measurement from the FDMS sites was calculated and used in the VCM calculations.

The corrected data for 2018 and calculated summary statistics have been provided to the local authorities. A flow chart showing the overall process employed for VCM correction of 2018 SAQD TEOM data is provide in Appendix 3. It should be noted that it is not possible to correct historical data with the VCM as measurements of volatile particle concentrations are not available prior to 2008.

Table 5.4 TEOM Sites data corrected using VCM in 2018

Site Name	Local Authority
Aberdeen Anderson Dr	Aberdeen City Council
Dundee Broughty Ferry Road	Dundee City Council
Dundee Mains Loan	Dundee City Council
Edinburgh Currie	Edinburgh City Council
Edinburgh Glasgow Road	Edinburgh City Council
Edinburgh Queen Street	Edinburgh City Council
Edinburgh Salamander St	Edinburgh City Council
Falkirk Bainsford	Falkirk Council
Falkirk Grahams Rd	Falkirk Council
Falkirk Grangemouth MC	Falkirk Council
Falkirk Haggs	Falkirk Council

[5] Grubbs' Test is a statistical method for identifying outliers within a dataset. For more information, visit the Engineering Statistics Handbook at:

http://www.itl.nist.gov/div898/handbook/eda/section3/eda35h.htm

Site Name	Local Authority
Glasgow Dumbarton Road	Glasgow City Council
Glasgow Waulkmillglen Reservoir	Glasgow City Council
N Lanarkshire Coatbridge Whifflet	North Lanarkshire Council
N Lanarkshire Croy	North Lanarkshire Council
N Lanarkshire Motherwell	North Lanarkshire Council
Perth Atholl Street	Perth and Kinross Council
Perth High Street	Perth and Kinross Council
Stirling Craig's Roundabout	Stirling Council

5.6 NO_2 and PM_{10} Data Capture Rates

Figures 5.2 and 5.3 show the average data capture rates achieved between 2008 and 2018 for NO_2 and PM_{10} sites, respectively. Note that 2006 and 2007 data capture rates have not been included due to the rapid change in site numbers.

With the introduction of a harmonised QA/QC regime, the data capture rates for NO_2 and PM_{10} monitoring continue to improve. The sudden increase in PM_{10} data captures in 2017 has been attributed to the change in analyser type measuring Particulate Matter (PM) at a significant number of local authority sites, coinciding with the requirement for local authorities to measure $PM_{2.5}$. Likewise, a number of new PM sites were introduced half way through 2018 resulting in a decrease in the average data capture rate during 2018.

6 Air Pollution in Scotland 2018

In this section we present a statistical summary of the available air quality data for Scotland as follows:

- Section 6.1 - Automatic monitoring of the pollutants NO_2, PM_{10}, $PM_{2.5}$ CO, SO_2 and O_3 summary data for 2018.

- Section 6.2 - Other pollutants covered by the Air Quality Strategy – PAH (benzo[a]pyrene), Benzene, 1,3-butadiene and lead - summary statistics for 2018 or 2017 depending on the availability of data.

- Section 6.3 - Other pollutants and/or other methods of monitoring:
  1. NO_2 Diffusion Tube Samplers
  2. Non-methane Volatile Organic Compounds (NMVOC)
  3. Poly-aromatic Hydrocarbons (PAH)
  4. Toxic Organic Micropollutants (TOMPS)
  5. Metals (Urban network)
  6. Metals (Rural and deposition network)
  7. United Kingdom Eutrophying & Acidifying Pollutants Network:
     a. The Precipitation Network
     b. NO_2 Rural Diffusion Tube Network
     c. Acid Gases and Aerosol Network (AGANET)
     d. National Ammonia Monitoring Network

6.1 Automatic monitoring of pollutants NO_2, PM_{10}, $PM_{2.5}$, CO, SO_2 and Ozone

Tables 6.1.1 – 6.1.7 show the 2018 annual average data statistics for NO_2, PM_{10}, $PM_{2.5}$, CO, SO_2 and O_3 respectively, for the ratified automatic data from monitoring sites included in the Scottish Air Quality Database. These are shown along with the corresponding data capture for the year.

These data will have been used by local authorities to assess air quality within their area as part of the review and assessment process. Where any of the Air Quality Objectives for Scotland have been exceeded, at locations where there is relevant exposure of the general public, then the authority will need to carry out a Detailed Assessment as an addendum to their Annual Progress Report to confirm the exceedance and estimate its extent. Where the exceedance is confirmed then the authority will declare an Air Quality Management Area (AQMA). At the time of writing, 14 local authorities in Scotland have declared a total of 38 AQMAs (see http://www.scottishairquality.co.uk/laqm/aqma). Based on the data in the database, a brief summary of the air quality situation throughout Scotland, along the lines of that already provided in the Newsletter, is given under each table.

6.1.1 Nitrogen Dioxide

Table 6.1.1 Ratified data annual average concentration and data capture for NO_2 in 2018 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average NO_2 2018 ($\mu g\ m^{-3}$)	No. hours >200 $\mu g\ m^{-3}$	Data capture NO_2 2018 (%)
Aberdeen Anderson Dr	RS	17.4	0	94.4
Aberdeen Errol Place	UB	20.3	1	99.0
Aberdeen King Street	RS	22.1	0	86.9
Aberdeen Market Street 2	RS	32.5	0	98.8
Aberdeen Union Street Roadside	RS	38.2	0	99.0

Site Name	Type	Annual Average NO_2 2018 ($\mu g\ m^{-3}$)	No. hours >200 $\mu g\ m^{-3}$	Data capture NO_2 2018 (%)
Aberdeen Wellington Road	RS	39.3	0	99.3
Alloa A907	RS	23.5	0	96.9
Bush Estate	R	5.3	0	99.1
Dumfries	RS	29.5	0	99.4
Dundee Broughty Ferry Road	RS	23.3	0	98.8
Dundee Lochee Road	RS	43.4	6	99.3
Dundee Mains Loan	UB	12.3	0	91.0
Dundee Meadowside	RS	34.3	0	92.8
Dundee Seagate	KS	45.9	0	93.1
Dundee Whitehall Street	KS	37.5	0	94.4
E Ayrshire Kilmarnock St Marnock St	RS	30.1	0	90.8
East Dunbartonshire Bearsden	RS	32.7	0	59.8
East Dunbartonshire Bishopbriggs	RS	27.0	0	83.6
East Dunbartonshire Kirkintilloch	RS	28.6	0	98.9
East Dunbartonshire Milngavie	RS	19.6	0	83.5
East Lothian Musselburgh N High St	RS	19.5	0	99.7
Edinburgh Currie	UB	8.0	0	89.8
Edinburgh Glasgow Road	RS	25.6	0	99.4
Edinburgh Gorgie Road	RS	27.9	0	99.5
Edinburgh Queensferry Road	RS	52.2	3	99.3
Edinburgh Nicolson Street	RS	50.9	0	99.7
Edinburgh Salamander St	RS	24.8	0	96.7
Edinburgh St John's Road	KS	42.9	2	99.0
Edinburgh St Leonards	UB	17.9	0	96.8
Eskdalemuir	R	1.9	0	97.4
Falkirk Grangemouth MC	UB	17.8	0	98.7
Falkirk Haggs	RS	27.6	0	93.1
Falkirk Hope St	RS	21.0	0	94.8
Falkirk Main St Bainsford	RS	21.8	0	96.2
Falkirk West Bridge Street	RS	39.0	0	85.2
Fife Cupar	RS	25.7	0	99.5
Fife Dunfermline	RS	21.7	0	99.3
Fife Kirkcaldy	RS	16.9	0	94.0
Fife Rosyth	RS	21.5	0	99.8
Fort William	S	8.8	1	99.3
Glasgow Anderston	UB	24.1	0	81.7
Glasgow Burgher St.	RS	24.8	0	99.2
Glasgow Byres Road	RS	33.9	9	91.8
Glasgow Dumbarton Road	RS	34.0	0	94.6
Glasgow Great Western Road	RS	29.1	0	99.3
Glasgow High Street	RS	30.7	0	98.2
Glasgow Kerbside (Hope Street)	KS	60.6	2	99.2
Glasgow Townhead	UB	23.7	0	99.1
Glasgow Waulkmillglen Reservoir	R	8.7	0	99.0
Grangemouth	UI	14.4	0	93.6
Grangemouth Moray	UB	16.8	0	94.2

Site Name	Type	Annual Average NO_2 2018 (µg m^{-3})	No. hours >200 µg m^{-3}	Data capture NO_2 2018 (%)
Inverclyde Greenock A8	RS	32.3	0	99.6
Inverness	RS	17.8	0	98.8
Inverness Academy Street	RS	37.8	0	99.3
Lerwick	R	2.8	0	97.4
N Lanarkshire Chapelhall	RS	39.6	0	25.8
N Lanarkshire Croy	RS	24.1	0	25.8
N Lanarkshire Shawhead Coatbridge	RS	27.2	0	29.3
North Ayrshire Irvine High St	RS	17.5	0	90.5
North Lanarkshire Kirkshaw	RS	25.0	0	25.8
Paisley Gordon Street	RS	30.9	0	92.9
Peebles	S	5.7	0	87.5
Perth Atholl Street	RS	37.2	0	93.8
Perth Crieff	RS	17.4	0	94.4
Perth High Street	RS	20.5	0	93.3
Renfrew Cockels Loan	RS	31.2	0	96.5
South Ayrshire Ayr Harbour	RS	9.1	0	99.3
South Ayrshire Ayr High St	RS	11.9	0	49.7
South Lanarkshire Cambuslang	RS	35.3	0	99.8
South Lanarkshire East Kilbride	RS	31.9	0	74.4
South Lanarkshire Hamilton	RS	30.5	0	98.9
South Lanarkshire Lanark	RS	19.3	0	99.8
South Lanarkshire Raith Interchange 2	RS	23.7	0	97.6
South Lanarkshire Rutherglen	RS	37.8	1	98.5
South Lanarkshire Uddingston	RS	24.4	0	99.8
Stirling Craig's Roundabout	RS	21.7	0	89.2
West Dunbartonshire Clydebank	RS	20.5	0	51.3
West Dunbartonshire Glasgow Road	RS	17.7	0	96.3
West Lothian Broxburn	RS	27.3	0	99.7
West Lothian Linlithgow High Street 2	RS	27.8	0	99.6
West Lothian Newton	RS	17.4	0	95.1

Shaded sites indicate data only available for part year and/or <75% data capture
Highlighted figures (in yellow) indicate exceedances of Scottish Air Quality Objectives

Table 6.1.1 shows nitrogen dioxide data for 82 sites utilising automatic monitoring during 2018. Although, data for 8 of these are only available for part of the year with the overall data capture less than 75%. These include sites which opened or closed during the year, sites which were closed for part of the year due to instrument problems.

Of the remaining 74 sites with 75% data capture or more, 6 of these (kerbside or roadside sites) exceeded the annual mean Objective for NO_2 (40 µg m^{-3}). The Objective of not more than 18 exceedances of 200 µg m^{-3} for the hourly mean was not exceeded at any site. The highest annual average concentrations were measured at Glasgow Kerbside, with a measured concentration of 60.6 µg m^{-3}. The greatest number of exceedances of the hourly mean objective was measured at Dundee Lochee Road with 6 exceedances.

6.1.2 Particulate Matter – PM_{10}

Table 6.1.2 Ratified data annual average concentration and data capture for PM_{10} in 2018 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	PM_{10} Analyser Type*	Annual Average PM_{10} 2018 ($\mu g\ m^{-3}$)	No. Days > 50 $\mu g\ m^{-3}$	Data Capture (%)
Aberdeen Anderson Dr	RS	VCM	13.0	0	96.4
Aberdeen Errol Place	UB	FDMS	14.3	1	96.5
Aberdeen King Street	RS	FIDAS	15.1	5	68.1
Aberdeen Market Street 2	RS	FIDAS	17.1	5	74.8
Aberdeen Union Street	RS	FDMS	14.7	0	84.7
Aberdeen Wellington Road	RS	FIDAS	17.0	3	99.4
Alloa A907	RS	FIDAS	11.3	0	99.8
Angus Forfar Glamis Rd	RS	FDMS	12.7	0	94.5
Auchencorth Moss	R	FDMS/FIDAS	7.0	0	95.2
Dundee Broughty Ferry	RS	VCM	12.3	0	83.2
Dundee Lochee Road	KS	FIDAS	12.6	1	98.8
Dundee Mains Loan	UB	FIDAS	9.1	0	99.5
Dundee Meadowside	RS	BAM (unheated inlet)	15.2	4	91.0
Dundee Seagate	KS	BAM (unheated inlet)	15.6	2	88.7
Dundee Whitehall Street	KS	BAM (unheated inlet)	16.2	4	79.4
E Ayrshire Kilmarnock St	RS	FIDAS	10.7	0	99.8
East Dunbartonshire	RS	Eberline (heated inlet)	13.8	0	93.0
East Dunbartonshire	RS	Eberline (heated inlet)	17.0	7	96.3
East Dunbartonshire	RS	FIDAS	11.4	0	88.6
East Dunbartonshire	RS	FDMS	13.1	0	87.4
East Lothian Musselburgh	RS	BAM (unheated inlet)	13.7	1	90.0
Edinburgh Currie	UB	VCM	9.3	0	96.7
Edinburgh Glasgow Road	RS	VCM	14.7	0	97.5
Edinburgh Queensferry	RS	FDMS	25.0	4	91.0
Edinburgh Salamander St	RS	VCM	18.7	3	92.6
Edinburgh St John's Road	UB	FIDAS	13.1	1	98.9
Edinburgh St Leonards	UB	FDMS	10.7	0	93.1
Edinburgh Tower Street	RS	FIDAS	9.1	0	21.0
Falkirk Banknock	RS	FIDAS	10.9	0	99.7
Falkirk Graham's Road	RS	VCM	13.9	0	73.2
Falkirk Grangemouth MC	UB	VCM	12.4	0	88.7
Falkirk Haggs	RS	VCM	14.0	0	90.0
Falkirk Hope St	RS	VCM	11.1	0	19.8
Falkirk Main St Bainsford	RS	VCM	11.6	0	70.3
Falkirk West Bridge Street	RS	FIDAS	12.3	0	67.1
Fife Cupar	RS	FIDAS	13.7	1	99.8
Fife Dunfermline	RS	FIDAS	10.9	0	99.7
Fife Kirkcaldy	RS	FIDAS	10.3	0	99.7
Fife Rosyth	RS	FIDAS	10.5	0	99.8
Glasgow Abercromby	RS	FDMS	15.6	2	71.2
Glasgow Anderston	UB	FDMS/FIDAS	12.1	0	67.2
Glasgow Broomhill	RS	FDMS	12.3	0	7.6
Glasgow Burgher St.	RS	FDMS	12.8	0	97.3

Site Name	Type	PM_{10} Analyser Type*	Annual Average PM_{10} 2018 ($\mu g\ m^{-3}$)	No. Days > 50 $\mu g\ m^{-3}$	Data Capture (%)
Glasgow Byres Road	RS	FIDAS	13.5	0	95.2
Glasgow Dumbarton Road	RS	FIDAS	13.9	0	99.1
Glasgow High Street	RS	FDMS	13.8	0	97.5
Glasgow Nithsdale Road	RS	FDMS	13.8	1	88.1
Glasgow Townhead	UB	FDMS	11.1	0	96.0
Glasgow Waulkmillglen	R	FIDAS	8.7	0	97.7
Grangemouth	UI	FDMS	11.8	0	90.0
Inverclyde Greenock A8	RS	FIDAS	11.7	0	99.9
Inverness	RS	FIDAS	8.3	0	44.0
N Lanarkshire Chapelhall	RS	FIDAS	10.1	0	100.0
N Lanarkshire Coatbridge	RS	VCM	13.0	0	26.2
N Lanarkshire Croy	RS	VCM	12.1	2	70.7
N Lanarkshire Motherwell	RS	VCM	9.9	0	72.5
N Lanarkshire Motherwell	RS	FIDAS	8.8	0	25.2
N Lanarkshire Shawhead	RS	BAM (unheated inlet)	7.9	0	46.6
North Ayrshire Irvine High	RS	FIDAS	14.4	0	86.5
North Lanarkshire	RS	BAM (unheated inlet)	9.3	0	53.3
Paisley Gordon Street	RS	FDMS	11.9	0	98.3
Paisley St James St	RS	FDMS	13.7	0	33.6
Perth Atholl Street	RS	FIDAS	13.7	0	94.7
Perth Crieff	RS	FIDAS	10.2	0	96.9
Perth Muirton	RS	FDMS	10.3	0	86.0
Renfrew Cockels Loan	RS	FDMS	15.9	1	97.8
Renfrewshire Johnstone	RS	FIDAS	13.4	1	98.4
South Lanarkshire	RS	FIDAS	12.3	2	99.8
South Lanarkshire East	RS	FIDAS	10.1	0	99.5
South Lanarkshire	RS	FIDAS	10.9	0	99.8
South Lanarkshire Lanark	RS	FIDAS	10.7	1	95.2
South Lanarkshire Raith	RS	FDMS/FIDAS	11.0	0	86.3
South Lanarkshire	RS	FIDAS	13.4	0	99.7
South Lanarkshire	RS	FIDAS	11.6	0	99.7
Stirling Craig's	RS	VCM	13.6	0	96.6
West Dunbartonshire	RS	FIDAS	10.1	0	98.8
West Lothian Broxburn	RS	FIDAS	13.1	0	99.6
West Lothian Linlithgow	RS	FIDAS	10.9	0	99.9
West Lothian Newton	RS	FDMS	14.4	1	90.5

Shaded sites indicate data only available for part year and/or <75% data capture
Highlighted figures (in yellow) indicate exceedance of Scottish Air Quality Objectives
*FDMS data are equivalent to gravimetric and hence are not adjusted
FIDAS data are equivalent to gravimetric and hence are not adjusted
BAM (heated inlet) data are adjusted using gravimetric equivalent factor of 0.966
BAM (un-heated inlet) data are adjusted using gravimetric equivalent factor of 0.8333
VCM data are TEOM data corrected using the Volatile Correction Model

Table 6.1.2 shows the 2018 gravimetric equivalent PM_{10} data from 79 sites utilising automatic monitoring (note that the Partisol daily sampler is no longer used at Auchencorth Moss and Inverness). Of these sites, 18 have less than 75% data capture. As discussed in Section 4.2.2, all TEOM data have been adjusted using the VCM.

Of the 61 sites with 75% or greater data capture, two sites exceeded the annual average PM_{10} Objective of 18 µg m^{-3}: Edinburgh Queensferry Road and Edinburgh Salamander St. The daily mean objective of 50 µg m^{-3} not to be exceeded more than 7 times in a year was not exceeded at any site but equaled at East Dunbartonshire Bishopbriggs.

The maximum PM_{10} annual mean concentration was measured at Edinburgh Queensferry Road with a measured annual mean concentration of 25.0 µg m^{-3}. Of the 18 sites with less than 75% data capture, no site measured average PM_{10} concentrations greater than the annual average PM_{10} Objective of 18 µg m^{-3}. No sites exceeded the UK AQS Objective of 40 µg m^{-3} for the annual mean PM_{10} and the daily mean objective of no more than 35 exceedances of 50 µg m^{-3}.

6.1.3 Particulate Matter – $PM_{2.5}$

Table 6.1.3 Ratified data annual average concentration and data capture for $PM_{2.5}$ in 2018 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	$PM_{2.5}$ Analyser Type	Annual Average $PM_{2.5}$ 2018 (µg m^{-3} gravimetric equivalent)	Data Capture (%)
Aberdeen Errol Place	UB	FDMS	6.9	97.5
Aberdeen King Street	RS	FIDAS	7.3	68.1
Aberdeen Market Street 2	RS	FIDAS	8.1	74.8
Aberdeen Union Street	RS	FDMS	8.1	85.3
Aberdeen Wellington Road	RS	FIDAS	7.5	99.4
Alloa A907	RS	FIDAS	6.1	99.8
Auchencorth Moss	R	FDMS/FIDAS	4.9	91.6
Dundee Lochee Road	KS	FIDAS	5.6	77.4
Dundee Mains Loan	UB	FIDAS	5.4	99.5
E Ayrshire Kilmarnock St	RS	FIDAS	6.1	99.8
East Dunbartonshire Kirkintilloch	RS	FIDAS	6.3	88.6
Edinburgh St John's Road	KS	FIDAS	6.3	98.8
Edinburgh St Leonards	UB	FDMS	6.3	93.5
Edinburgh Tower Street	RS	FIDAS	5.4	21.0
Falkirk Banknock	RS	FIDAS	5.9	99.7
Falkirk West Bridge Street	RS	FIDAS	6.3	67.1
Fife Cupar	RS	FIDAS	6.6	99.8
Fife Dunfermline	RS	FIDAS	6.1	99.7
Fife Kirkcaldy	RS	FIDAS	5.8	99.7
Fife Rosyth	RS	FIDAS	5.9	99.8
Glasgow Anderston	UB	FIDAS	7.1	8.8
Glasgow Broomhill	RS	FIDAS	8.0	7.6
Glasgow Byres Road	RS	FIDAS	7.9	95.3
Glasgow Dumbarton Road	RS	FIDAS	6.7	99.7
Glasgow High Street	RS	FDMS/FIDAS	7.4	97.4
Glasgow Nithsdale Road	UB	FIDAS	7.6	88.1
Glasgow Townhead	UB	FDMS/FIDAS	6.9	94.2
Glasgow Waulkmillglen	R	FIDAS	5.4	97.7
Grangemouth	UI	FDMS/BAM	7.2	92.3
Inverclyde Greenock A8	RS	FIDAS	6.1	99.9
Inverness	RS	FIDAS	4.6	44.0
N Lanarkshire Chapelhall	RS	FIDAS	5.2	100.0
N Lanarkshire Croy	RS	FIDAS	4.9	46.6

Site Name	Type	$PM_{2.5}$ Analyser Type	Annual Average $PM_{2.5}$ 2018 (µg m^{-3} gravimetric equivalent)	Data Capture (%)
N Lanarkshire Motherwell	RS	FIDAS	4.5	47.4
N Lanarkshire Motherwell Civic	RS	FIDAS	5.3	25.2
N Lanarkshire Shawhead	RS	FIDAS	4.3	46.6
North Ayrshire Irvine High St	KS	FIDAS	7.9	86.5
North Lanarkshire Kirkshaw	RS	FIDAS	4.0	34.5
Paisley St James St	RS	FDMS	7.2	54.2
Perth Atholl Street	RS	FIDAS	6.9	94.7
Perth Crieff	RS	FIDAS	5.9	96.9
Perth High Street	RS	TEOM	6.7	98.6
Renfrewshire Johnstone	RS	FIDAS	7.2	98.4
South Ayrshire Ayr Harbour	RS	FDMS	8.2	90.6
South Ayrshire Ayr High St	UB	FDMS	7.8	61.5
South Lanarkshire Cambuslang	RS	FIDAS	6.6	99.8
South Lanarkshire East Kilbride	RS	FIDAS	5.3	99.5
South Lanarkshire Hamilton	RS	FIDAS	5.8	99.8
South Lanarkshire Lanark	RS	FIDAS	5.8	95.2
South Lanarkshire Raith	RS	FIDAS	4.4	36.9
South Lanarkshire Rutherglen	RS	FIDAS	7.0	99.7
South Lanarkshire Uddingston	RS	FIDAS	6.5	99.7
West Dunbartonshire Clydebank	RS	FIDAS	6.1	98.8
West Lothian Broxburn	RS	FIDAS	7.2	99.6
West Lothian Linlithgow High	RS	FIDAS	6.0	99.9

Shaded sites indicate data only available for part year and/or <75% data capture
FIDAS data are adjusted using gravimetric equivalent factor of 0.943, all other data are not adjusted

For compliance with the EU Directive, three $PM_{2.5}$ urban background monitoring sites are required in Scotland. These have been established as part of the AURN in Edinburgh, Glasgow and Aberdeen. In addition, for research purposes, additional monitors have been installed at the rural site at Auchencorth Moss. With the introduction of the $PM_{2.5}$ annual mean objective of 10 µg m^{-3} introduced in April 2016 by Scottish government, local authorities have continued to introduce $PM_{2.5}$ monitoring with the number of $PM_{2.5}$ monitoring sites increasing from 41 to 55 between 2017 and 2018.

Data capture rates of less than 75% were measured at 15 sites. $PM_{2.5}$ concentrations in excess of the Scottish AQS Objective of 10 µg m^{-3} as an annual mean was not measured at any site. Figure 6.1.1 shows the 2018 annual average $PM_{2.5}$ and PM_{10} concentrations for all SAQD monitoring sites.

The $PM_{2.5}/PM_{10}$ ratios calculated for each site for the years 2009 to 2018 are shown in Table 6.1.4. The maximum and minimum $PM_{2.5}/PM_{10}$ ratios during 2018 for sites with greater than 75% data capture were calculated at Auchencorth Moss with calculated ratios of 0.71, and Aberdeen Wellington Road/Dundee Lochee Rd with a calculated ratio of 0.44.

Table 6.1.4 $PM_{2.5}/PM_{10}$ ratios for 2009 - 2018 annual average concentrations

Site Name	Annual Average $PM_{2.5}$ 2018 (µg m^{-3})	Annual Average PM10 2018 (µg m^{-3})	Ratio									
			2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Aberdeen Errol Place	6.9	14.3	0.48	0.40	0.46	0.67	0.67	0.69	0.75	0.57	0.54	0.47

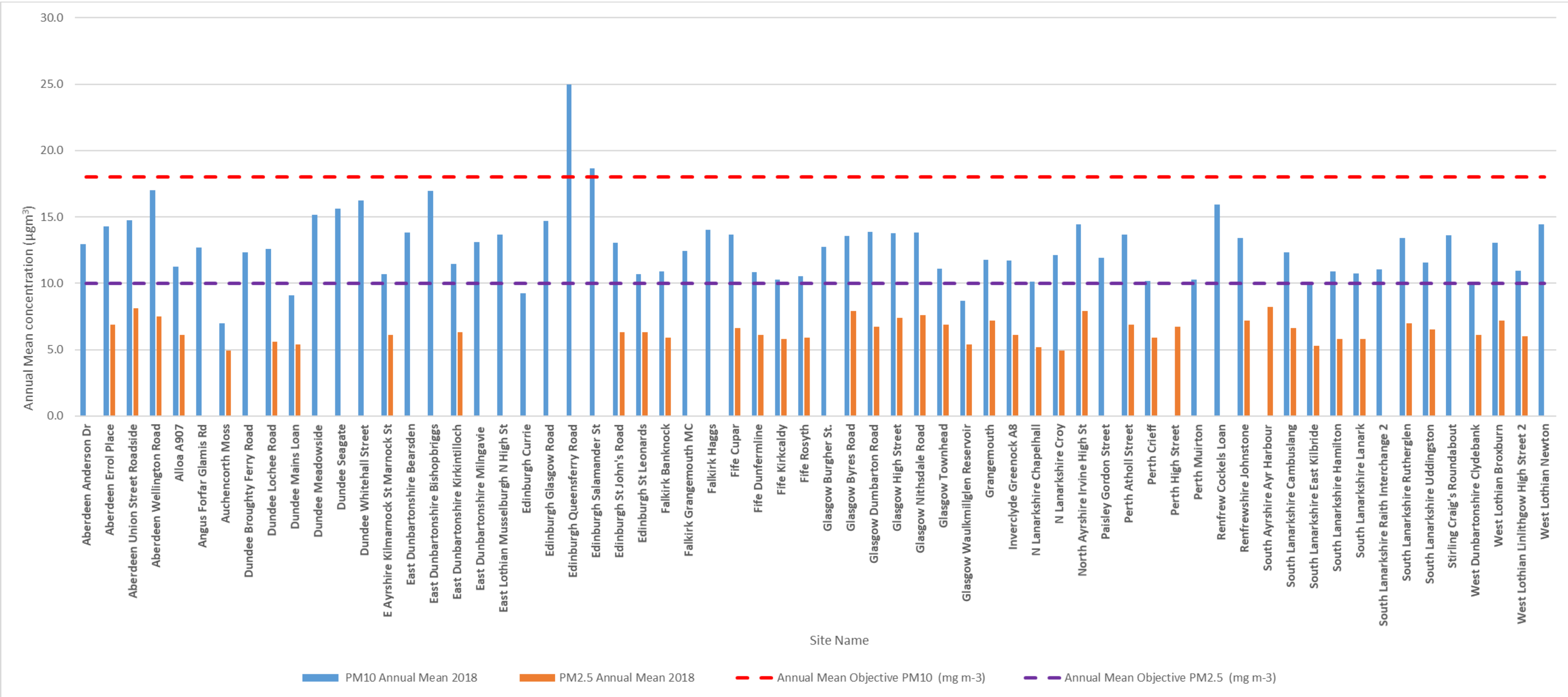
Site Name	Annual Average PM2.5 2018 (µg m-3)	Annual Average PM10 2018 (µg m-3)	Ratio									
			2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Aberdeen King Street	7.3	15.1	0.48	0.32	-	-	-	-	-	-	-	-
Aberdeen Market Street 2	8.1	17.1	0.48	0.35	0.53	0.42	-	-	-	-	-	-
Aberdeen Union Street Roadside	8.1	14.7	0.55	0.50	-	-	-	-	-	-	-	-
Aberdeen Wellington Road	7.5	17.0	0.44	0.36	0.42	-	-	-	-	-	-	-
Alloa A907	6.1	11.3	0.55	0.54	-	-	-	-	-	-	-	-
Auchencorth Moss	4.9	7.0	0.71	0.65	-	-	-	-	-	-	-	-
Dundee Lochee Road	5.6	12.6	0.44	-	-	-	-	-	-	-	-	-
Dundee Mains Loan	5.4	9.1	0.59	0.33	-	-	-	-	-	-	-	-
E Ayrshire Kilmarnock St Marnock St	6.1	10.7	0.57	0.57	0.43	-	-	-	-	-	-	-
East Dunbartonshire Kirkintilloch	6.3	11.4	0.55	0.49	-	-	-	-	-	-	-	-
Edinburgh St John's Road	6.3	13.1	0.48	0.47	0.53	-	-	-	-	-	-	-
Edinburgh St Leonards	6.3	10.7	0.59	0.62	0.60	0.55	0.69	0.57	0.69	0.80	0.64	0.50
Edinburgh Tower Street	5.4	9.1	0.60	-	-	-	-	-	-	-	-	-
Falkirk Banknock	5.9	10.9	0.54	0.57	0.50	0.55	-	-	-	-	-	-
Falkirk West Bridge Street	6.3	12.3	0.52	0.46	0.56	-	-	-	-	-	-	-
Fife Cupar	6.6	13.7	0.48	0.47	0.58	-	-	-	-	-	-	-
Fife Dunfermline	6.1	10.9	0.56	0.53	-	-	-	-	-	-	-	-
Fife Kirkcaldy	5.8	10.3	0.56	0.52	0.57	-	-	-	-	-	-	-
Fife Rosyth	5.9	10.5	0.56	0.59	0.50	-	-	-	-	-	-	-
Glasgow Anderston	7.1	12.1	0.59	-	-	-	-	-	-	-	-	-
Glasgow Broomhill	8.0	12.3	0.65	-	-	-	-	-	-	-	-	-
Glasgow Byres Road	7.9	13.5	0.58	0.58	-	-	-	-	-	-	-	-
Glasgow Dumbarton Road	6.7	13.9	0.48	0.38	-	-	-	-	-	-	-	-
Glasgow High Street	7.4	13.8	0.54	0.51	-	-	-	-	-	-	-	-
Glasgow Nithsdale Road	7.6	13.8	0.55	-	-	-	-	-	-	-	-	-
Glasgow Townhead	6.9	11.1	0.62	0.70	0.52	0.58	0.54	0.50	0.83	1.22	0.79	0.81

Site Name	Annual Average $PM_{2.5}$ 2018 (µg m^{-3})	Annual Average PM10 2018 (µg m^{-3})	Ratio									
			2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
Glasgow Waulkmillglen Reservoir	5.4	8.7	0.62	-	-	-	-	-	-	-	-	-
Grangemouth	7.2	13.4	0.54	0.54	0.54	0.75	0.67	0.64	0.79	0.79	0.79	0.68
Inverclyde Greenock A8	6.1	11.7	0.52	0.45	0.50	-	-	-	-	-	-	-
Inverness	4.6	8.3	0.55	-	-	-	-	-	-	-	-	-
N Lanarkshire Chapelhall	5.2	10.1	0.52	0.41	-	-	-	-	-	-	-	-
N Lanarkshire Croy	4.9	12.1	0.41	-	-	-	-	-	-	-	-	-
N Lanarkshire Motherwell	4.5	9.9	0.45	-	-	-	-	-	-	-	-	-
N Lanarkshire Motherwell Civic Centre	5.3	8.8	0.61	-	-	-	-	-	-	-	-	-
N Lanarkshire Shawhead Coatbridge	4.3	7.9	0.54	-	-	-	-	-	-	-	-	-
North Ayrshire Irvine High St	7.9	14.4	0.55	0.48	0.50	0.50	-	-	-	-	-	-
North Lanarkshire Kirkshaw	4.0	9.3	0.43	-	-	-	-	-	-	-	-	-
Paisley St James St	7.2	13.7	0.53	-	-	-	-	-	-	-	-	-
Perth Atholl Street	6.9	13.7	0.50	0.58	-	-	-	-	-	-	-	-
Perth Crieff	5.9	10.2	0.58	0.57	-	-	-	-	-	-	-	-
Renfrewshire Johnstone	7.2	13.4	0.53	0.41	-	-	-	-	-	-	-	-
South Lanarkshire Cambuslang	6.6	12.3	0.53	0.44	-	-	-	-	-	-	-	-
South Lanarkshire East Kilbride	5.3	10.1	0.52	0.44	-	-	-	-	-	-	-	-
South Lanarkshire Hamilton	5.8	10.9	0.53	0.46	-	-	-	-	-	-	-	-
South Lanarkshire Lanark	5.8	10.7	0.54	0.54	0.61	0.60	-	-	-	-	-	-
South Lanarkshire Raith Interchange 2	4.4	11.0	0.40	-	-	-	-	-	-	-	-	-
South Lanarkshire Rutherglen	7.0	13.4	0.52	0.44	-	-	-	-	-	-	-	-
South Lanarkshire Uddingston	6.5	11.6	0.56	0.51	0.54	0.55	-	-	-	-	-	-

Site Name	Annual Average $PM_{2.5}$ 2018 (µg m^{-3})	Annual Average PM10 2018 (µg m^{-3})	Ratio									
			2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
West Dunbartonshire Clydebank	6.1	10.1	0.60	0.54	0.64	0.60	-	-	-	-	-	-
West Lothian Broxburn	7.2	13.1	0.55	0.50	-	-	-	-	-	-	-	-
West Lothian Linlithgow High Street 2	6.0	10.9	0.55	0.46	0.70	-	-	-	-	-	-	-

Shaded sites indicate data only available for part year and/or <75% data capture

Figure 6.1.1 Annual Average PM_{10} and $PM_{2.5}$ concentrations ($\mu g\ m^{-3}$) for all SAQD sites in 2018



6.1.4 Carbon Monoxide

Table 6.1.5 Ratified data annual average concentration and data capture for CO in 2018 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average CO 2018 (mg m^{-3})	Max. Running 8hr Mean CO 2018 (mg m^{-3})	Data Capture (%)
Edinburgh St Leonards	UB	0.09	0	90.2
N Lanarkshire Croy	UB	0.08	0	25.7

Shaded sites indicate data only available for part year and/or <75% data capture

Table 6.1.5 shows carbon monoxide was monitored using automatic techniques at two sites during 2018. All monitoring sites achieved the Air Quality Strategy Objective for this pollutant.

6.1.5 Sulphur Dioxide

Table 6.1.6 Ratified data annual average concentration and data capture for SO_2 in 2018 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average SO_2 2018 (µg m^{-3})	No. 15 min SO_2 > 266µg m^{-3} 2018	No. 1 hr SO_2 > 350µg m^{-3} 2018	No. 24 hr SO_2 > 125µg m^{-3} 2018	Data Capture (%)
Edinburgh St Leonards	UB	2.3	0	0	0	93.3
Falkirk Bo'ness	UI	1.6	0	0	0	97.0
Falkirk Grangemouth MC	UB	5.2	0	0	0	97.4
Falkirk Grangemouth Zetland Park	UI	1.5	0	0	0	90.5
Falkirk Hope St	RS	2.4	0	0	0	94.0
Grangemouth	UI	2.3	0	0	0	95.6
Grangemouth Moray	UB	4.7	1	0	0	93.6
Shetland Lerwick	R	1.1	0	0	0	49.9
N Lanarkshire Croy	RS	0.6	0	0	0	25.8

Shaded sites indicate data only available for part year and/or <75% data capture
Highlighted figures (in yellow) indicate exceedance of Scottish Air Quality Objectives

Table 6.1.6 shows sulphur dioxide data from the 9 sites utilising automatic monitoring for 2018. All sites in Scotland met the requirements of the Air Quality Strategy for the 15-minute (no more than 35 times), 1-hour (no more than 24 times) and 24-hour (no more than 3 times) mean objectives SO_2 in 2018.

6.1.6 Ozone

Table 6.1.7 Ratified data annual average concentration and data capture for O_3 in 2016 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average O_3 2018 (µg m^{-3})	No of days with running 8-hr mean >100 ug m^{-3}	Data capture O_3 2018 (%)
Aberdeen Errol Place	UB	48.8	3	99.2
Auchencorth Moss	R	59.0	11	99.2
Bush Estate	R	58.9	15	99.1
Edinburgh St Leonards	UB	51.4	13	98.4
Eskdalemuir	R	58.2	16	95.3
Fort William	S	55.4	18	98.8
Glasgow Townhead	UB	42.7	6	99.3

Site Name	Type	Annual Average O_3 2018 ($\mu g\ m^{-3}$)	No of days with running 8-hr mean >100 ug m^{-3}	Data capture O_3 2018 (%)
Glasgow Waulkmillglen Reservoir	R	54.3	15	91.2
Lerwick	R	72.2	31	85.3
Peebles	S	57.6	13	94.4
Strath Vaich	R	66.3	12	99.5

Highlighted figures (in yellow) indicate exceedance of Scottish Air Quality Objectives

Table 6.1.7 shows ozone data from 11 sites utilising automatic monitoring for 2018. Ozone (O_3) is a secondary pollutant formed by reactions involving other pollutant gases in the presence of sunlight and over several hours; it may persist for several days and be transported over long distances. This means that local authorities have little control over ozone levels in their area. In 2018, the Air Quality Strategy Objective of not more than 10 days with a maximum 8 hour running mean greater than 100 $\mu g\ m^{-3}$ was exceeded at all sites excluding Aberdeen Errol Place and Glasgow Townhead.

6.2 Other pollutants covered by the Air Quality Strategy – PAH (benzo[a]pyrene), Benzene, 1,3-butadiene and Lead

In this section, we present a summary of data from a range of national monitoring networks. Summaries are provided for pollutants covered by the Air Quality Strategy. As some of these networks are based on sampler measurement techniques and subsequent chemical analysis, there is often a considerable delay in the availability of data. Hence, in some cases, the latest data available at the time of preparing this report is for 2017. Where other pollutants are also monitored in these networks, these pollutants are listed, but the data are not provided in this report.

6.2.1 PAH Monitoring Network[6]

The UK Monitoring and Analysis Network monitor some 39 Poly Aromatic Hydrocarbon (PAH) species at about 30 sites.

PAH monitoring of the compound benzo[a]pyrene is undertaken to provide data in compliance with the EU Air Quality Directive (Directive 2004/107/EC). An air quality objective for this compound is also set in the Air Quality Strategy. A wide range of other PAH species are also monitored in the particulate phase and in the gaseous phase at some sites, for research purposes. The monthly summary results for all species monitored in the PAH network can be downloaded as spreadsheet summary data from http://uk-air.defra.gov.uk/interactive-map.

The airborne PAH monitoring is undertaken using Digitel DHA-80 Air Sampling System with PM_{10} inlet. Particulate collection is undertaken on a filter and at some sites, vapour-phase collection is also undertaken using polyurethane foam in addition to filter. At two sites, deposition samplers are also used to determine deposited PAH material.

The PAH monitoring sites in Scotland are shown in Table 6.2.1. The sites at Edinburgh and Glasgow are co-located with the Edinburgh St Leonards and Glasgow Townhead AURN sites respectively. The site at Kinlochleven is located close to the closed aluminium works and the site at Auchencorth Moss is a rural EMEP site as discussed in the automatic hydrocarbon section.

[6] Conolly C. et al Final Contract Report for the UK PAH Monitoring and Analysis Network (2004-2010) [online] Available at http://uk-air.defra.gov.uk/reports/cat05/1103040911_AEA_PAH_Network_Report_2010_Final_v3.1.pdf [Accessed no 30/05/2012]

Table 6.2.1 PAH Monitoring Sites in Scotland

Site	Address	Grid Reference
Auchencorth Moss	Rural site in Scotland, south of Edinburgh	322167,656123
Edinburgh	145 Pleasance, Edinburgh, EH8 9RU	326265, 673136
Glasgow Townhead	Not available	259692, 665899
Kinlochleven	Electrical Substation, Kinlochleven	219305,761905

Annual average concentrations for Benzo(a)pyrene (B(a)P) for 2017 and 2018 are shown in Table 6.2.2. As can be seen, the Air Quality Objective for B(a)P of 0.25 ng m^{-3} as an annual average or the EU Directive target value of 1 ng m^{-3} was not exceeded at any site in 2017 or 2018.

Table 6.2.2 Annual Average Benzo(a)Pyrene Concentrations for 2017 - 2018 at Four Sites in Scotland

Site	2017 Annual Mean B(a)P Concentration (ng m^{-3})	2018 Annual Mean B(a)P Concentration (ng m^{-3})
Auchencorth Moss	0.013	0.019
Edinburgh St Leonards	0.047	0.056
Glasgow Townhead	0.067	0.065
Kinlochleven	0.163	0.250

Shaded sites indicate data only available for part year and/or <75% data capture
Highlighted figures (in yellow) indicate exceedance of Scottish Air Quality Objectives

6.2.2 Benzene

Non- automatic hydrocarbon monitoring

Monitoring of benzene is undertaken on a two-weekly basis with pumped tube samplers at 34 sites throughout the UK – The UK Non-automatic Hydrocarbon Network. Two of these sites are located in Grangemouth and Glasgow Kerbside (Hope Street) and are co-located with the Grangemouth and Glasgow Kerbside AURN sites. The non-automatic monitoring network provides benzene data for compliance with the EU Air Quality Directive and Scottish objective of 16.25 µg m^{-3} as an annual mean.

The benzene monitoring method used in this network involves pumping ambient air at a rate of 10 ml min^{-1} through nominally duplicate tubes containing the sorbent Carbopack X, with subsequent laboratory analysis of the benzene content of the tubes. Results for this site for 2017 and 2018 are provided in Table 6.2.3.

Table 6.2.3 Annual Mean Benzene Concentrations in 2017 and 2018 at 2 sites in Scotland in the UK Non-Automatic Hydrocarbon Network

Site Name	Annual Mean benzene for 2017 (µg m^{-3})	Annual Mean benzene for 2018 (µg m^{-3})
Glasgow Kerbside (Hope St)	0.68	0.66
Grangemouth	0.65	0.74

6.2.3 Automatic Hydrocarbon Monitoring

Table 6.2.4 gives the site details for the one automatic hydrocarbon monitoring station in Scotland - Auchencorth Moss; a rural site south of Edinburgh. The data from this site are used both to provide data for ozone precursor hydrocarbon species, in compliance with the EU Air Quality Directive (2008/50/EC). In addition, this site is one of the two European Monitoring and Evaluation Programme (EMEP) level II sites (EMEP "supersites") in the UK. The other EMEP supersite is located at Chilbolton in Hampshire. A much wider range of hydrocarbon species is monitored at Auchencorth Moss. However, the rural nature of this site means that often the concentrations are below the detection limit and hence, the data capture is low. Data for the full range of hydrocarbon species monitored at Auchencorth Moss can be downloaded from www.scottishairquality.co.uk.

Table 6.2.4 Location of Automatic Hydrocarbon Monitoring Sites in Scotland

Site Name	Site Type	Species Measured	Grid Reference
Auchencorth Moss	RURAL	Benzene and 1,3-butadiene and 24 other ozone precursor hydrocarbon species*	322167,656123

*EU requirement and part of the EMEP long-range transboundary air pollution monitoring programme.

Table 6.2.5 Annual Average Benzene Concentration at Auchencorth Moss in the UK Automatic Hydrocarbon Network, for 2018

Site	2017 Benzene Annual mean concentration ($\mu g\ m^{-3}$)	2018 Benzene Maximum running annual concentration ($\mu g\ m^{-3}$)	2018 % Data Capture
Auchencorth Moss	0.20	0.24	86

Table 6.2.3 and 6.2.5 indicate that it is unlikely that the EU limit value for benzene of 5 $\mu g\ m^{-3}$ and the Scottish Objective of 3.25 $\mu g\ m^{-3}$ for the annual running mean concentration will have been exceeded at Auchencorth Moss during 2018.

6.2.4 1,3-Butadiene

The species 1,3-butadiene is also measured as part of the UK Automatic Hydrocarbon Network at the same sites as for Benzene. Table 6.2.6 shows that 1,3-butadiene concentrations less than the Scottish air quality Objective of 2.25 $\mu g\ m^{-3}$ were measured during 2018, however, the data capture rate is less than 75% and so no conclusion can be made whether the objective is likely to have been exceeded or not . There is no EU Directive covering 1,3-butadiene.

Table 6.2.6. Annual Average 1,3-butadiene Concentration at Auchencorth Moss in the UK Automatic Hydrocarbon Network, for 2017 and 2018

Site	2017 1,3-butadiene Annual mean concentration ($\mu g\ m^{-3}$)	2018 1,3-butadiene maximum running annual concentration ($\mu g\ m^{-3}$)	2018 % Data capture
Auchencorth Moss	0.013	0.029	11

6.2.5 Heavy Metals

Lead and a wide range of other metals are monitored in two UK networks – the UK Heavy Metals Monitoring Network (mainly urban sites) and the National Monitoring Network for Heavy Metals (mostly rural sites). The urban network determines airborne particulate concentrations of 15 metals, including the metals lead, nickel, arsenic, cadmium and mercury which are covered by the EU Directive (Directives 2008/50/EC for lead and Directive 2004/107/EC for other metals). The rural network determines the concentration of more than 20 metals both as airborne particulate matter and as deposited material in rainwater samples. Results for all metals monitored in the UK Heavy Metals Monitoring Network and for a selection of metals monitored in the National Monitoring Network for Heavy Metals are available from annual average spreadsheet summaries at www.uk-air.defra.gov.uk.

6.2.5.1 Rural Heavy Metals

In the National Monitoring Network for Heavy Metals, particles are collected using either single sample or multiple-sample FH95 samplers which draw air through a PM_{10} head at a flow rate of 1 $m^3\ h^{-1}$. Particulate metals are collected on a filter paper for subsequent analysis. The sampling period is normally one week. Rainwater collectors are used to collect samples for rainwater analysis of metals to determine metal deposition. Details of the two rural sites in Scotland are provided in Table 6.2.9 and data for the measurement of lead, nickel, arsenic and cadmium in 2018 are provided in Table 6.2.10.

Table 6.2.9 Rural Network Metals Monitoring Sites in Scotland

Site	Address	Grid Reference
Auchencorth Moss	Rural site, SE Scotland	322167,656123
Eskdalemuir	The Met Office Eskdalemuir Observatory, Langholm, Dumfries & Galloway, DG13 0QW	323552,603018

Table 6.2.10 Annual Mean Metal Concentrations 2018 (Rural Network)

Site	Annual Mean Lead Concentration (ng m^{-3})	Annual Mean Nickel Concentration (ng m^{-3})	Annual Mean Arsenic Concentration (ng m^{-3})	Annual Mean Cadmium Concentration (ng m^{-3})
Auchencorth Moss	1.03	0.25	0.20	0.026
Eskdalemuir	0.96	0.24	0.16	0.024

The results from these networks show that the EU limit value for lead, and the target values for nickel, arsenic and cadmium were not exceeded at any site in Scotland. The air quality Objectives for lead (500 ng m^{-3} for 2004 and 250 ng m^{-3} for 2008) were also not exceeded at any site in Scotland.

6.3 Discussion of additional pollutants monitored and/or other methods of monitoring

This section discusses other air pollution measurements made in Scotland. Detailed results are not provided but are available in the annual reports of the various networks. The exception to this is for concentrations of NO_2 reported from passive diffusion tubes, where the annual mean data is now collated and provided within the Air Quality Scotland Website. The following additional pollutants or additional monitoring methods are discussed:

1. NO_2 diffusion tube samplers
2. Non- methane Volatile Organic Compounds (NMVOC)
3. Poly aromatic hydrocarbons (PAH)
4. Toxic Organic Micropollutants (TOMPS)
5. Metals (Urban network)
6. Metals (Rural and deposition network)
7. United Kingdom Eutrophying & Acidifying Pollutants Network:
    1. The Precipitation Network
    2. NO_2 rural diffusion tube Network
    3. Acid Gases and Aerosol Network (AGANET)
    4. National Ammonia Monitoring Network

6.3.1 NO_2 Diffusion Tube Results

There is no specific requirement for local authorities to provide their NO_2 diffusion tube data to a central storage facility. However, through the local authority Air Quality Support contract, a mechanism has been provided for authorities to provide these data. This data entry system is available from http://airquality.aeat.com/NO2admintools/NO2_logon.php. Where these data are provided by the authorities, they are then made available via the Scottish air quality website (www.scottishairquality.co.uk).

Diffusive samplers (as described in paragraphs 7.179 - 7.199 of the Technical Guidance LAQM.TG(16)) are widely used for indicative monitoring of ambient nitrogen dioxide (NO_2) in the context of Review and Assessment.

Diffusion tubes are particularly useful:

- When simple, indicative techniques will suffice;
- To give an indication of longer-term average NO_2 concentrations;
- For highlighting areas of high NO_2 concentration where installation of an automatic analyser is not feasible.

They are useful for identifying areas of high NO_2 concentration, particularly when dealing with sources such as traffic emissions, which do not change much from day to day.

6.3.1.1 NO_2 Diffusion Tube Map Data

In October 2018 Scottish Government commissioned Ricardo to develop a NO_2 diffusion tube database and map similar to what is already provided for the automated site data. The map was release on the Air Quality in Scotland website in June 2019. The map provides bias corrected annual mean data previously published in the local authority's annual progress report. The database and map brings all the diffusion tube monitoring for each year together and in turn enables the user to identify the number of sites that exceeded the annual mean objective out of the more than 1100 monitoring sites across Scotland.

According to data collected for the map, there were 74 sites that exceeded the annual man objective of 40 $\mu g\ m^{-3}$ in 2018. The majority of these sites were located in the busy urban city centre areas of the 4 major cities in Scotland (Glasgow, Edinburgh, Dundee and Aberdeen) however there were also a number of sites in other busy urban locations. All sites that exceeded are provided in table 6.3.1 below. For more information on the data provide in table 6.3.1, all other 2018 and historical diffusion tube data, go the Air Quality in Scotland website (http://www.scottishairquality.scot/latest/diffusion-sites).

Table 6.3.1 NO_2 Diffusion Tube sites exceeding the Annual Mean Objective in 2018

Site Name	Annual Mean Concentration ($\mu g\ m^{-3}$)	Local Authority Name
107 Anderson Dr	48	Aberdeen City Council
39 Market St	46	Aberdeen City Council
184/192 Market St	47	Aberdeen City Council
105 King St	48	Aberdeen City Council
40 Union St	44	Aberdeen City Council
43/45 Union St	44	Aberdeen City Council
468 Union St	40	Aberdeen City Council
469 Union St	45	Aberdeen City Council
335 Union St	41	Aberdeen City Council
16 East North St	40	Aberdeen City Council
115 Menzies Rd/Wellington Rd	42	Aberdeen City Council
819 Gt Northern Rd	43	Aberdeen City Council
852 Fullerton Ct (roadside)	40	Aberdeen City Council
Powis Terrace	41	Aberdeen City Council
61 Skene Square	40	Aberdeen City Council
7 Virgina Street	44	Aberdeen City Council

Site Name	Annual Mean Concentration (µg m^{-3})	Local Authority Name
Broughty Ferry Rd (129)	40.1	Dundee City Council
Dock St (57)	46.4	Dundee City Council
Forfar Rd (104)	41.0	Dundee City Council
Lochee Rd (138)	48.4	Dundee City Council
Lochee Rd (140) Traffic Lts	48.8	Dundee City Council
Lochee Rd (Romon) Average	43.1	Dundee City Council
Logie St (114)	48.2	Dundee City Council
Meadowside (Romon) Average	40.4	Dundee City Council
Nethergate (88)	41.3	Dundee City Council
Seagate (97)	41.7	Dundee City Council
Seagate (99)	41.3	Dundee City Council
Seagate(Romon) Average	40.0	Dundee City Council
Victoria Rd/Hilltown	49.2	Dundee City Council
West Marketgait / Guthrie St	41.4	Dundee City Council
West Marketgait/Old Mill (23)	47.0	Dundee City Council
Whitehall St (1)	42.5	Dundee City Council
Glasgow Road Newbridge	45	City of Edinburgh Council
Glasgow Road Newbridge	40	City of Edinburgh Council
Queensferry Road 550	41	City of Edinburgh Council
St John's Road 131	40	City of Edinburgh Council
Dundee Street/Yeaman Place	40	City of Edinburgh Council
London Road/Earlston Place	42	City of Edinburgh Council
London Rd/East Norton Place	43	City of Edinburgh Council
London Road/Wolseley Terrace	40	City of Edinburgh Council
Grassmarket 41	56	City of Edinburgh Council
Nicolson Street 69	43	City of Edinburgh Council
North Bridge – South	40	City of Edinburgh Council
Princes Street (Eastbound)	40	City of Edinburgh Council
Princes Street/Mound	40	City of Edinburgh Council
Queen Street/Hanover Street	42	City of Edinburgh Council

Site Name	Annual Mean Concentration (µg m^{-3})	Local Authority Name
Shandwick Place	40	City of Edinburgh Council
South Bridge 59	41	City of Edinburgh Council
Torphichen Place 1	43	City of Edinburgh Council
Torphichen Place CH	43	City of Edinburgh Council
West Port 42	51	City of Edinburgh Council
West Port 62	65	City of Edinburgh Council
West Bridge Street Falkirk	43.8	Falkirk City Council
Union St	47	Glasgow City Council
Bath St	41	Glasgow City Council
Glassford St	40	Glasgow City Council
Buchanan St	41	Glasgow City Council
Hope St 3	40	Glasgow City Council
Renfield St	45	Glasgow City Council
Hope St 1	63	Glasgow City Council
Gordon St	60	Glasgow City Council
Heilanman's Umbrella	48	Glasgow City Council
High St	40	Glasgow City Council
Under bridge Central Way eastbound Cumbernauld	43.6	North Lanarkshire Council
Central Way westbound Cumbernauld	45.7	North Lanarkshire Council
17 Atholl Street	41	Perth and Kinross Council
19 West High Street Crieff PH7 4AU	47	Perth and Kinross Council
Inchinnan Road Renfrew	41.1	Renfrewshire Council
High Street Johnstone	40	Renfrewshire Council
20 Farmeloan Road Rutherglen	40.5	South Lanarkshire Council
24 Low Patrick Street Hamilton	59.2	South Lanarkshire Council
233 Glasgow Road Blantyre	52.9	South Lanarkshire Council
Milton 3	43.9	West Dunbartonshire Council
Milton 4	42.6	West Dunbartonshire Council

6.3.2 Non-Methane Volatile Organic Compounds (NMVOC)

At Auchencorth Moss a much wider range of NMVOCs are monitored to provide ozone precursor pollutant concentrations in compliance with the EU Directive (2008/50/EC). The following compounds are monitored:

- Ethane
- Ethene
- Propane
- 2-Methylbutane
- n-Pentane
- 1,3-Butadiene
- n-Heptane
- n-Octane
- Toluene

- Propene
- Ethyne
- 2-Methylpropane
- n-Butane
- trans-2-Butene
- 1-Butene
- cis-2-Butene
- trans-2-Pentene
- 1-Pentene
- 2-Methylpentane
- n-Hexane
- Isoprene
- Benzene
- 2,2,4-trimethylpentane
- Ethylbenzene
- (m+p)-Xylene
- o-Xylene
- 1,3,5-Trimethylbenzene
- 1,2,4-Trimethylbenzene
- 1,2,3-Trimethylbenzene

Hourly data for all these species are available on the Scottish Air Quality website.

6.3.3 Poly-Aromatic Hydrocarbons (PAH)

As discussed in Section 6.2.1, a wide range of particulate and gaseous PAH compounds are monitored within the UK PAH network. The following PAH species are sampled on a daily basis (but bulked into monthly results after analysis) at the four PAH sites in Scotland:

- Benzo(c)phenanthrene
- Benzo(a)anthracene
- Chrysene
- Cyclopenta(c,d)pyrene
- Benzo(b)naph(2,1-d)thiophene
- 5-Methyl Chrysene
- Benzo(b+j)fluoranthene
- Benzo(k)fluoranthene
- Benzo(e)pyrene
- Benzo(a)pyrene
- Perylene
- Indeno(1,2,3-cd)pyrene
- Dibenzo(ah.ac)anthracene
- Benzo(ghi)perylene
- Dibenzo(al)pyrene
- Dibenzo (ae)pyrene
- Dibenzo(ai)pyrene
- Dibenzo(ah)pyrene
- Coronene
- Cholanthrene
- Dibenzo(al)pyrene

6.3.4 Toxic Organic Micropollutants

Toxic Organic Micropollutants (TOMPs) include Polychlorinated Dibenzo-p-Dioxins, Polychlorinated Dibenzofurans (PCDD/Fs), PAHs, and Polychlorinated Biphenyls (PCBs). PCDD/Fs and PAHs are formed as unwanted by-products during various industrial, chemical and combustion processes. PCBs were formerly manufactured for use in a wide range of electrical and other products until 1986. These highly toxic and persistent species are ubiquitous in the environment, but are normally present at extremely low concentrations, the atmosphere being the principal route for their redistribution in the environment. The TOMPs network provides data on concentrations of these species in the air throughout the UK. There were six sites in the TOMPs network during 2018; one in Scotland at Auchencorth Moss.

The TOMPs network samples are analysed for PCDD/Fs and PCBs. Portions from the extracts of samples are also analysed for PAHs as part of the PAH network. The sampling method is based around the use of a modified Andersen GPS-1 sampler with subsequent chemical analysis requiring the use of a range of sophisticated chemical analysis techniques. These include gas chromatography coupled with high-resolution mass spectrometry for the PCDD/Fs and for those PCBs with dioxin-like effects and low-resolution mass spectrometry for the other PCBs.

6.3.5 Heavy Metals Network

As discussed in Section 6.2.5 a wide range of metals are monitored in both air and rainwater within the National Monitoring Network for Heavy Metals. At the two sites in Scotland, Auchencorth Moss and Eskdalemuir, the following metals are monitored:
Arsenic (As), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Nickel (Ni), Selenium (Se), Vanadium (V) and Zinc (Zn).

6.3.6 United Kingdom Eutrophying & Acidifying Pollutant Network (UKEAP)

This network focuses on the measurement of Eutrophying & Acidifying Pollutants in rural areas. The number of sites in Scotland is different for the various species measured.

The UKEAP has four component networks:

- The Precipitation Network (PrecipNet),
- Rural NO_2 network (NO_2-Net),
- Acid Gas and Aerosol Network (AGANET),
- National Ammonia Monitoring Network (NAMN),
- Automatic Mercury Network.

Each network functions on a national scale, however with differing spatial and temporal resolution which reflects the spatial and temporal heterogeneity of the atmospheric pollutant concerned.

The Precipitation Network (Precip-Net)

There are 38 sites in PrecipNet at which the chemical composition of precipitation (i.e. rainwater) is measured. Six of the sites, Lochnagar, Llyn Llagi, Scoat Tarn, Loch Chon/Tinker, River Etherow, Beaghs Burn and Crai Reservoir (Head of the Valleys) were specifically located within sensitive ecosystems. The network allows estimates of wet deposition of sulphur and nitrogen chemicals.

Fortnightly precipitation samples are collected at 38 sites throughout the UK, of which, 13 are in Scotland (see Appendix 1). Sampling is undertaken with using a bulk rainwater collector. The collected rainwater samples are analysed for sulphate, nitrate, chloride, phosphate, sodium, magnesium, calcium, potassium, pH and conductivity.

Rural NO_2 Network (NO_2-Net)

The nitrogen dioxide measurements are made at 24 of the 38 Precip-Net composition sites. Diffusion tubes are used to measure nitrogen dioxide. The tubes are mounted on the upright of the rain collector stand and exposed for four- or five-week periods throughout each year.

Triplicate nitrogen dioxide diffusion tube measurements are run at three AURN sites with co-located automatic instruments (Yarner Wood, Harwell and Eskdalemuir). The annual average NO_2 concentration measured at the Eskdalemuir automatic monitoring site was 2.0 µg m^{-3} in 2018 with a data capture rate of 97%. Nitrogen dioxide is measured with diffusion tube samplers at nine sites in Scotland. The annual average concentrations measured in 2018 are provided in Table 6.3.2.

Table 6.3.2 NO_2 Annual Average Concentrations 2018 at Rural Monitoring Sites

Site	NO_2 (ug m^{-3})	Data Capture (%)
Allt a'Mharcaidh	1.4	100
Balquhidder 2	2.4	100
Eskdalemuir	2.4	100
Forsinard RSPB	1.5	100
Glensaugh	3.2	100
Loch Dee	2.5	100
Polloch	1.2	100
Strath Vaich	1.0	100
Whiteadder	3.1	100

Acid Gas and Aerosol Network (AGANET)

The UK Acid Gases and Aerosols Monitoring Network has been in operation since September 1999, providing monthly measurement data of acid gases and aerosols.

An extension of the CEH Denuder for Long Term Atmospheric sampling (DELTA) system at the network sites is used to additionally sample gaseous HNO_3, SO_2, HCl and particulate NO^{3-}, SO_4^{2-}, Cl^-, Na^+, Ca^{2+}, Mg^{2+}. The new expanded network includes measurements of gaseous SO_2 and particulate SO_4^{2-} .

The 11 sites in this network located in Scotland are listed in Appendix 1.

National Ammonia Monitoring Network (NAMN)

Established in 1996, the objectives of the network are to quantify temporal and spatial changes in air concentrations and deposition in NH_3 and NH_4^+ (included since 1999) on a long-term basis. The monitoring provides a baseline in the reduced nitrogen species (NH_3 + NH_4^+), which is necessary for examining responses to changes in the agricultural sector and to verify compliance with targets set by international agreements. The 22 sites in this network located in Scotland are listed in Appendix 1.

7 Air Quality Mapping for Scotland

As part of the Scottish Air Quality Database project, Ricardo Energy & Environment provide mapped concentrations of modelled background air pollutant concentrations on a 1 km x 1 km basis for the whole of Scotland. Modelled roadside air pollutant concentrations are provided for road links in Scotland. The air pollution maps are derived from a combination of (1) measurements from Scotland's network of air quality monitoring stations, and (2) spatially disaggregated emissions information from the UK National Atmospheric Emissions Inventory (NAEI). They provide estimated pollutant concentrations for the whole of Scotland. The methodology for producing the Scottish maps is based on the UK Pollution Climate Mapping (PCM) approach, used for producing air pollution maps for the whole UK for the purposes of annual compliance reporting to the European Commission.

The PCM methodology has been applied to provide pollution maps of Scotland for the Scottish Government for 2017 using measurements exclusively from Scottish air quality monitoring sites and Scottish meteorology. The maps provide spatial representation of the annual mean concentrations of:

- PM_{10} (gravimetric equivalent), and
- NO_X and NO_2.

The air pollution measurements used to prepare the maps presented here consists of appropriately scaled PM_{10} monitoring data (FDMS, Partisol, FIDAS and VCM-corrected TEOM data) and automatic monitoring measurements for NO_X and NO_2 from the model year. The model also uses Scottish meteorology observations (from RAF Leuchars) to create the Scotland-specific maps.

In 2009 Ricardo undertook a short study[7] on behalf of the Scottish Government which demonstrated that air pollutant source apportionment data and forward-projected concentrations of air pollutants were required for the Scottish pollution maps. These parameters were calculated for 2009, using Scotland-specific data, for use by Scottish local authorities for their Local Air Quality Management Review and Assessment (LAQM) reports. These Scotland-specific air pollutant source apportionment data and forward-projected concentrations of air pollutants for LAQM were updated to a base year of 2017 during 2018 and are available at: http://www.scottishairquality.scot/maps.php?n_action=data.

7.1 Air Quality Maps for Scotland 2017

The details of the methodology and full results of the mapping study are provided in a separate report[8]. In this report, we summarise the main findings of this work.

7.1.2 NO_2 maps for 2017

The 2017 annual mean NO_2 concentrations for Scotland were modelled for background and roadside locations. Figure 7.1 and Figure 7.2 show modelled annual mean NO_2 concentrations in Scotland, for background and roadside locations respectively.

[7] Stevenson, K., Kent, A.J., and Stedman, J. (2010). Investigation of the possible effect of the use of Scottish specific air quality maps in the LAQM process in four selected Local Authorities. AEA Report AEAT/ENV/R/2948. http://www.scottishairquality.co.uk/documents/reports2/258100203_LA_mapping_Report_Issue_1_FINAL.PDF

[8] TO BE PUBLISHED

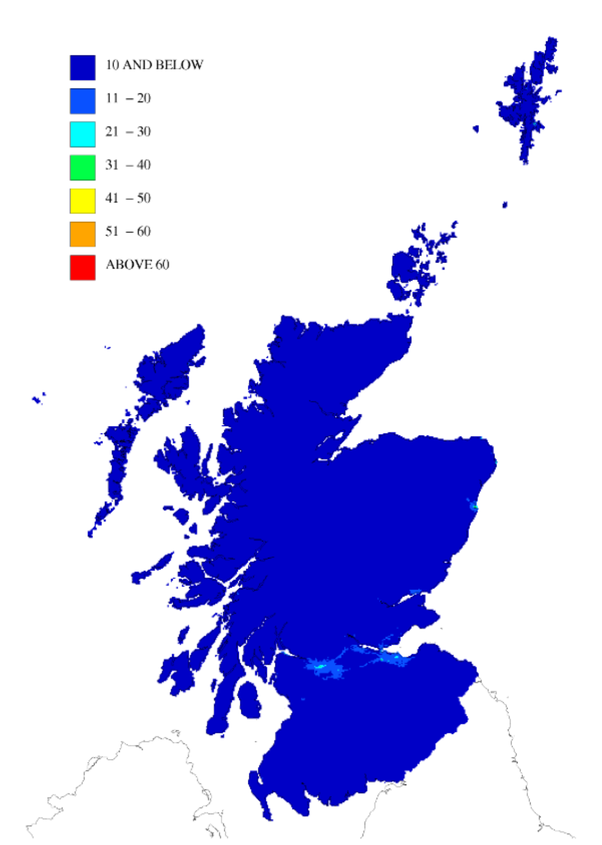
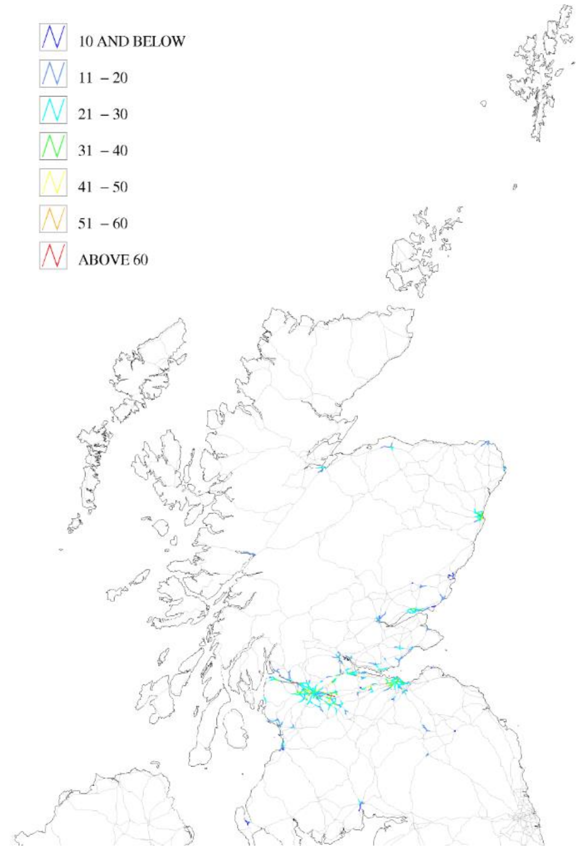
Figure 7.1 Background NO_2 map for 2017, μgm^{-3} (Scotland specific model)	Figure 7.2 Roadside NO_2 map for 2017, μgm^{-3} (Scotland specific model)
	

Table 7.1 shows that there were no modelled exceedances of the Scottish annual mean NO_2 objective of 40 µg m^{-3} at background locations. Overall exceedances of the Scottish annual mean NO_2 air quality objective were modelled at roadside locations in four of the six zones and agglomerations in Scotland. Exceedances of the annual mean NO_2 objective at roadside locations were modelled at 38 road links (57.5 km of road) in the Glasgow Urban Area and at 11 road links (21.7 km of road) in Central Scotland. In the Edinburgh Urban Area and the North East Scotland zone there were fewer than five road links where exceedances of the Scottish annual mean NO_2 air quality objective were modelled, affecting 4-6 km of roads. No roadside exceedances of the Scottish annual mean NO_2 air quality objective were modelled in the more rural zones and agglomerations of Scotland, i.e. the Highlands and Scottish Borders. More detailed maps showing the roadside annual mean NO_2 concentrations can be found in the Scottish Air Quality Mapping report 2017.

Table 7.1 Annual mean exceedance statistics for background NO_2 in Scotland based on the Scotland-specific model, 2017.

Zone or agglomeration	Total		>40 µg m^{-3}	
	Area (km^2)	**Population**	**Area (km^2)**	**Population**
Glasgow Urban Area	367	1,105,095	0	0
Edinburgh Urban Area	134	468,399	0	0
Central Scotland	9,984	1,942,272	0	0
North East Scotland	19,024	1,121,019	0	0
Highland	43,514	393,586	0	0
Scottish Borders	11,400	265,466	0	0
Total	**84,423**	**5,295,838**	**0**	**0**

Table 7.2 Annual mean exceedance statistics for roadside NO_2 in Scotland based on the Scotland-specific model, 2017.

Zone or agglomeration			>40 µg m^{-3}	
	Road links	**Length (km)**	**Road links**	**Length (km)**
Glasgow Urban Area	292	344.1	38	57.5
Edinburgh Urban Area	60	99.5	4	6.0
Central Scotland	235	352.9	11	21.7
North East Scotland	136	234.4	3	4.8
Highland	11	36.6	0	0.0
Scottish Borders	37	47.1	0	0.0
Total	**771**	**114.5**	**56**	**90.0**

7.1.3 PM_{10} maps for 2017

2017 annual mean PM_{10} concentrations for Scotland were modelled for background and roadside locations. The modelling methodology used to calculate the annual mean PM_{10} concentration was similar to that used in previous years and used a mixture of appropriately scaled PM_{10} monitoring (FIDAS, FDMS, Partisol and VCM corrected TEOM) data. Many of the chemical components of the PM_{10} model are not affected by the Scotland-specific changes to the UK PCM model. This includes the contribution to the total PM_{10} mass from the following components:

- secondary inorganic aerosols (SIA, e.g., sulphate, nitrate, ammonium-based particles)
- secondary organic aerosols (SOA)
- primary particles from long-range transport (e.g., soot particles from biomass burning)
- sea salt aerosol, and
- iron and calcium-based dusts.

Maps of the modelled 2017 annual mean PM_{10} concentrations for Scotland's background and roadside locations are shown in Figures 7.3 and 7.4, respectively.

Figure 7.3 Background PM10 map for 2017, μgm^{-3} (Scotland specific model)

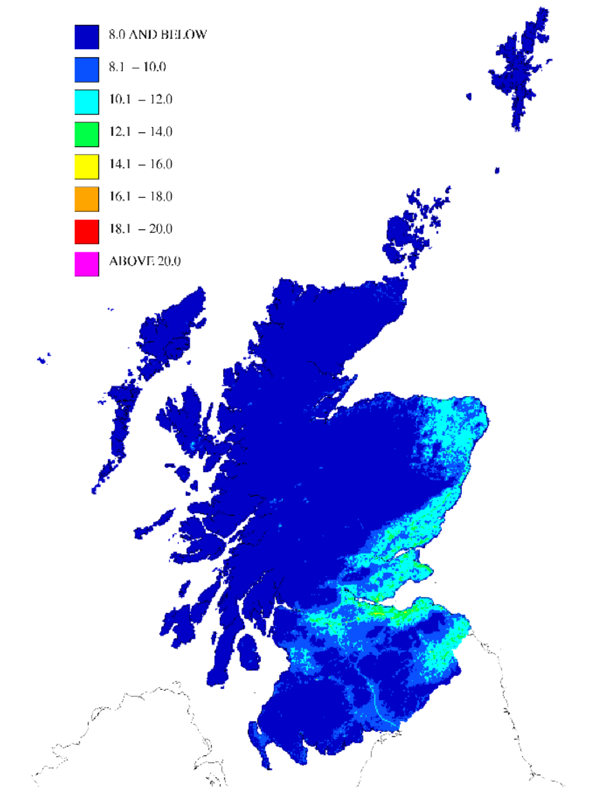


Figure 7.4 Roadside PM_{10} map for 2017, μgm^{-3} (Scotland specific model)

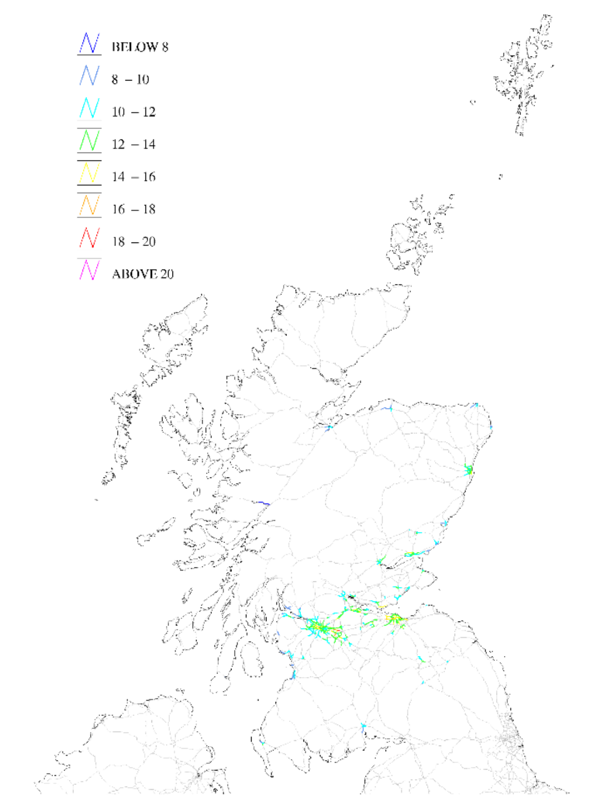


Table 7.3 shows that there were no modelled exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} at background locations. Two road links (3.9 km of road) were identified as exceeding the Scottish annual mean PM_{10} air quality objective, as shown in Table 7.4. Exceedances of the Scottish annual mean PM_{10} objective were modelled in the Glasgow Urban Area only.

Table 7.3 Annual mean exceedance statistics for background PM_{10} in Scotland based on the Scotland-specific model, 2017.

Zone or agglomeration	Total		>18 µg m^{-3}	
	Area (km^2)	**Population**	**Area (km^2)**	**Population**
Glasgow Urban Area	367	1,105,095	0	0
Edinburgh Urban Area	134	468,399	0	0
Central Scotland	9,984	1,942,272	0	0
North East Scotland	19,024	1,121,019	0	0
Highland	43,514	393,586	0	0
Scottish Borders	11,400	265,466	0	0
Total	**84,423**	**5,295,838**	**0**	**0**

Table 7.4 Annual mean exceedance statistics for roadside PM_{10} in Scotland based on the Scotland specific model, 2017.

Zone or agglomeration	Total		>18 µg m^{-3}	
	Road links	**Length (km)**	**Road links**	**Length (km)**
Glasgow Urban Area	292	344.1	2	3.9
Edinburgh Urban Area	60	99.5	0	0.0
Central Scotland	235	352.9	0	0.0
North East Scotland	136	234.4	0	0.0
Highland	11	36.6	0	0.0
Scottish Borders	37	47.1	0	0.0
Total	**771**	**1114.5**	**2**	**3.9**

7.1.4 Forward projections from a base year of 2017

Background maps of PM_{10}, NO_X and NO_2 for the years 2017 to 2030 are provided to assist Scottish local authorities in support of the Review and assessment of local air quality. These are available for download from the Data for Local Authority Review and Assessment purposes page on the Air Quality in Scotland website[9].

[9] http://www.scottishairquality.co.uk/data/mapping?view=data

8 Air Quality Trends for Scotland

This section of the report summarises how air quality in Scotland has changed in recent years. It focuses on those pollutants for which not all monitoring stations (or sites) in Scotland currently meet the Air Quality Strategy Objectives. These pollutants are nitrogen dioxide and particulate matter. This section will also look at the pollutant ozone as previous trend analysis has indicated an increasing trend in some instances.

Automatic monitoring of oxides of nitrogen and of ozone has been routinely carried out in Scotland since 1987, with automatic PM_{10} monitoring carried out since the 1990s. However, until 2000 there were relatively few automatic monitoring sites. Subsequent years have seen the number of monitoring sites in the Scottish Air Quality database increase from 20 sites (in 2000) to the current total of 99 sites (as of July 2019). The data produced by these monitoring sites have improved our understanding of Scotland's pollution climate. However, the increase in site numbers potentially complicates the investigation of trends in air quality. If trend investigation is based on all available data, the apparent trends we see may not reflect real changes in Scotland's air quality; instead, they may be due to the changes in the number of sites (and their distribution). Therefore, in reports in this series from 2010 onwards, investigation of trends has been based on subsets of long-running sites.

All the sites featured in this section have been in operation for a minimum of five consecutive years, as this is usually considered to be the minimum required in order to assess long-term trends at a monitoring site. In most cases it is now possible to do trend analysis for longer periods, for example ten years.

The trend analysis presented in this section has been carried out using Openair: a free, open-source software package of tools for analysis of air pollution data. Openair was initially funded by the Natural Environment Research Council (NERC), with additional funds from Defra[10]. The Openair project is now maintained by Dr David Carslaw, of Ricardo Energy & Environment and Dr Karl Ropkins of the University of Leeds. A range of Openair tools are available on the "Air Quality in Scotland" website: for more information on the tools and how to use them, please see:
http://www.scottishairquality.scot/openair/openair.php

The trend analyses were done using the Openair "TheilSen" tool. This uses the Theil-Sen statistical method to determine trends in pollutant concentrations over several years. The trend analysis is based on monthly mean pollutant concentrations. Openair includes an option to "de-seasonalise" the data (i.e. statistically modify the plotted data to remove the influence of seasonal cycles, thus providing a clearer indication of the overall trend over the relevant time). The "de-seasonalise" option has been used in all the Theil-Sen trend graphs presented here. When the de-seasonalise option is used, Openair fills in any gaps in the data using a linear interpolation method.

In these plots the trend line is shown by a solid red line, with 95% confidence intervals for the trend shown by dotted red lines. The trend is given at the top of the plot in green, with confidence intervals shown in square brackets. The trend is given as units (i.e. $\mu g\ m^{-3}$) per year, over the period shown. This may be followed by a number of stars, with * indicating that the trend is statistically significant at the 0.05 level, ** indicating significance at the 0.01 level and *** indicating significance at the 0.001 level. The symbol + indicates that the trend is significant at the 0.1 level.

8.1 Nitrogen Dioxide

In Scotland (as elsewhere in the UK) the largest number of Air Quality Management Areas (AQMAs) has been declared in response to exceedances of objectives for nitrogen dioxide (NO_2). This is also reflected in the number of monitoring stations reporting exceedances for this pollutant (see Section 6 of this report). In particular, the objective of 40 $\mu g\ m^{-3}$ for annual mean NO_2 concentration is the most widely exceeded. It is therefore important to understand how concentrations of this pollutant are varying with time.

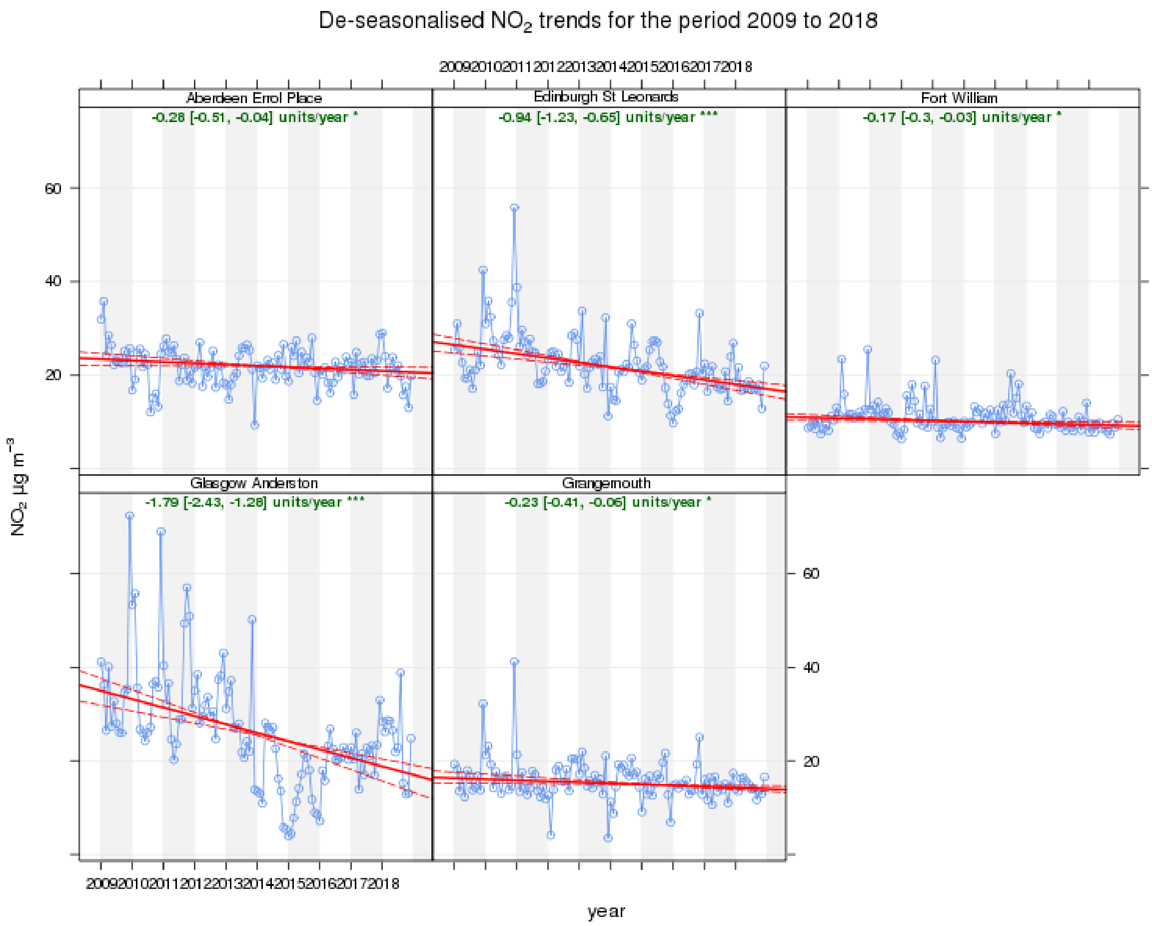
[10] Carslaw DC and Ropkins K (2012). "Openair — An R package for air quality data analysis." Environmental Modelling & Software, 27–28(0), pp. 52–61. ISSN 1364-8152, doi: 10.1016/j.envsoft.2011.09.008.

8.1.1 NO_2 at Urban Background Sites

There are relatively few long-running urban background monitoring stations in Scotland. Five urban non-roadside sites have been in operation for the past 11 years, 2008-2018. These are as follows: Aberdeen Errol Place, Edinburgh St Leonards, Fort William, Glasgow Anderston and Grangemouth. Fort William is classified as a 'suburban' site, Grangemouth is an 'urban industrial' site, and the other three are 'urban background'.

The Openair Theil-Sen function has been used to quantify trends in NO_2 at these five urban non-roadside monitoring stations, over the 10-year period 2009-2018: the trend plots for NO_2 are shown in**Error! Reference source not found.**. *Please note that both Edinburgh St Leonards and Glasgow Anderston have large gaps in their 2014 and 2015 datasets: as stated above, where there are gaps in the data, Openair fills these in using an interpolation method*.

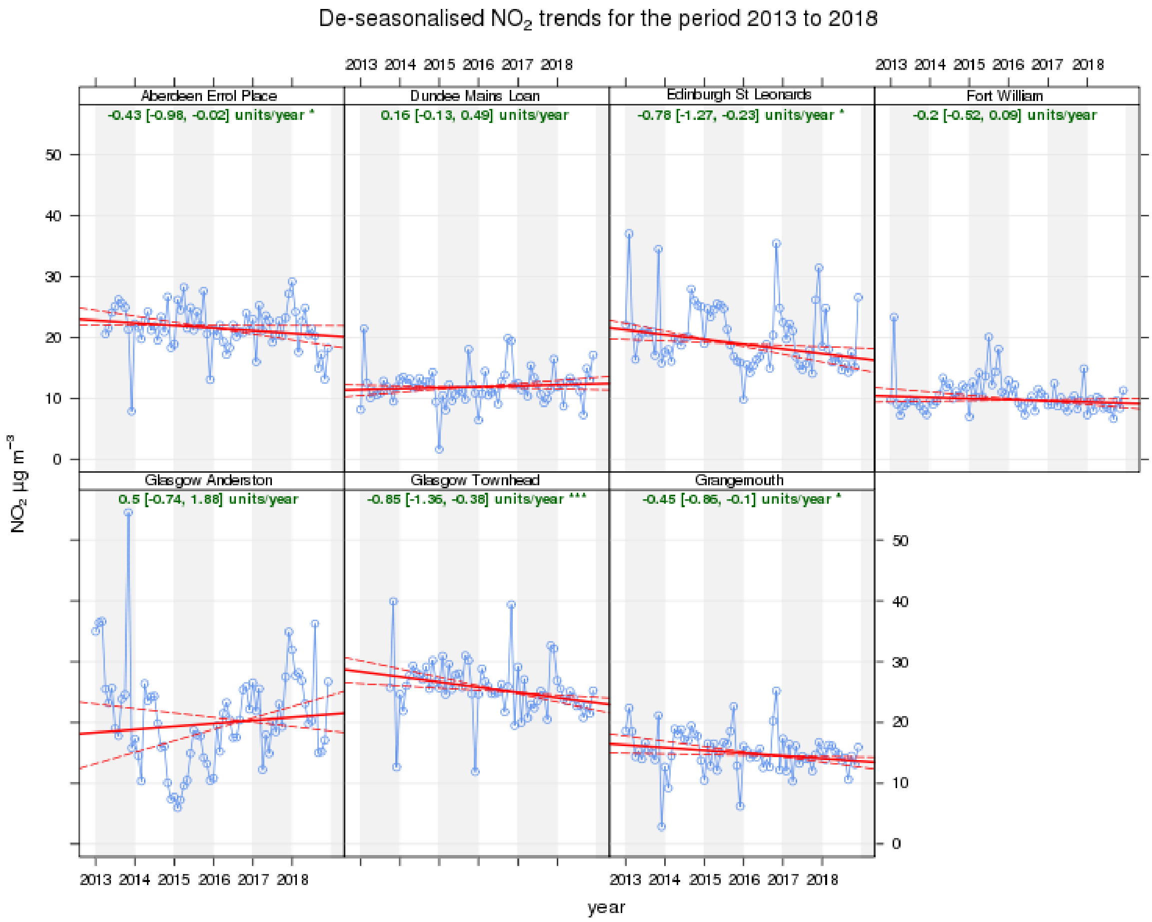
Figure 8-1 Trends in NO_2 Concentration at Five Long-running Urban Non-Roadside Sites, 2009-2018



Edinburgh St Leonards and Glasgow Anderston showed highly significant negative trends (at the 0.001 level). This is the same as previous reports. For Aberdeen Errol Place, Fort William and Grangemouth, they all have significant negative trends (at the 0.05 level). For Fort William, this has changed from last year's report when trend analysis indicated that concentrations have stayed, on average, static for the last 10 years. This analysis suggests that NO_2 concentrations are not decreasing at all urban non-roadside locations at the same rate. It also indicates that NO_2 concentrations are decreasing at a greater rate in the larger urban areas where concentrations were higher.

If the analysis considers all urban background site in Scotland over the past 6 years, which includes sites Dundee Mains Loan and Glasgow Townhead in most cases the trends are the same as the long-term trends. The exception to this is Glasgow Anderston where the trend switches from a highly significant negative trend to a positive or increasing trend. In addition, Dundee Mains Loan also shows a slight increasing trend contrary to other urban background areas in Scotland.

Figure 8-2 Trends in NO_2 Concentration at all Urban Non-Roadside Sites, 2013-2018

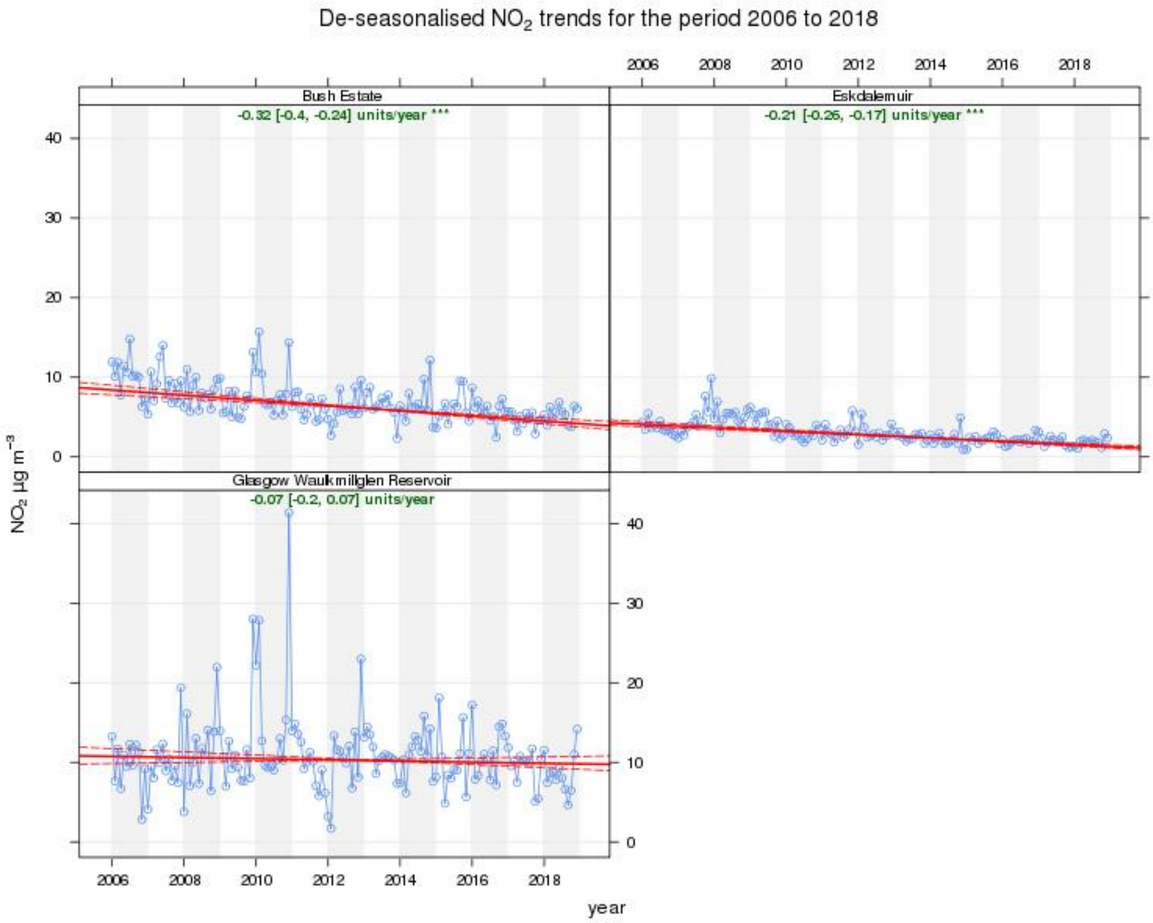


8.1.2 NO_2 at Rural Sites

There are three long-running rural sites which have monitored oxides of nitrogen for more than 10 years: Bush Estate (to the south of Edinburgh close to the Pentland Hills Regional Park), Eskdalemuir and Glasgow Waukmillglen Reservoir. Figure 8-3 shows trends in NO_2 concentration at these sites.

The sites at Bush Estate and Eskdalemuir showed small but highly significant downward trends. However, this was not the case for Glasgow Waukmillglen Reservoir, where concentrations were decreasing very slightly year-on-year, though the trend was not significant.

Figure 8-3 Trends in NO_2 Concentration at Three Rural Sites, 2006 – 2018



8.1.3 NO2 at Traffic-related Urban Sites

Recent years have seen a substantial increase in the number of monitoring stations at urban traffic-related sites in Scotland. There are now 30 roadside or kerbside monitoring stations that have been in operation for 10 years or more and are still in operation. These are as follows:

- Aberdeen Anderson Drive
- Aberdeen Union Street
- Aberdeen Wellington Road
- Dumfries
- Dundee Lochee Road
- Dundee Seagate
- Dundee Whitehall Road
- East Dunbartonshire Bearsden
- East Dunbartonshire Bishopbriggs
- East Dunbartonshire Kirkintilloch
- Edinburgh Gorgie Road
- Edinburgh St John's Road
- Falkirk Hope Street
- Falkirk West Bridge Street
- Fife Cupar
- Fife Dunfermline

- Fife Rosyth
- Glasgow Byres Road
- Glasgow Kerbside (Hope Street)
- Inverness
- N Lanarkshire Chapelhall
- N Lanarkshire Croy
- Paisley Gordon Street
- Perth Atholl Street
- Perth High Street
- South Ayrshire Ayr High St
- South Lanarkshire East Kilbride
- West Dunbartonshire Clydebank
- West Dunbartonshire Glasgow Road
- West Lothian Broxburn

This is a large number of sites, so for the purposes of this report we have selected eight of the above long-running sites which have measured exceedances of the Air Quality Strategy Objective for annual mean NO_2 (40 µg m^{-3}) in recent years (though not necessarily 2018). These are as follows: Aberdeen Union Street, Aberdeen Wellington Road, Dundee Lochee Road, Dundee Seagate, Edinburgh St John's Road, Glasgow Kerbside (Hope Street), N Lanarkshire Chapelhall, Perth Atholl.

Figure 8-4 shows the trend plot. As with the previous report in this series (the 2017 edition), all eight sites show highly significant downward trends (at the 0.001 level).

Trends over the most recent five complete years, 2014 – 2018, have also been examined for these sites. These are shown in Figure 8-55. Comparing the ten-year and five-year trends, the patterns are similar in that they all have downward trends but of varying significance. The exception to this is North Lanarkshire Chapelhall, where over the past 5 years there has been a slight upward trend (however not statistically significant) contrasting to the 10-year downward trend. At both Aberdeen sites, Dundee Seagate, & Perth Atholl St, the downward trend has become greater in magnitude over past 5 years compared to past 10. The other site to note is Edinburgh St Johns. The downward trend at this site has become greater during the past five years. This decrease is not consistent across all sites so though analysis suggests that concentration is continuing to fall in most cases it cannot be said that NO_2 concentrations during 2018 were generally lower than in recent years.

Figure 8-4 Trends in NO_2 Concentration at Eight Long-running Urban Traffic Sites with Exceedances, 2009 - 2018

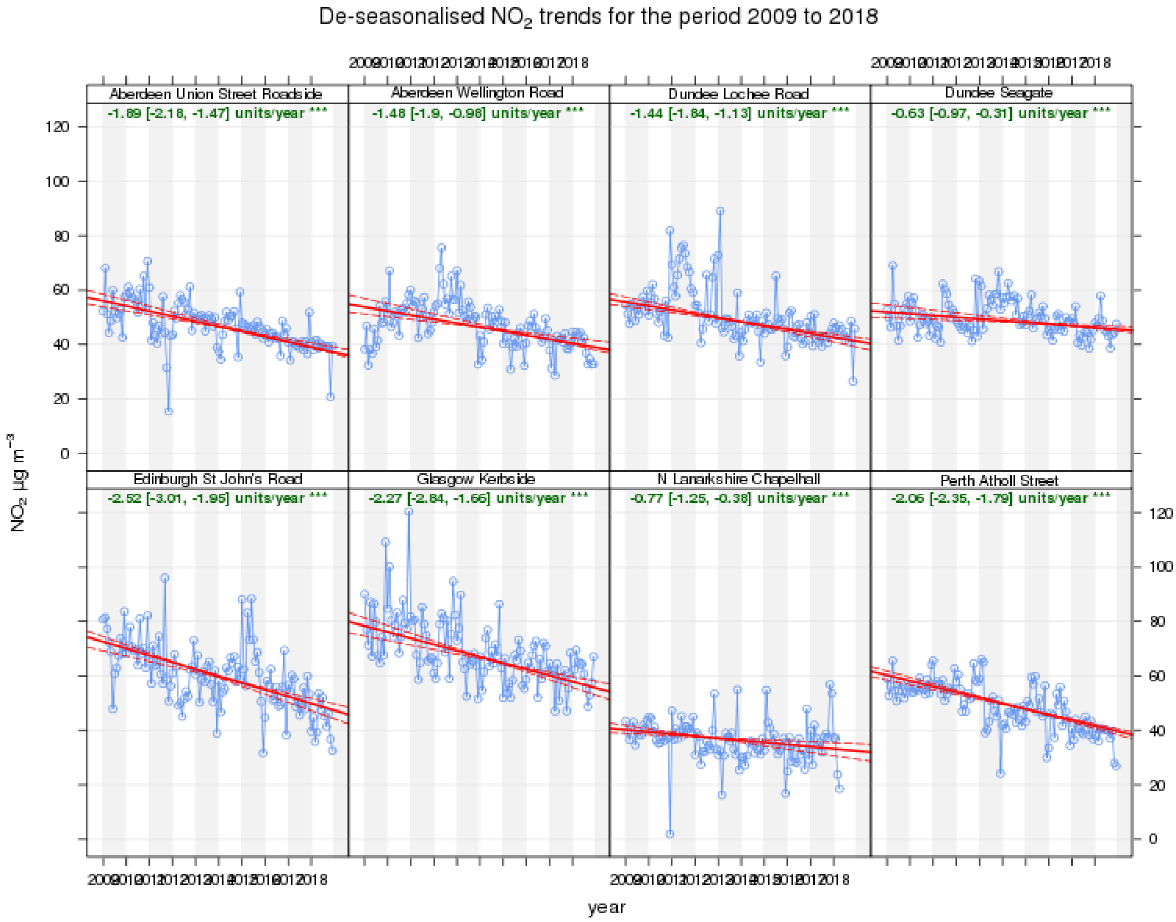
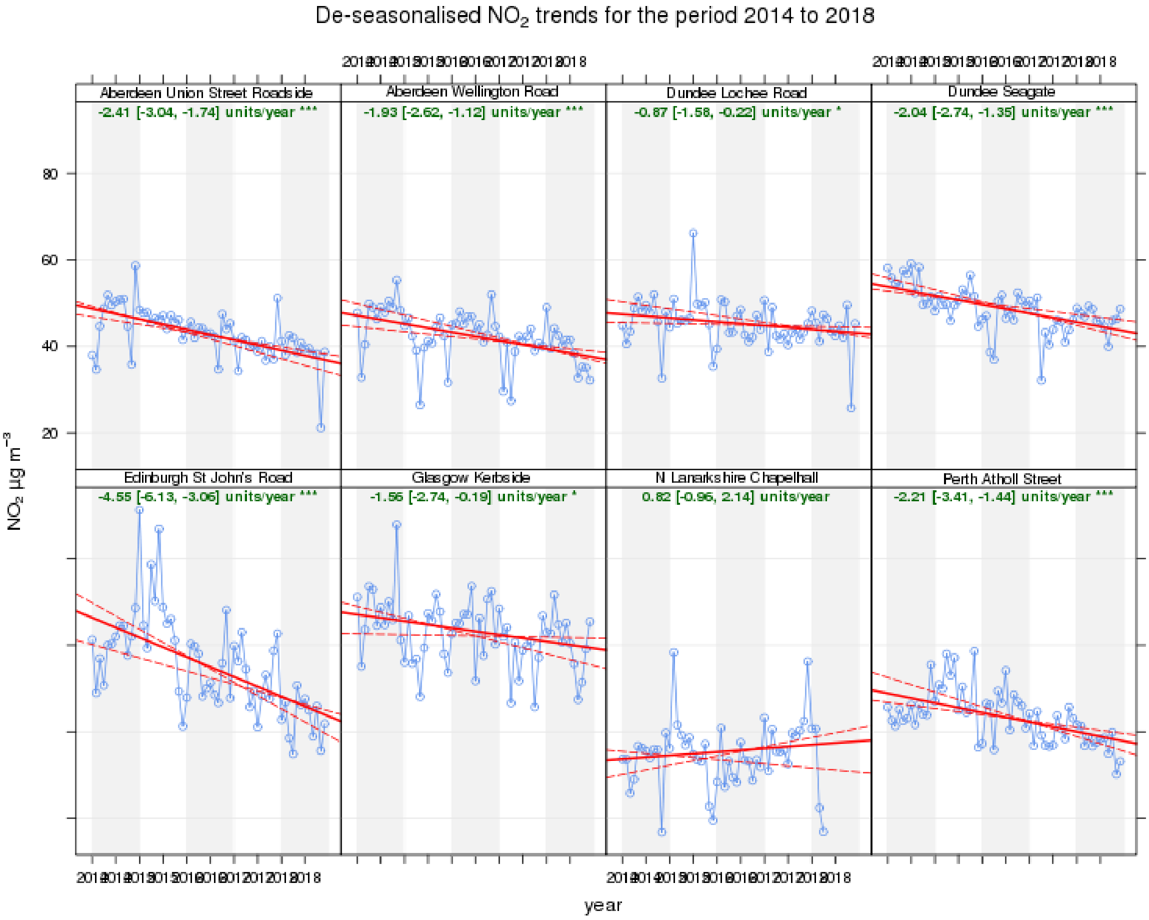


Figure 8-5 Recent Trends in NO_2 Concentration at Eight Long-running Urban Traffic Sites with Exceedances, 2014-2018



8.2 Particulate Matter

This pollutant is of particular interest because:

- current evidence suggests that there is no safe level of particulate matter in terms of human health effects.
- Scotland's current annual mean PM_{10} objective is 18 µg m^{-3}, which is more stringent than the objective of 40 µg m^{-3} adopted in the rest of the UK.
- In 2016 Scotland opted to make its annual mean $PM_{2.5}$ objective more stringent, by reducing it from 12 µg m^{-3} to 10 µg m^{-3} in line with the World Health Organization guideline.

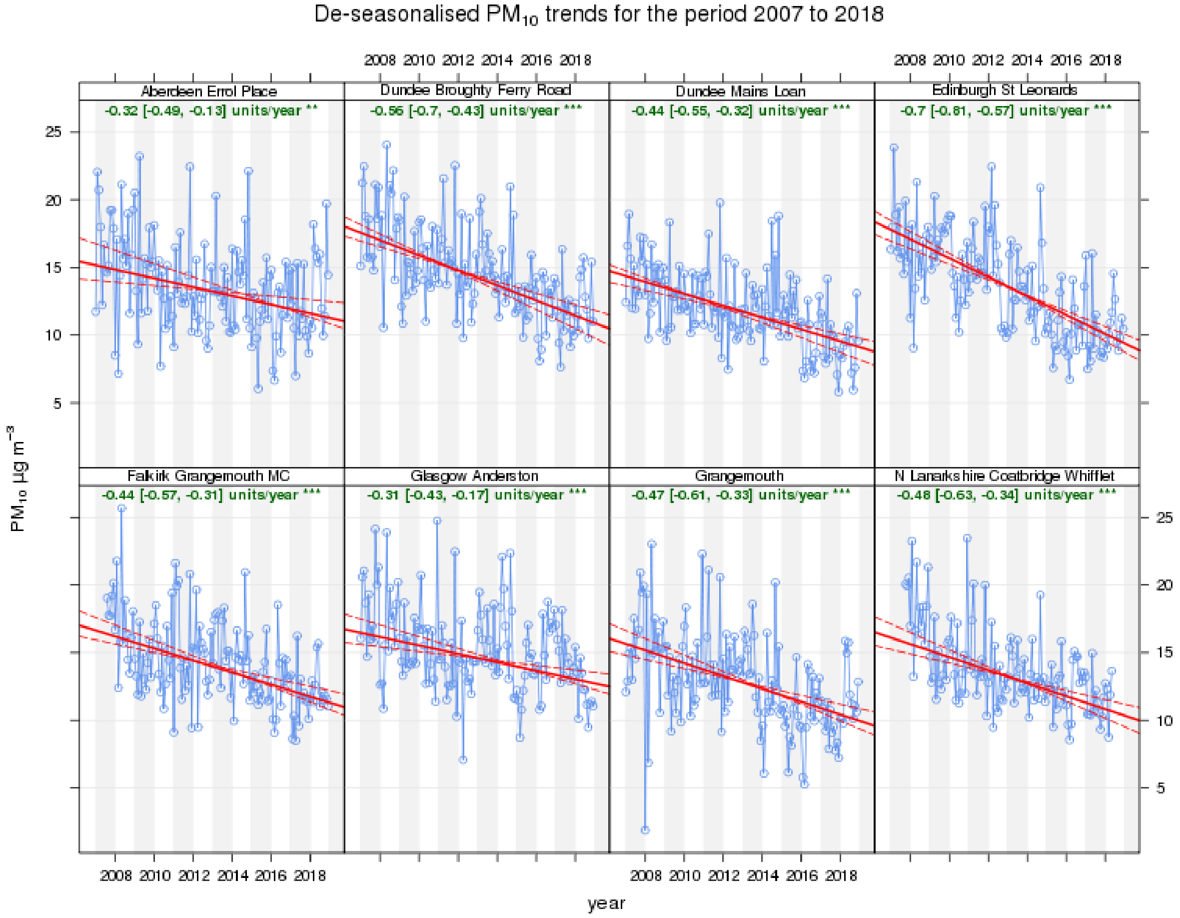
During the period covered by this trend analysis, many of Scotland's monitoring sites have used the Tapered Element Oscillating Microbalance (TEOM) to monitor PM_{10}. For the reasons discussed in Section 5 it is necessary to correct TEOM data for possible evaporation of the volatile component (due to the high operating temperature of the TEOM, necessary to prevent condensation on the filter). For years up to and including 2008 the conventional way of doing this was to apply a factor of 1.3 to the data, and the data presented here for those years have been adjusted in this way. However, in 2009 a better correction method became available: the King's College Volatile Correction Model (VCM), which can be found at http://www.volatile-correction-model.info/ . This model uses measurements from nearby FDMS-TEOM instruments (which measure both the volatile and non-volatile fraction) to calculate and apply a correction to the daily or hourly dataset. This is now the recommended method and has been used for the data presented here for years 2009 onwards, from sites where the TEOM are still being used. Over the past three years the number of TEOM and FDMS-TEOM used to measure particulate matter has significantly reduced.

8.2.1 PM_{10} at Urban Background Sites

There are now eight urban non-roadside sites in Scotland that have been monitoring PM_{10} for ten years or longer. These are: Aberdeen Errol Place (TEOM, converted to FDMS in 2009), Dundee Broughty Ferry Road (TEOM, data VCM corrected), Dundee Mains Loan (TEOM, data VCM corrected, converted to Fidas in October 2017), Edinburgh St Leonards (FDMS since 2007), Glasgow Anderston (FDMS since 2011, changed to Fidas in November 2018), Grangemouth (FDMS since 2009, changed to BAMs June 2018), Falkirk Grangemouth MC, and North Lanarkshire Coatbridge Whifflet (TEOM). Dundee Broughty Ferry Road and Grangemouth are urban industrial; the rest are urban background.

Figure 8-6 shows trends in de-seasonalised monthly mean PM_{10} at this subset of long-running sites. All eight sites showed a highly statistically significant (at the 0.001 level) negative trend, at all sites except Aberdeen Errol Place where it was significant at the 0.01 level.

Figure 8-6 Trends in PM_{10} Concentration at Six Long-Running Urban Background and Urban Industrial Sites, 2007 – 2018



8.2.2 PM_{10} at Urban Traffic sites

Trends in de-seasonalised monthly mean PM_{10} concentrations for eight traffic-related sites in operation since 2009 or earlier are shown in Figure 8-77. These sites are Aberdeen Market Street, Aberdeen Wellington Road, East Dunbartonshire Bishopbriggs, Edinburgh Salamander, Fife Cupar, Glasgow Abercromby Street, and Glasgow Byres Road. These sites were chosen to be analysed because; of the length of time they have been monitoring (10 years or more), present or historical exceedances of the annual mean objective and geographical coverage.

All sites showed highly statistically significant downward trends (at the 0.001 level), with the exception of East Dunbartonshire Bishopbriggs which was significant at 0.05 level. The trends indicate that PM_{10}

over the past 10 years is decreasing year on year at these roadside sites. This is the same finding as the previous report (2017) in this series.

Trends in de-seasonalised monthly mean PM_{10} concentrations for the same eight sites (plus Edinburgh Queensferry Road), for the most recent five complete years 2014 – 2018, are shown in Figure 8-88. At four of the nine sites (the two located in Aberdeen, plus Fife Cupar and Perth Atholl Street) the downward trend is similar to the 10-year trend. However, for East Dunbartonshire Bishopbriggs, Edinburgh Salamander Street and Glasgow Abercromby Street, the downward trend has weakened or become less or insignificant. For Glasgow Byres Road the trend switches from a downward trend to a highly significant upward trend at 0.001 level. The reason for including Edinburgh Queensferry in the trend analysis is because it is one of two sites in Scotland (the other being Edinburgh Salamander) to exceed the annual mean objective in 2018. As can be seen, Edinburgh Queensferry Road has a statistically significant upward trend over the past five years. This may however be skewed by the 2018 data: during 2018 the PM_{10} concentrations at the site were heavily influence be ongoing construction work. This shorter-term trend analysis highlights that the long-term downward trend has not continued everywhere over more recent years and concentrations may either be stable or even increase in areas. As in the case of NO_2, ongoing, targeted efforts are therefore still needed to ensure air quality continues to improve where necessary.

Figure 8-7 Trends in PM_{10} Concentration at Eight Long-Running Urban Traffic Sites, 2009 – 2018

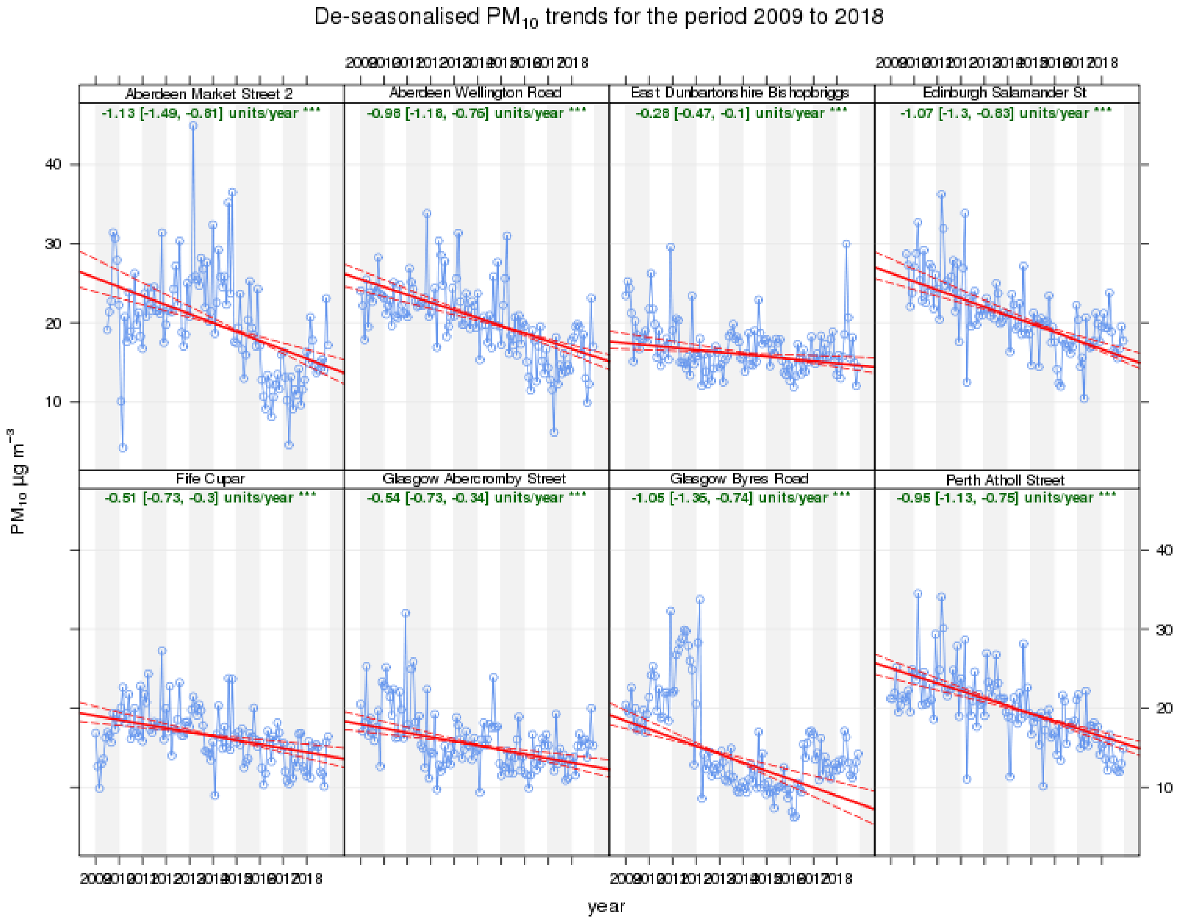
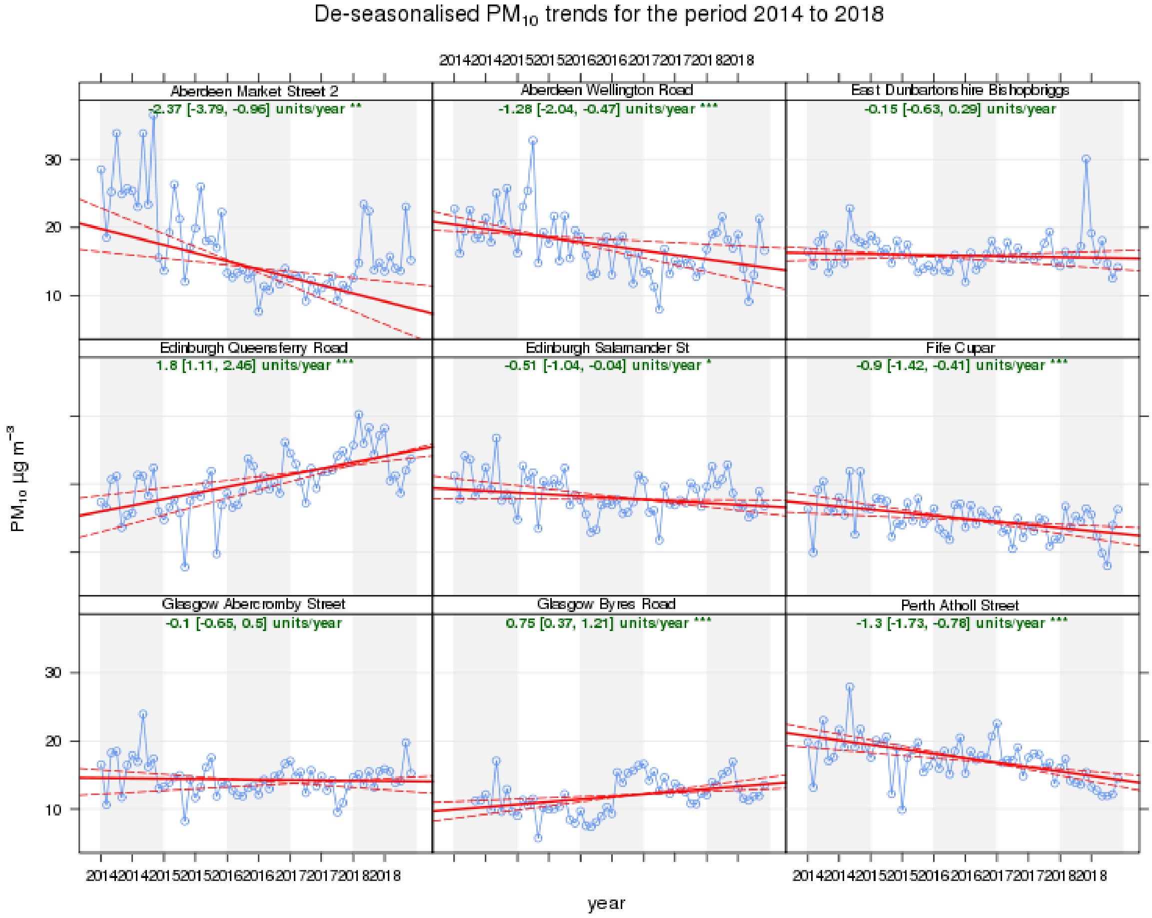


Figure 8-8 Recent Trends in PM_{10} Concentration at Nine Urban Traffic Sites, 2014 – 2018



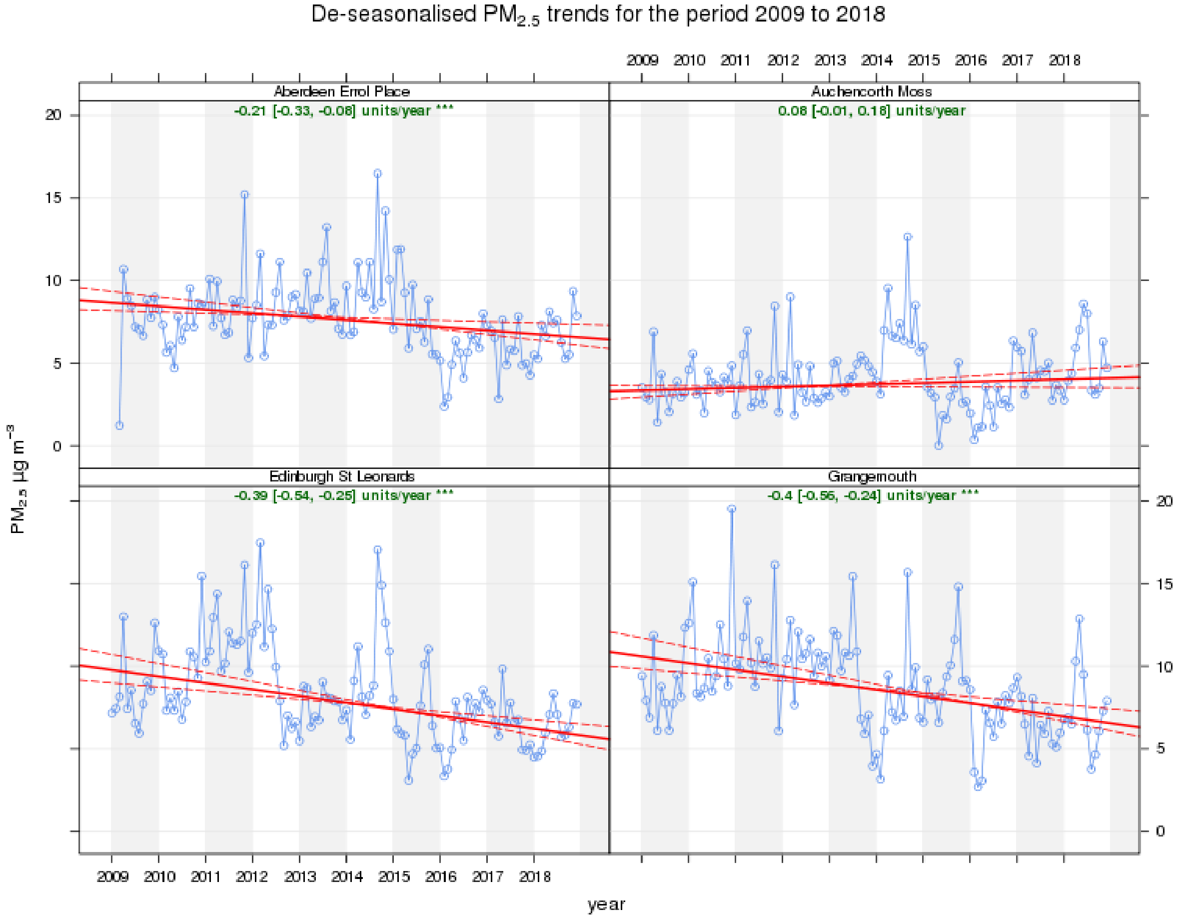
8.3 Particulate Matter as $PM_{2.5}$

In earlier years, most monitoring of particulate air pollution was focused on the PM_{10} size fraction. However, the finer fractions such as $PM_{2.5}$ are now of more interest in terms of health effects. Fine particles can be carried deep into the lungs where they can cause inflammation and a worsening of the condition of people with heart and lung diseases. They may also carry harmful compounds, absorbed on their surfaces, into the lungs.

At the time of writing this report there are 63 sites monitoring $PM_{2.5}$ in Scotland. However, the vast majority of these sites started monitoring in the last three years with the introduction of the $PM_{2.5}$ objective and the requirement for local authorities to measure the pollutant. By the end of 2018 there were four sites with 10 consecutive years of $PM_{2.5}$ data. These sites are as follows: Aberdeen Errol Place (urban background), Auchencorth Moss (rural), Edinburgh St Leonards (urban background), and Grangemouth (urban industrial). The trend plot for these sites is shown in Figure 8-9. Previous reports in this series have provide trend analysis for daily $PM_{2.5}$ concentrations at the Inverness site, which used to monitor daily mean $PM_{2.5}$ concentrations using a Partisol gravimetric sampler. However, in July 2018 the Partisol was replaced by an automatic Fidas instrument, so Inverness now monitors $PM_{2.5}$ concentrations on an hourly basis.

Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth sites show slight but highly statistically significant (at the 0.001 level) downward trends for $PM_{2.5}$. Contrary to this, the rural site Auchencorth Moss shows a slight upward trend however it is not statistically significant.

Figure 8-9 Trends in $PM_{2.5}$ Concentration at Four Long-Running Monitoring Sites, 2009 – 2018



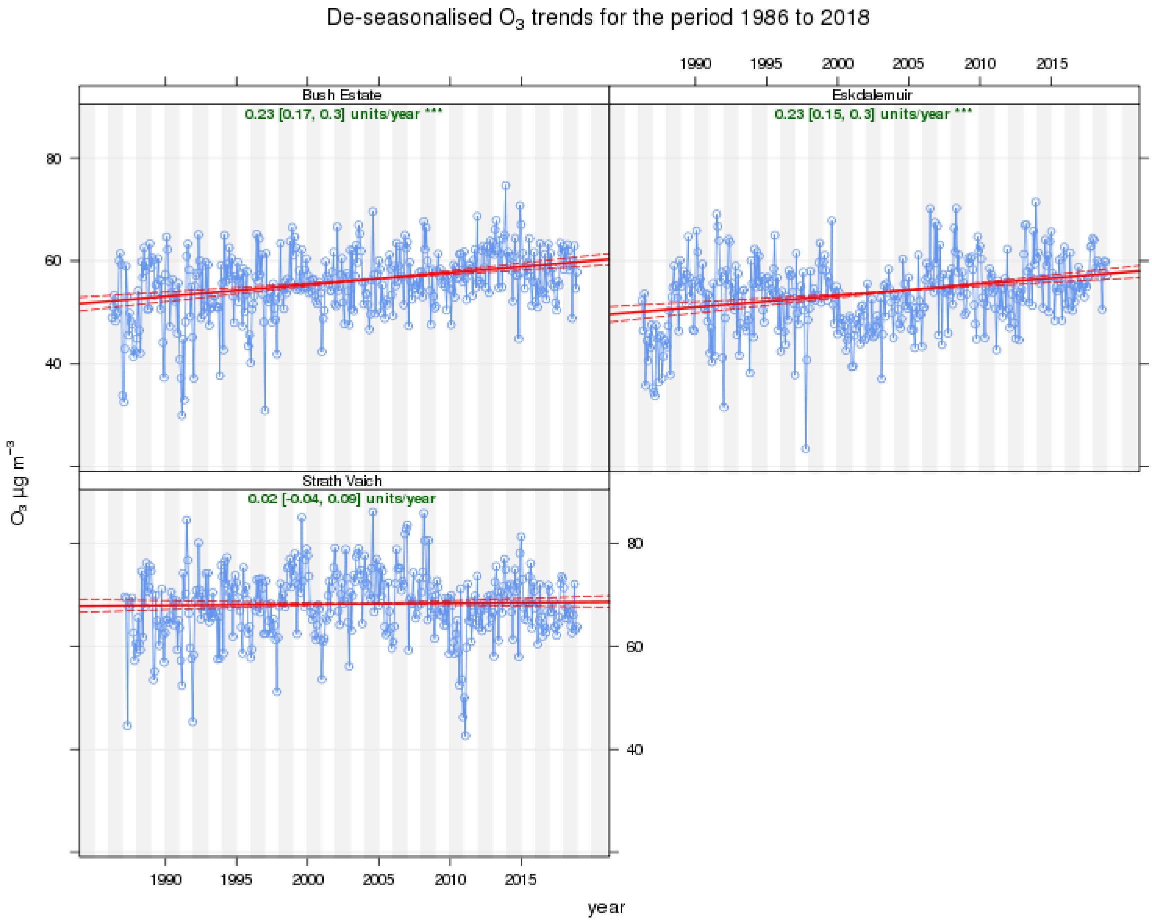
8.4 Ozone

8.4.1 Rural Ozone

Three of Scotland's rural air quality monitoring stations have been monitoring ozone for 31 years, 1986 – 2018. These are Bush Estate, Eskdalemuir and Strath Vaich. Figure 8-2 shows long-term trends in de-seasonalised monthly mean ozone (O_3) concentrations at these three exceptionally long-running rural monitoring sites. All three sites showed a small upward trend in monthly mean rural ozone concentrations over this period. For Bush Estate and Eskdalemuir this trend was highly statistically significant at the 0.001 level. For Strath Vaich the trend was smaller and was not statistically significant. The charts also show considerable fluctuation; this may reflect the fact that ozone is formed by reactions involving other pollutant gases, in the presence of sunlight. Thus, ozone concentrations depend substantially on weather conditions. There is also evidence that the "hemispheric background" concentration of O_3 has increased since the 1950s due to the contribution from human activities.[11]

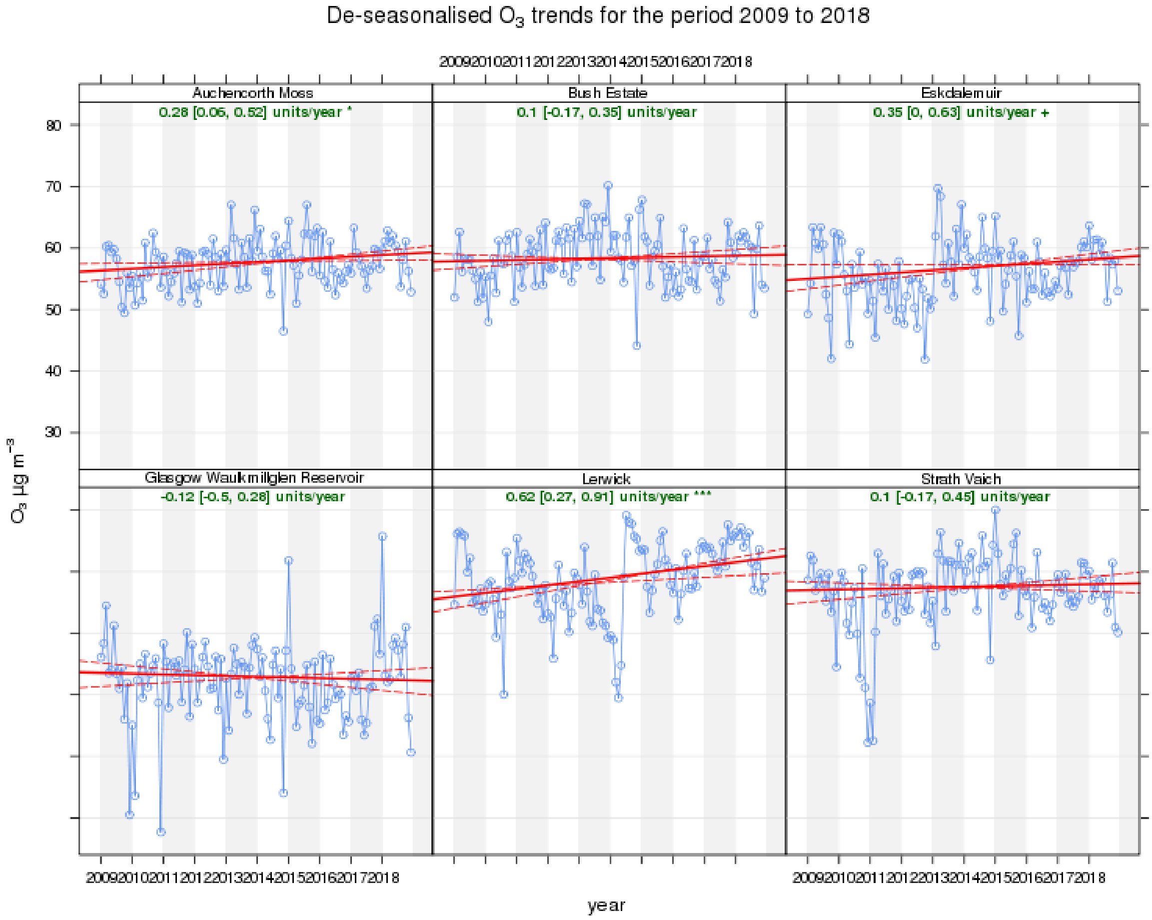
[11] See the APIS webpage "Ozone" at http://www.apis.ac.uk/overview/pollutants/overview_O3.htm

Figure 8-2 Trends in O_3 Concentrations at Long-Running Rural Sites, 1986 – 2018



Six sites have been in operation for over 10 years. These are the above three sites, plus Auchencorth Moss, Glasgow Waukmillglen Reservoir and Lerwick. Trends in ozone concentration at these six sites are shown in Figure 8-3. In contrast to the thirty-year trends, the ten-year trends were less consistent. Five of the sites showed increasing trends, with only Lerwick being highly statistically significant (at 0.001 level), Auchencorth Moss (at 0.05 level) and Eskdalemuir (at 0.1 level) statistically significant. Bush Estate and Eskdalemuir showed increasing trends that were not statistically significant. The remaining site, Glasgow Waulkmillglen showed a not statistically significant decreasing trend.

Figure 8-3 Trends in O_3 Concentrations at Six Long-Running Rural Sites, 2009 – 2018



8.4.2 Urban Background Ozone

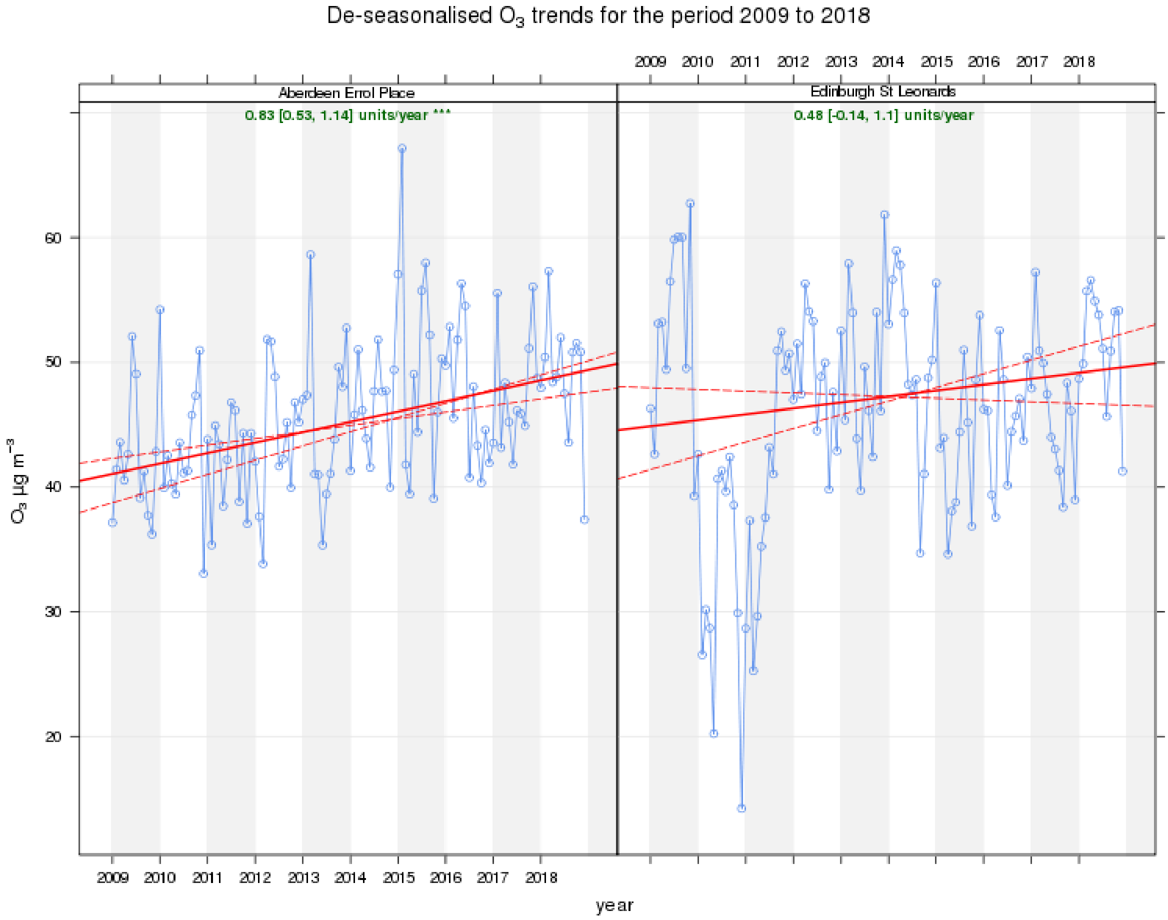
Figure 8-4 shows trends in de-seasonalised monthly mean ozone concentrations at the two Scottish urban background monitoring sites which have been monitoring ozone for the past 10 years, 2009-2018: Edinburgh St Leonards and Aberdeen Errol Place.

There is again a slight upward trend at both sites, however only Aberdeen Errol Place was highly significant at the 0.001 level.

At Edinburgh St Leonards there was a noticeable dip in measured ozone concentrations throughout 2010 and into 2011. The reason for this is unknown and investigation of these low data has confirmed that the analysers were operating well throughout 2010 – 2011. Since no reason can be found to discard the data, they must be assumed to be genuine.

Contrary to other pollutants analysed in this section there appears to be a slight (though not always statistically significant) upwards trend in ozone concentrations.

Figure 8-4 Trends in O_3 Concentration at Two Long-Running Urban Background Sites, 2009 – 2018



8.5 Sites with Significant Increasing Trends

The Scottish Environment Protection Agency (SEPA) provides a range of advanced air quality data analysis tools which are available via the Air Quality in Scotland website at http://analysistools.scottishairquality.scot/advanced.html . These have been used to identify *any* monitoring stations which have statistically significant increasing trends in nitrogen dioxide or particulate matter concentration (the tools do not at present provide trend analysis for ozone).

These trends are summarised in Table 8-1 below. The table only shows active sites (as of the end of 2018) and only shows those that had been in operation for at least five years, as of the end of 2018, and have significant ***increasing*** trends. (Five years is usually considered the minimum length of time needed to assess long-term trends in air quality). Trends have been calculated from the beginning of 2006 at the earliest (this being the earliest the SEPA trend analysis tools go back to), or from when the site started up, if that was later.

Table 8-1 Monitoring Stations with Significant Increasing Trends in Pollutant Concentration

Site Name	Site type	Pollutant	Trend	Period	Significance level
Edinburgh Queensferry Rd	Roadside	PM_{10}	Increasing	01/01/2011 – 31/12/2018	0.001

Only one site was identified, using the SEPA tools, as having significant upward trends in one or more pollutants. This was as follows:

- Edinburgh Queensferry Road: a roadside monitoring station where the Scottish AQS objective of 18 µg m^{-3} for annual mean PM_{10} is exceeded and has been since 2016. Prior to 2015 the objective was also exceeded in 2012 and 2013, with poor data capture in 2011 (when the site started monitoring) 2014 preventing an average being calculated. For 2018 the annual mean was 25 ugm^{-3}, significantly higher than in previous years. This increase was attributed to long-term construction work being carried out near the site.

8.6 Summary of Trends

The following trends have been observed in the measurements from Scottish air quality monitoring stations:

1. Trend analysis of nitrogen dioxide concentrations at Scotland's five long-running urban non-roadside (i.e. urban background and urban industrial) sites suggests that NO_2 concentrations are in general decreasing however not all at the same rate. It also indicates that NO_2 concentrations are decreasing at a greater rate in the larger urban areas where concentrations were higher.
2. Nitrogen dioxide concentrations at Scotland's three long-running rural sites showed decreasing trends. Bush Estate and Eskdalemuir showed small but highly significant downward trends. However, this was not the case for Glasgow Waukmillglen Reservoir, where concentrations were decreasing very slightly year-on-year, though the trend was not significant.
3. Scotland has a large number of urban traffic (roadside and kerbside) monitoring sites monitoring NO_2, of which 30 have now been operating for at least 10 years. This trend analysis therefore focussed on eight of these sites that have operated for 10 years and have reported exceedances of the AQS objective in recent years. All these sites showed significant downward trends, with seven of the eight site trends highly significant at the 0.001 level.
4. Examination of trends at the same nine sites over the most recent five complete years (2014 to 2018) indicates that the patterns are mostly like the 10-year trends. The exception was North Lanarkshire Chapelhall where the trend switches from a downwards to an upward trend (though not statistically significant).
5. PM_{10} particulate matter at Scotland's eight long-running urban non-roadside sites showed a significant or highly significant downward trend.
6. PM_{10} particulate matter at Scotland's nine long-running urban traffic (roadside and kerbside) sites showed highly statistically significant downward trends at all sites with the exception of one.
7. Examination of trends in PM_{10} at the same nine sites over the most recent five complete years (2014 to 2018) indicates that, at some of these, the decreasing trends have continued but at others they have weakened, levelled off or switched to an increasing trend (e.g. Glasgow Byres Road). For Edinburgh Queensferry Road analysis indicates a highly significant increasing trend. However this may have been influenced by ongoing construction works close to the monitor location.

8. Only four sites in Scotland have 10 years or more $PM_{2.5}$ data. Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth sites show slight but highly statistically significant downward trends. Contrary to this, the rural site Auchencorth Moss shows a slight upward trend however it is not statistically significant.
9. Ozone has been measured at three rural sites in Scotland (Bush Estate, Eskdalemuir and Strath Vaich) for thirty years. All three sites showed small positive trends over this very long period; insignificant at Strath Vaich but highly statistically significant at the other two sites.
10. Ozone has been measured for the past 10 years at six rural sites. Over this more recent period only one site (Lerwick) showed a significant trend (positive)– so trends over this more recent period are less consistent.
11. Ozone concentrations showed no significant trends at one of the two urban background sites which have monitored this pollutant for the past 10 years, while the other site showed a small but highly significant positive trend (at 0.001).

9 Emissions of Pollution Species

In this chapter we provide information on emissions of pollutants into the atmosphere in Scotland. The UK National Atmospheric Emissions Inventory (NAEI) calculates total emissions for the UK from a comprehensive range of sources including industry, domestic, transport etc. The UK inventory is now disaggregated into the UK constituent countries[12]. The inventory covers a wide range of pollutants, but in this report will mainly focus on NO_x, PM_{10}, and $PM_{2.5}$. Information on other pollutants can be found at www.naei.org.uk.

Within Scotland, SEPA collates the detailed information on emissions from industrial sources into the Scottish Pollution Release Inventory (SPRI); this includes emissions to water and soil as well as to air. Full details are available on the SEPA SPRI database:
http://www.sepa.org.uk/air/process_industry_regulation/pollutant_release_inventory.aspx

There is also a link to the SEPA SPRI website on the home page of http://www.scottishairquality.scot/data/emissions. The data from the SPRI form the basis of the industrial emission data for Scotland which are incorporated into the NAEI.

Information provided in Section 9.1 of this report on the main industrial emissions of NO_x and PM in Scotland have been compiled from the information presented on SEPA's SPRI, with permission from SEPA. The data provided is up to 2017, which is the most recent data available at the time of writing this report.

9.1 NAEI data for Scotland

The NAEI data for Scotland are reported using the Nomenclature for Reporting (NFR) format. The Nomenclature for Reporting is a reporting structure that was introduced in 2001 and is used for submitting data to international organisations such as the United Nations Economic Commission for Europe (UNECE) and the European Monitoring and Evaluation Programme *(*EMEP).

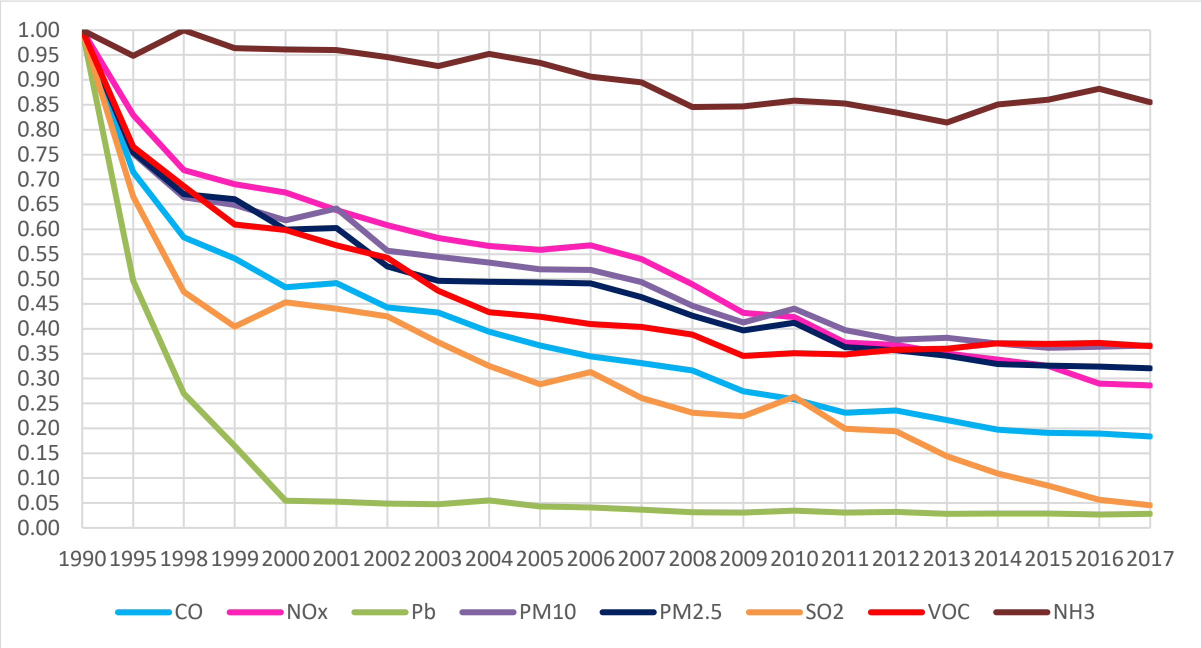
Since last year's report emissions data for $PM_{2.5}$ has now been included at the request of both the Scottish and Welsh Governments. It should be note however that the emissions dataset for $PM_{2.5}$ is very limited and the inventory is heavily based on assumptions of $PM_{2.5}$ share of the PM_{10} for different emissions sources. In addition, in should also be note that the indicative uncertainty rating for both PM_{10} and $PM_{2.5}$ is "High". For more information on the uncertainty assessment see section 1.4 of "*Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2017*".

When comparing previously report emissions data you will see a slight difference in the figures stated. This is because the emissions dataset is recalculated each year from 1990 and a revision of historic time series is carried out if a more accurate and applicable data source becomes available.

Figure 9.1 illustrates the decline in emissions since 1990 of all eight pollutants normalised to provide a relative rate of decline. It shows that all pollutant emission levels have significantly declined, at a similar rate (with exception of ammonia (NH3) and lead (Pb)), since 1990. However, this decline has levelled off and in some cases began to increase in recent years for some pollutants (Ammonia and Volatile Organic Compounds (VOC)). The higher rate of reduction in Pb between 1990 and 2000 coincides with the phasing out of leaded petrol in 1999.

[12] Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2016 http://naei.beis.gov.uk/reports/reports?report_id=970

Figure 9.1 Scotland normalised trends for all monitored pollutants



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2017

9.1.1 Scotland NOx Inventory by NFR Sector, 1990 – 2017

Table 9-1 and figure 9.2 provides a summary of NO_x emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

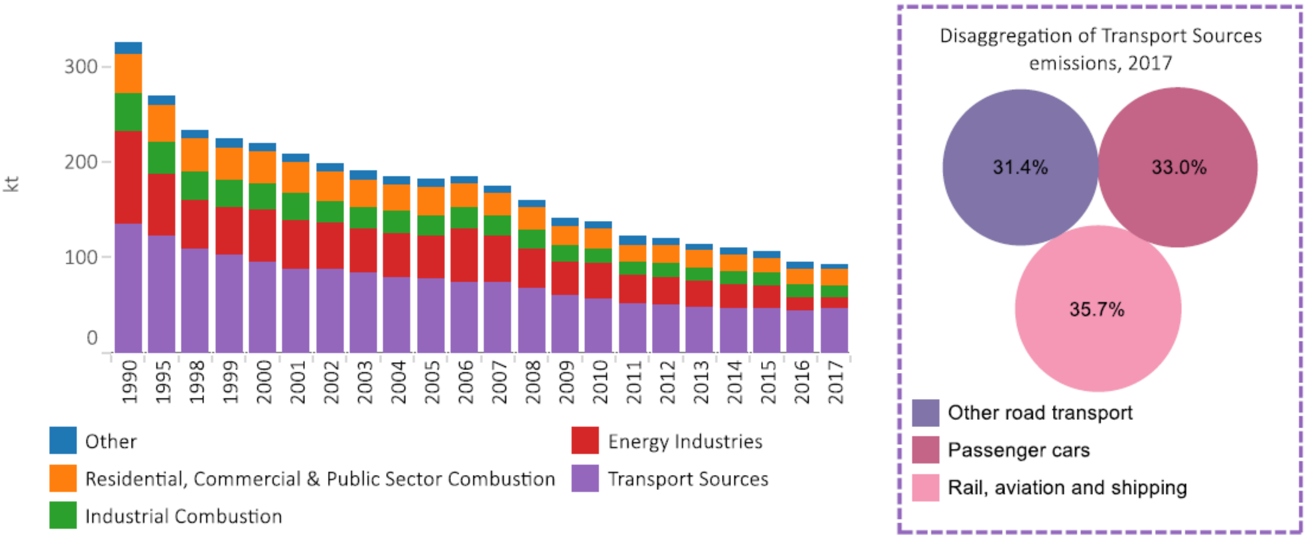
Table 9-1 Summary of NO_x emission estimates for Scotland (1990 – 2017)

Category	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006
Energy Industries	96.6	65.0	50.9	48.4	54.8	50.3	49.0	46.2	44.8	44.5	56.9
Industrial Combustion	40.0	32.8	29.9	28.7	28.5	28.3	23.0	22.1	22.7	22.5	21.0
Transport Sources	135.9	122.7	109.0	104.2	95.3	88.7	87.3	83.8	80.1	78.4	74.5
Other	10.42	8.77	8.05	8.56	7.92	8.33	7.77	7.77	7.38	6.96	6.73
Residential & other combustion	41.14	39.42	35.08	34.00	31.98	31.35	29.96	28.85	28.54	28.61	24.80
Total:	**324.0**	**268.7**	**233.0**	**223.8**	**218.4**	**206.9**	**197.0**	**188.8**	**183.6**	**181.0**	**183.9**

Category	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Energy Industries	50.1	40.1	35.8	37.1	28.9	30.2	28.0	26.2	23.9	14.3	11.6
Industrial Combustion	21.2	19.9	16.6	16.5	14.6	14.0	13.3	12.9	12.4	12.0	11.9
Transport Sources	73.3	69.0	60.3	56.1	52.6	50.6	48.2	46.9	46.8	45.2	47.4
Other	6.47	6.26	6.33	6.30	6.33	6.01	6.28	5.73	5.35	5.12	5.12
Residential & other combustion	23.84	23.27	20.93	21.45	18.12	18.45	17.81	17.79	16.85	17.26	16.68
Total:	**174.9**	**158.5**	**140.0**	**137.4**	**120.6**	**119.3**	**113.5**	**109.5**	**105.3**	**93.9**	**92.77**

Units: kilotonnes (kt)
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2017

Figure 9.2 Time series of Scotland NO_x emissions 1990-2017

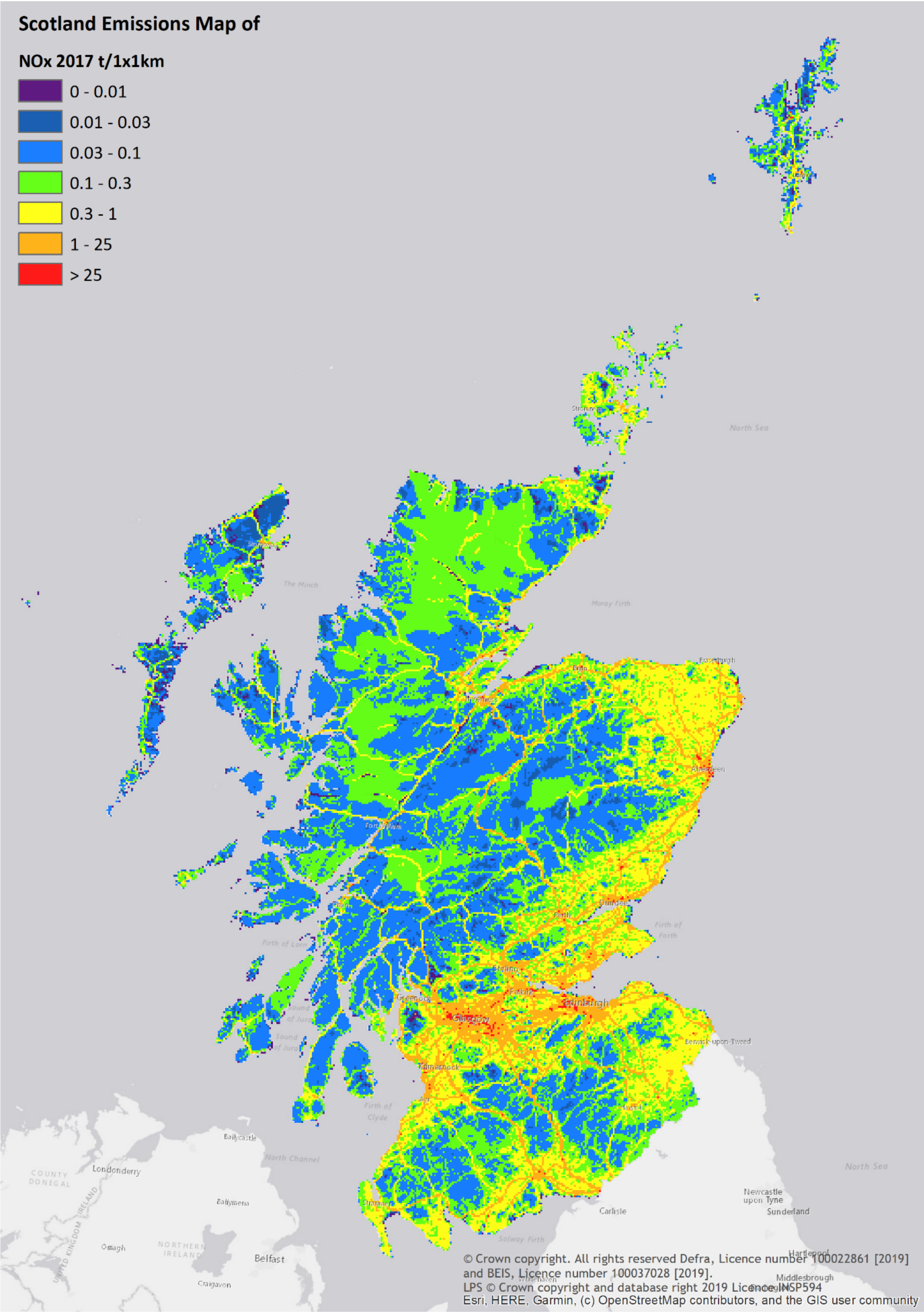


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2016

Scotland NOx emissions have declined by 73% since 1990 and were estimated to be 93kt in 2017 representing 11% of the UK total. This decline is driven by the continued introduction of tighter vehicle emissions standards over the last decade. Since 2008, emissions from passenger cars have further decreased, which is mainly driven by improvements in catalyst repair rates resulting from the introduction of regulations controlling the sale and installation of replacement catalytic converters and particle filters for light duty vehicles. However, the increasing number of diesel cars partly offsets these emissions reductions, because diesel cars emit higher NO_x relative to their petrol counterparts (88% of 2017 passenger car emissions is due to diesel cars). The peak in NO_x emissions in 2006 is due to an increase in emissions linked to the increased use of coal at power stations that year. The decline in NO_x emissions since 2007 is also linked to the power sector, as Boosted Over-Fire Air (BOFA) abatement systems were fitted to all four of Longannet's units, to reduce NO_x emissions from coal-fired generation by up to 25% (Scottish Power, Longannet Power Station, 2012). BOFA systems were also fitted on all four units at Cockenzie power station which then closed in 2013 (Scottish Power, 2011). Longannet power station closed in March 2016.

Figure 9.3 shows a map of Scotland's NOx emissions in 2017.

Figure 9.3 Map of NO_x Emissions in Scotland, 2016



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2017

9.1.2 Scotland PM_{10} Inventory by NFR Sector 1990 – 2017

The table 9-2 and Figure 9.4 give a summary of the Summary of PM_{10} emission estimates for Scotland by category. The detailed data are available in report and website cited in the introduction to this Chapter.

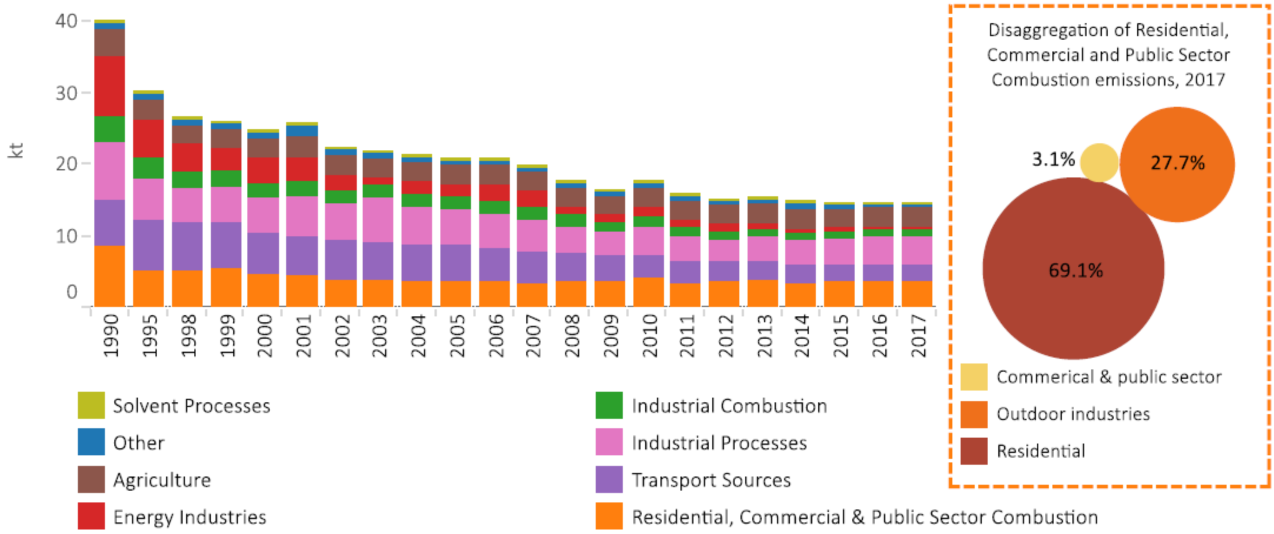
Table 9-2 Summary of PM_{10} emission estimates for Scotland (1990 – 2017)

Category	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006
Agriculture	3.97	2.78	2.79	2.67	2.74	2.75	2.75	2.69	2.74	2.70	2.67
Energy Industry	8.23	5.12	3.71	2.99	3.56	3.42	2.11	1.06	1.78	1.69	2.54
Industrial Combustion	3.65	3.19	2.35	2.34	2.08	2.03	1.82	1.79	1.75	1.81	1.83
Transport	6.61	6.84	6.56	6.45	5.76	5.36	5.43	5.24	5.15	5.07	4.81
Industrial Processes	8.03	5.83	4.89	4.94	4.87	5.80	5.20	6.24	5.27	4.94	4.54
Solvent Processes	0.37	0.32	0.27	0.20	0.18	0.17	0.15	0.13	0.11	0.10	0.11
Residential & Other Combustion	1.05	0.98	0.97	1.06	1.09	1.86	1.11	0.96	1.04	0.99	0.88
Other	8.45	5.29	5.28	5.52	4.65	4.51	3.92	3.86	3.70	3.67	3.54
Total:	**40.4**	**30.4**	**26.8**	**26.2**	**24.9**	**25.9**	**22.5**	**22.0**	**21.5**	**21.0**	**20.9**

Category	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Agriculture	2.69	2.73	2.68	2.70	2.71	2.69	2.67	2.70	2.62	2.66	2.69
Energy Industry	2.33	0.98	0.98	1.35	1.01	1.01	0.72	0.60	0.45	0.29	0.21
Industrial Combustion	1.74	1.64	1.47	1.49	1.35	1.27	1.16	1.18	1.21	1.17	1.24
Transport	4.35	3.94	3.71	3.32	2.99	2.83	2.64	2.54	2.49	2.45	2.48
Industrial Processes	4.36	3.63	3.23	3.75	3.37	2.85	3.43	3.33	3.41	3.70	3.81
Solvent Processes	0.10	0.09	0.08	0.08	0.09	0.09	0.09	0.10	0.10	0.10	0.10
Residential & Other Combustion	0.86	1.27	0.86	1.05	1.04	0.78	0.90	1.11	0.73	0.68	0.72
Other	3.49	3.71	3.64	4.04	3.48	3.75	3.80	3.38	3.58	3.65	3.54
Total:	**19.9**	**18.0**	**16.7**	**17.8**	**16.0**	**15.3**	**15.4**	**14.9**	**14.6**	**14.7**	**14.8**

Units: kilotonnes (kt)
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2017

Figure 9.4 Time series of Scotland's PM_{10} emissions 1990-2017



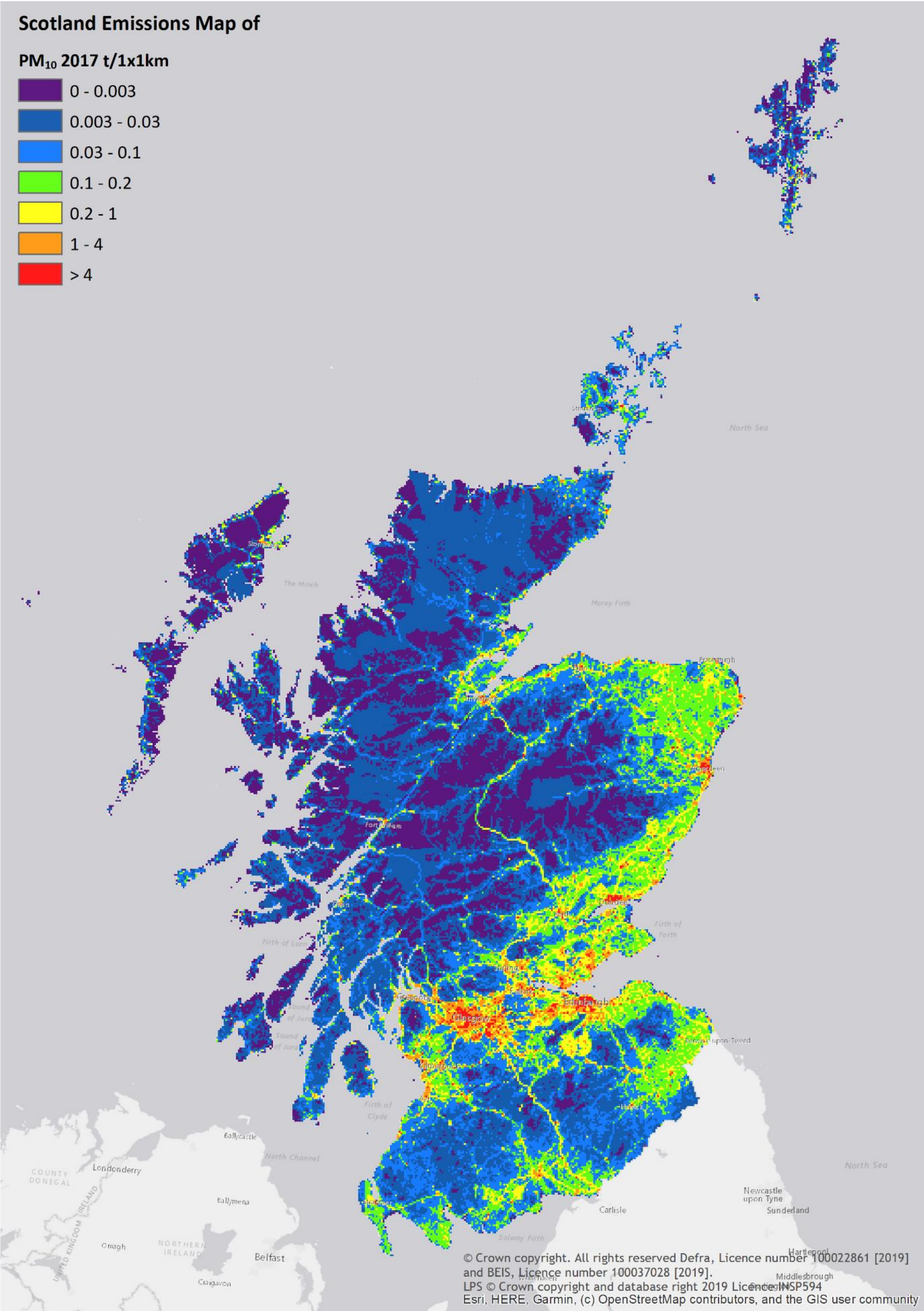
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2017

Emissions of PM_{10} have declined by 63% since 1990 and in 2017 and were estimated to be 15kt (9% of the UK total). Emissions from energy industries have had the most significant decline over the period shown, due to the abatement methods in place at coal fired stations. This is further impacted due to the increase in nuclear and renewable energy sources and the increased use of gas in the place of coal for energy generation. PM_{10} exhaust emissions from diesel vehicles have been decreasing due to the successive introduction of tighter emission standards over time. Increasingly, non-exhaust sources of PM_{10} (for example tyre wear) have become more important to consider as exhaust PM_{10} has reduced. In 2017, 75% of emissions from the road transport sector (72% in 2016) were related to non-exhaust sources.

The decline in PM_{10} emissions has basically stopped across all sectors over the past few years with some, such as Industrial Processes increasing. This has been attributed to an increased quantity of wood fuel use. In addition, almost all other emissions sources have remained stable since 2011. Though PM_{10} emissions have reduced since 1990, overall there has been no significant reduction in PM_{10} emissions since 2013.

Figure 9.5 shows a map of PM_{10} emission in Scotland for 2017.

Figure 9.5 Map of PM_{10} Emissions in Scotland, 2017



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2017

9.1.3 Scotland $PM_{2.5}$ Inventory by NFR Sector 1990 – 2017

The table 9-3 and Figure 9.6 below give a summary of the Summary of $PM_{2.5}$ emission estimates for Scotland by category. The detailed data are available in report and website cited in the introduction to this Chapter.

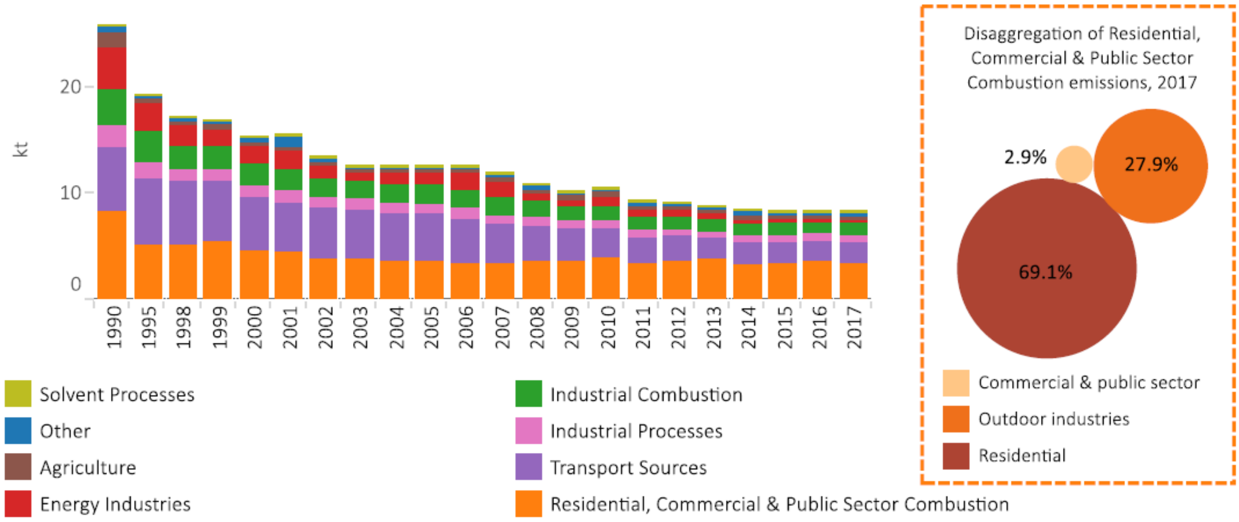
Table 9-3 Summary of $PM_{2.5}$ emission estimates for Scotland (1990 – 2017)

Category	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006
Agriculture	1.48	0.42	0.42	0.41	0.41	0.40	0.40	0.40	0.41	0.40	0.40
Energy Industry	3.86	2.54	1.92	1.58	1.79	1.72	1.12	0.60	0.97	1.04	1.49
Industrial Combustion	3.43	3.02	2.22	2.22	1.98	1.94	1.76	1.72	1.67	1.76	1.76
Transport	5.98	6.21	5.90	5.79	5.12	4.74	4.78	4.59	4.49	4.41	4.14
Industrial Processes	2.10	1.47	1.08	1.03	0.99	1.07	1.02	1.14	1.03	0.99	0.92
Solvent Processes	0.13	0.11	0.09	0.07	0.06	0.05	0.05	0.04	0.03	0.03	0.03
Residential & Other Combustion	8.27	5.18	5.18	5.42	4.57	4.43	3.85	3.79	3.63	3.60	3.47
Other	0.71	0.64	0.60	0.63	0.64	1.28	0.66	0.59	0.60	0.57	0.54
Total:	**26.0**	**19.6**	**17.4**	**17.1**	**15.6**	**15.6**	**13.6**	**12.9**	**12.8**	**12.8**	**12.8**

Category	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Agriculture	0.40	0.40	0.39	0.39	0.39	0.39	0.39	0.39	0.38	0.38	0.38
Energy Industry	1.44	0.64	0.64	0.85	0.64	0.61	0.43	0.37	0.30	0.23	0.17
Industrial Combustion	1.65	1.58	1.41	1.44	1.30	1.23	1.12	1.14	1.17	1.13	1.20
Transport	3.70	3.31	3.10	2.72	2.41	2.26	2.08	1.96	1.91	1.86	1.85
Industrial Processes	0.86	0.74	0.64	0.70	0.66	0.60	0.65	0.69	0.66	0.72	0.72
Solvent Processes	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Residential & Other Combustion	3.42	3.64	3.57	3.96	3.41	3.68	3.71	3.31	3.50	3.57	3.47
Other	0.53	0.72	0.52	0.60	0.59	0.48	0.56	0.66	0.50	0.48	0.50
Total:	**12.0**	**11.1**	**10.3**	**10.7**	**9.4**	**9.3**	**9.0**	**8.5**	**8.5**	**8.4**	**8.3**

Units: kilotonnes (kt)
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2017

Figure 9.6 Time series of Scotland's $PM_{2.5}$ emissions 1990-2017

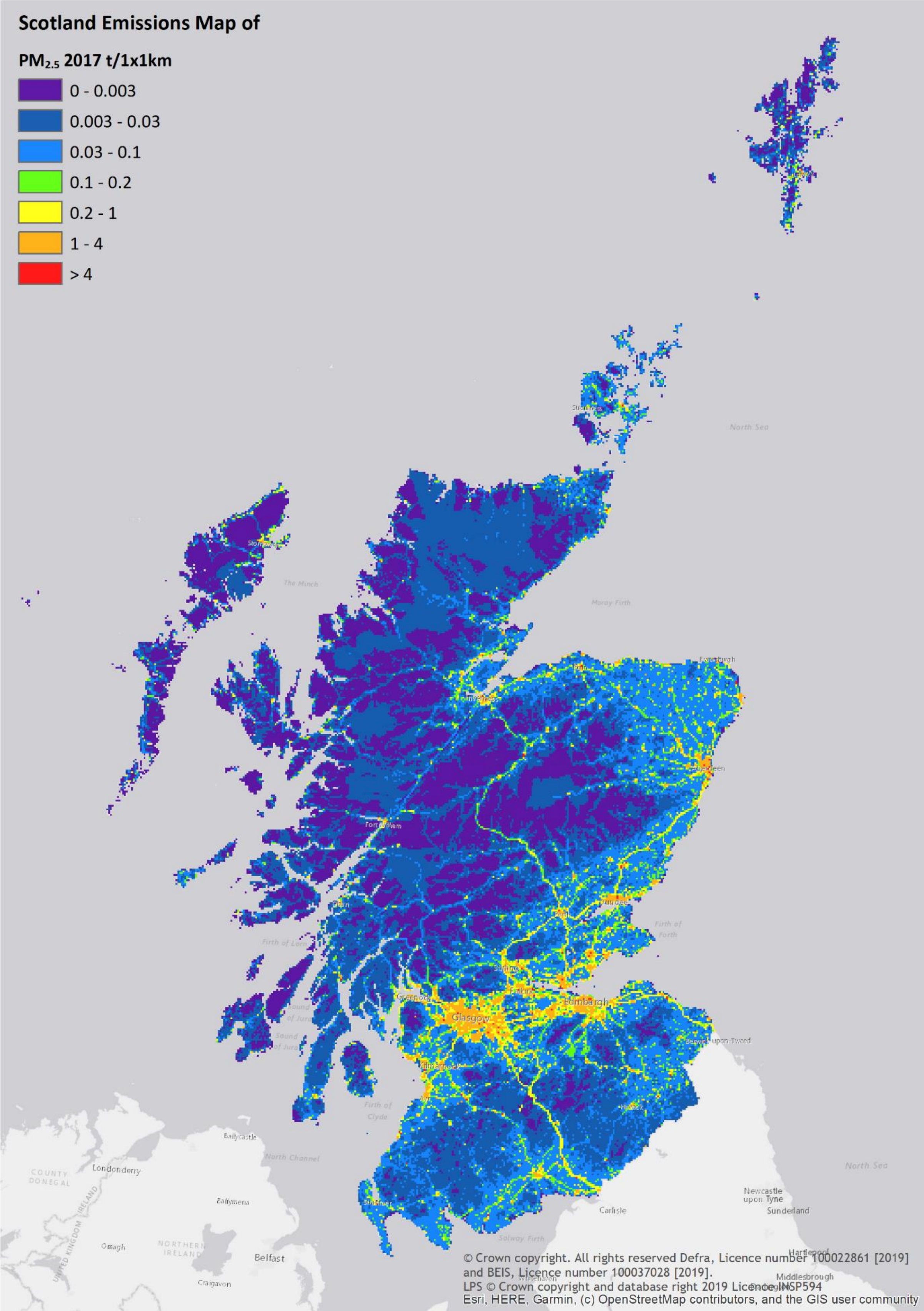


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2016

Emissions of $PM_{2.5}$ have declined by 68% since 1990 and in 2017 were estimated to be 8kt (8% of the UK total). Process emissions tend to produce coarser PM fractions and as such combustion emission area of greater importance for $PM_{2.5}$ compared to PM_{10} emissions. For $PM_{2.5}$, the residential, commercial and public sector combustion category accounts for 42% of 2017 emissions. The decline in emission since 1990 has primarily been attributed to the switch in the fuel mix use in electricity generation away from coal and towards natural gas, especially in the early time series. Later year reductions in emissions is attributed to the Transport sector, mainly due to the introduction of more stringent emissions standards through time. As can be seen in table 9-3 and figure 9.5 the decline in emissions has significantly reduced over the past few years with no significant decrease since 2013. One of the reasons for this slowing has been attributed to the increase in emissions from the residential sector and in particular the combustion of wood.

Figure 9.7 shows a map of $PM_{2.5}$ emissions in Scotland for 2017.

Figure 9.7 Map of $PM_{2.5}$ emissions in Scotland, 2017



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2017

10 SAQD Developments and Website Updates

10.1 Continued Expansion of the Scottish $PM_{2.5}$ Network

As outlined in CAFS, the Scottish Government replaced the non-statutory Scottish $PM_{2.5}$ annual objective of 12 μg m^{-3} with a statutory objective of 10 μg m^{-3}, in line with the World Health Organisation (WHO) guideline value. This came into force on the 1st April 2016. The full revised legislation and its extended series of associated technical annexes can be found on the Scottish Government website (http://www.scottishairquality.scot/air-quality/legislation). These moves resulted in Scotland being one of the leading countries in Europe and the rest of the world in the monitoring and mitigation of the pollutant $PM_{2.5}$.

A resulting effect of this new legislation has been the rapid expansion of the $PM_{2.5}$ monitoring network within the Scottish air quality database. In 2016 there were 11 new $PM_{2.5}$ sites added to the network. As part of the 2017/18 funding support for local authorities to assist with LAQM monitoring and modelling work, awards were made to fund an additional 17 (Figure 10.1) new $PM_{2.5}$ monitoring sites. This resulted in a total of 41 sites monitoring $PM_{2.5}$ during 2017. By the end of 2018 the $PM_{2.5}$ monitoring network had increase to 55 sites.

Table 10.1 below names the new $PM_{2.5}$ sites installed in 2018. Figure 10.1 illustrates the location of new sites added in 2018. Figure 10.2 shows all $PM_{2.5}$ sites in Scotland at the time of writing this report. More details on these monitoring locations is available at http://www.scottishairquality.scot/latest/. Figure 10.3 illustrates the increase in Monitoring sites over the past five years.

As the monitoring network has expanded, the Scottish Air Quality Database and Website has in turn expanded and developed to cope with the influx of new data. All the sites use analysers that are equivalent to the reference measurement. All data is ratified to the same QA/QC standards as stated in section 5 of this report.

Table 10.1 New Sites Monitoring $PM_{2.5}$ in 2018

new sites monitoring $PM_{2.5}$ in 2018		
Dundee Lochee Road	Edinburgh Tower Street	Glasgow Anderston
Glasgow Broomhill	Glasgow Nithsdale Road	Glasgow Waulkmillglen Res
Inverness*	N Lanarkshire Croy	N Lanarkshire Kirkshaws
N Lanarkshire Motherwell	N Lanarkshire Motherwell Civic Centre	N Lanarkshire Shawhead Coatbridge

* Inverness site has previously been monitoring $PM_{2.5}$ at a 24-hour average resolution using a Partisol Sampler.

Figure 10-1: Locations of new sites $PM_{2.5}$ added to the network in 2018

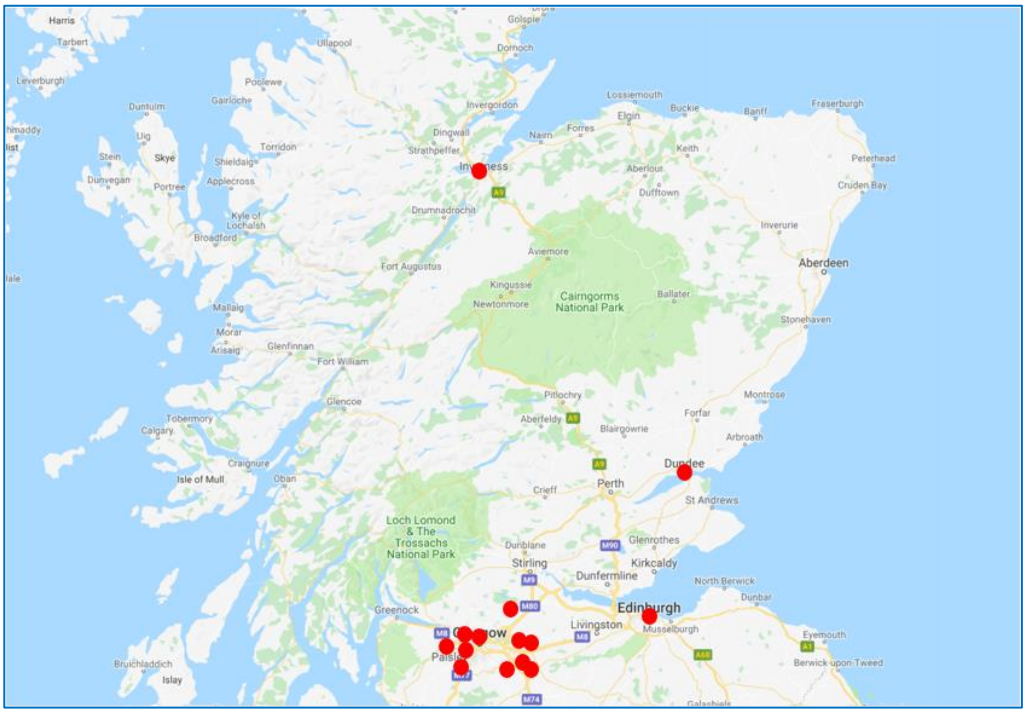
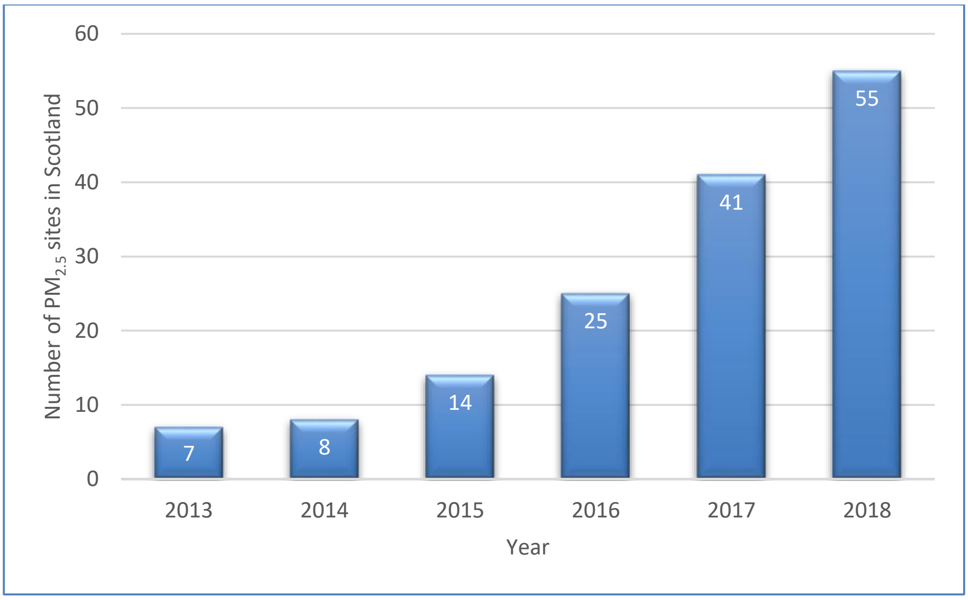


Figure 10-2: All $PM_{2.5}$ monitoring sites in the network

Figure 10-3 Number of $PM_{2.5}$ sites in Scotland since 2013



Figures stated as of December 2018

10.2 Website Maintenance/Updates

On a daily basis the web pages are checked by the Ricardo Energy and Environment IT and air quality team, both manually and using a number of automated software systems, in order to ensure that the website is fully functional with no broken links.

In addition to this, a number of routine maintenance tasks are carried on a daily/weekly/monthly basis as required in order to keep the underlying database up-to-date and fully populated. These include:

- Updates to the Scottish sites are made as required (e.g. If new monitoring instruments come on-line or other sites/instruments are changed for example, South Ayrshire PM_{10} analysers to $PM_{2.5}$ analysers & inclusion of FIDAS analysers (PM1, PM4 and TSP data)).
- New local authority monitoring sites are added to the database once agreement is reached with the local authority, 2018 welcomed Edinburgh Tower Street (August 2018), Motherwell Civic Centre (July 2018) to the network.
- The LAQM pages have been updated with any changes to the status of Local Authority Air Quality Management Areas.
- New technical guidance documents and reports (including local authority review and assessment reports) are added to the website when made available.
- Ratified data (or any improved provisional data) load automatically to the website from Ricardo Energy and Environment's data management software on a daily basis.
- Statistics are automatically recalculated every night:
  - Daily, Monthly & Annual Means etc.
  - All exceedance statistics.
- The news section is routinely updated with relevant information provided by the Scottish Government or other relevant outlets
- Site photos are updated as soon as Ricardo Energy and Environment carry out our QA/QC visits, or they are provided by the local authority.

During 2018 there were also a number of significant enhancements to the website under development to further enhance the performance and usability of the website. These have included;

- Development of Diffusion Tube Map
- Interactive Pollution Plots

10.2.1 Development of NO_2 Diffusion Tube Map

Since 2006 the Scottish Air Quality Database and Website (SAQDW) project via the Air Quality Scotland website has successfully disseminated air pollution data from local authority automatic sites to the general public. Local authority diffusion tube data has previously only been available to the general public via the submission of Annual Progress Reports. In recent years there have been increasing interest in providing better access to local authority diffusion tube data via the SAQDW so that the general public can obtain all the information easily and in a format that is straightforward to understand. The inclusion of this data would in turn increase the capabilities of the website and enhance its credentials as being the one stop shop for Scottish air quality data.

In October 2018 Scottish Government commissioned Ricardo to develop a NO_2 diffusion tube database and Map similar to what is already provided for the automated site data. The Map would provide bias corrected annual mean data previously published in the local authority's annual progress report. The Map would also have the following features;

- Due to the large number of diffusion tube sites compared to automatic sites, a cluster format will be applied (i.e. When the user is zoomed out and can see the full map of Scotland each area will display the number of diffusion tube sites available rather than individual sites. When selected the map zooms in to display the individual sites) enabling the user to easily select specific sites whilst at the same time having a map easy to use, isn't overly busy and is visually aesthetic.
- The colour of each site markers will be related to the NO_2 annual mean concentration (i.e. displayed red when the annual mean exceeds 40 µg m^{-3}).
- A Year Selector will enable the user to view historical data from current and closed sites.
- A Local Authority drop down list will provide the user an alternative way to specify which local authority and site they wish to obtain data from rather than using the map.
- When the user selects a site, specific site details will appear giving information such as, site type, location coordinates, historical data, graphing capabilities.

Figures 10-4 to 10-7 provide images of how the diffusion tube map looks on the website. The Map has been in development throughout the last 3 months of 2018 and into 2019 and was released in June 2019.

Figure 10-4 SAQD Diffusion Tube Map

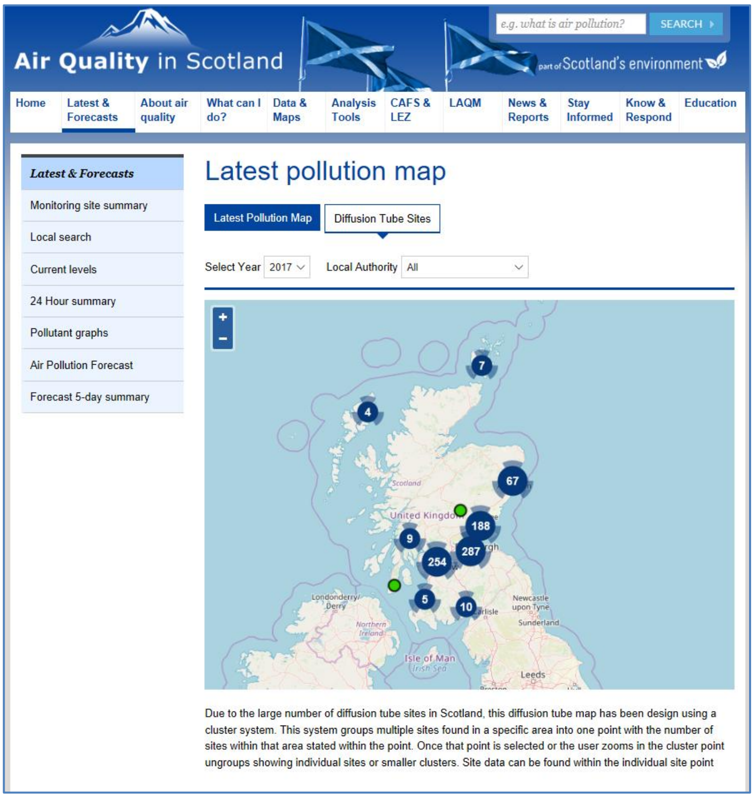


Figure 10-5 SAQD Diffusion Tube Map site cluster format

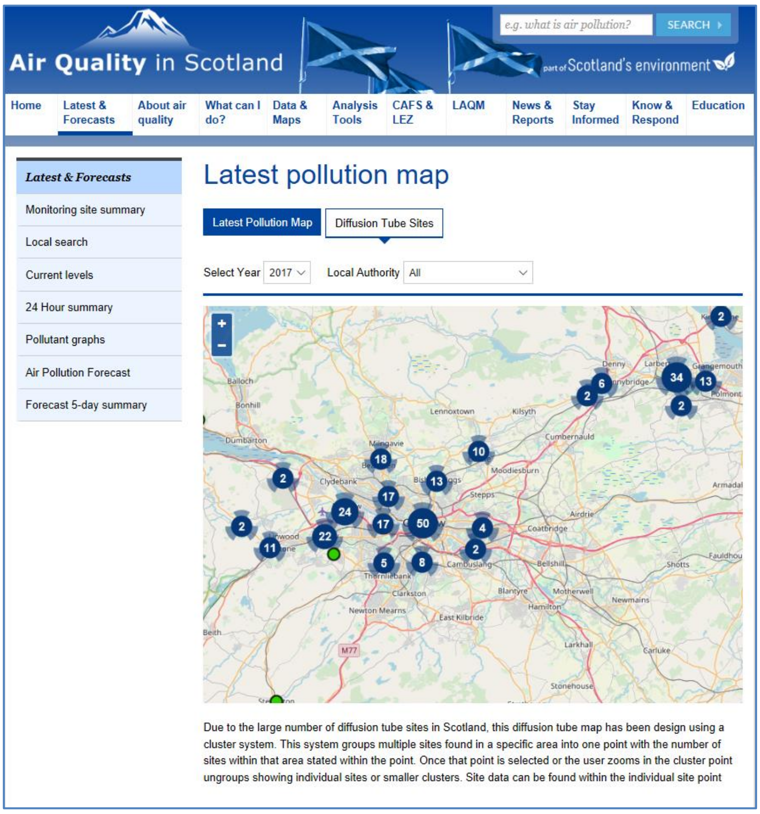


Figure 10-6 SAQD Diffusion Tube Map site summary page

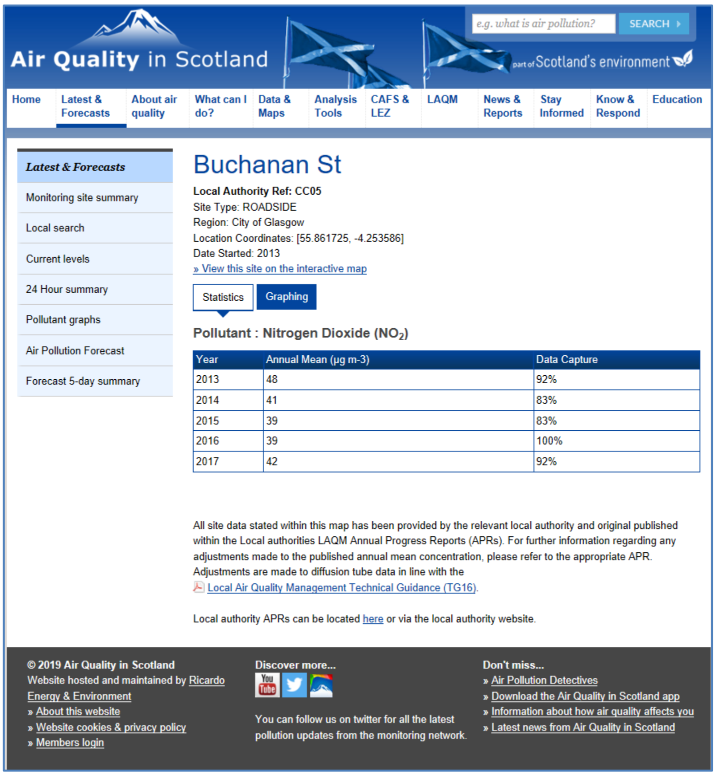
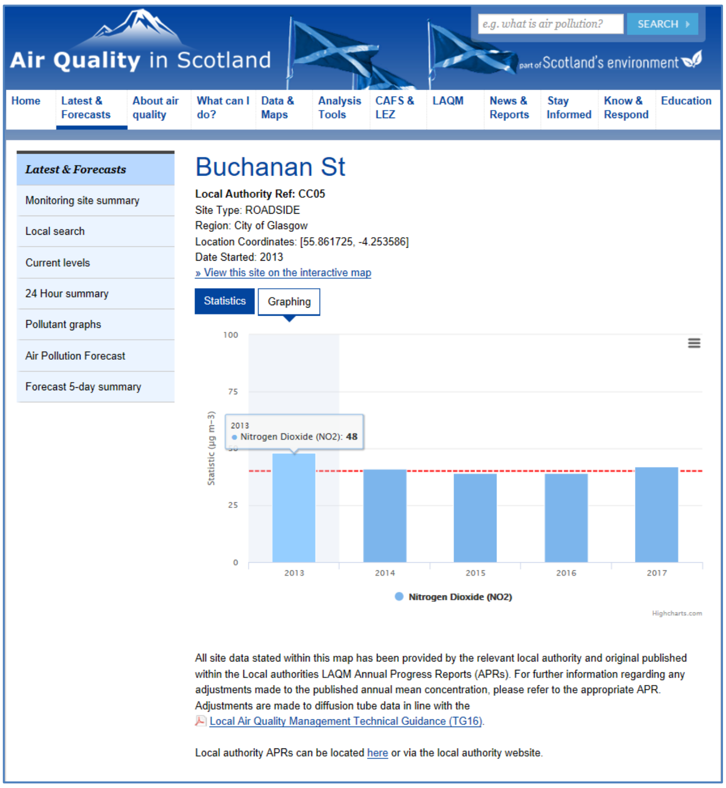


Figure 10-7 SAQD Diffusion Tube Map site summary page Graph



10.2.2 Interactive Pollution Plots

Previously the pollution graphs on Air Quality Scotland website were in the old static style. Scottish Government commissioned Ricardo to update these graphs to a more interactive, visually more attractive plotting format and they were release on the website in June 2019. The new graphing format allows the user to obtain actual concentrations, zoom in on certain dates and times, print and download (to various formats) individual graphs. In addition, a new site comparison functionality has been included enabling the user to compare their site data to any other site in Scotland on the same plot. In turn, giving them more insight and greater understanding of pollution concentrations in their area of interest. Figures 10-8 and 10-9 below illustrate the pollution graphs on the website. They can also been seen here; http://www.scottishairquality.scot/latest/pollutant-site-graphs.

Figure 10-8 Air Quality in Scotland Website Interactive Pollution Graph

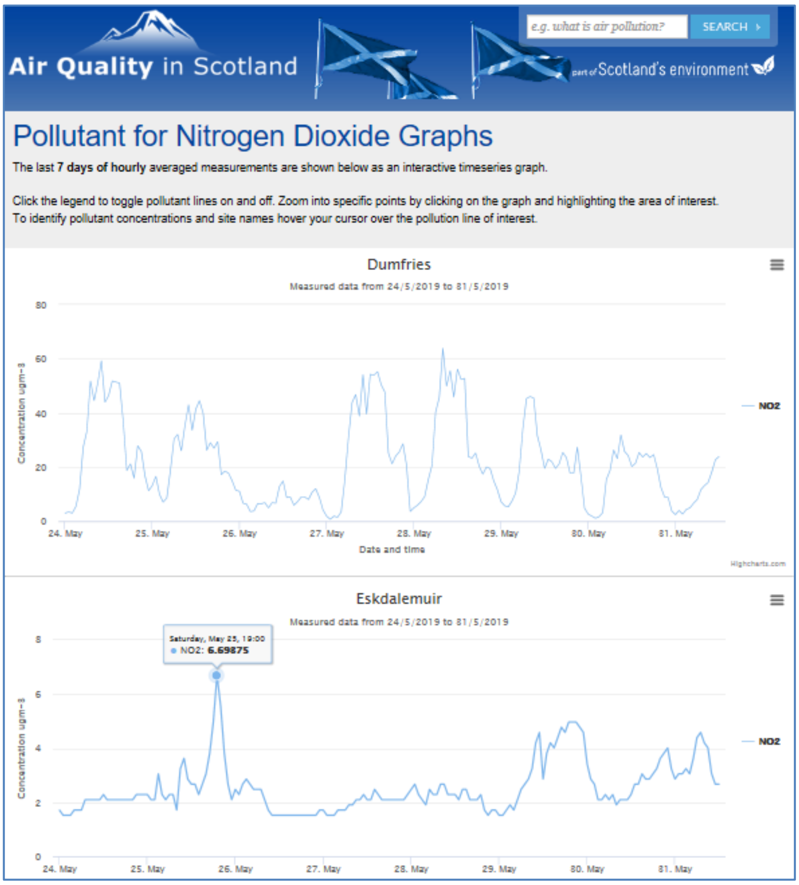
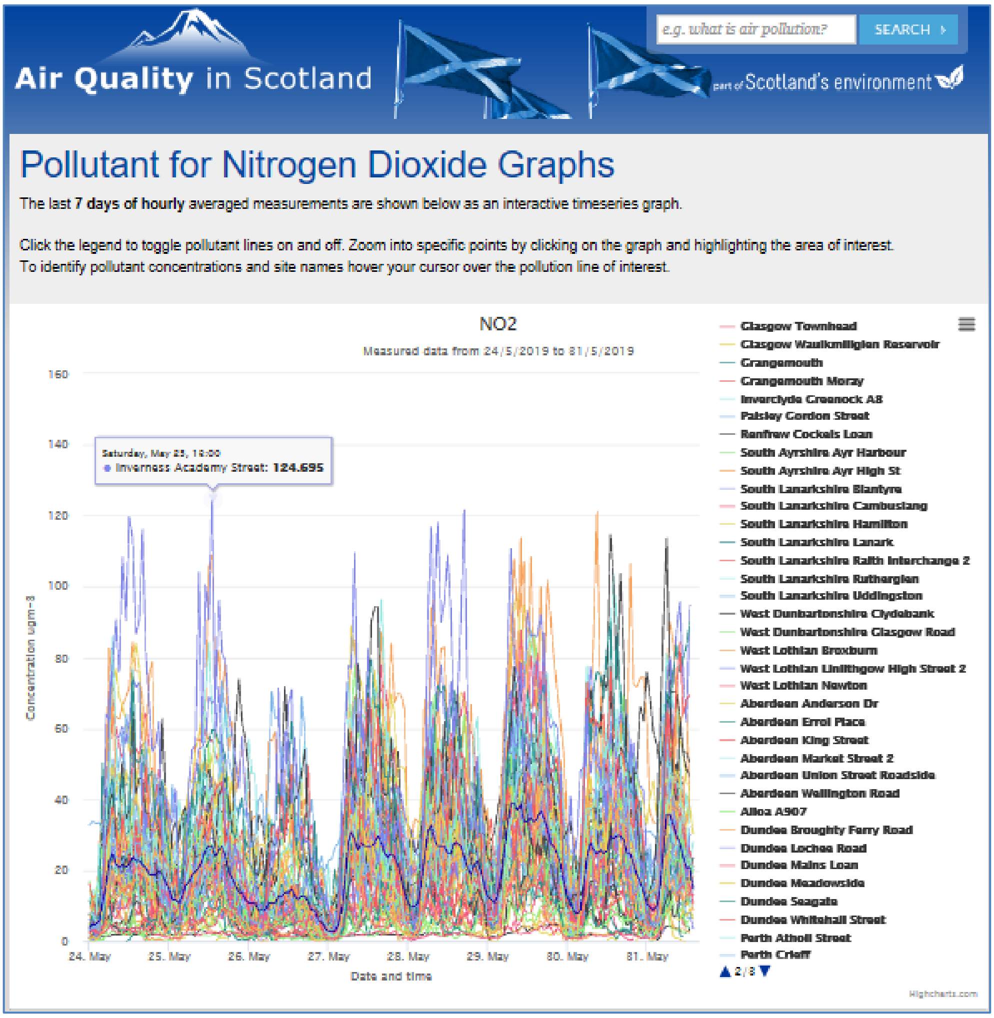


Figure 10-9 Air Quality in Scotland Website Interactive Comparison Pollution Graph



10.3 Air Quality in Scotland App

The Air Quality in Scotland App was first released in 2012. It is essential to keep mobile Apps continually up to date to prevent errors from occurring and ensure that the code is compatible with the latest mobile devices and operating systems. There are key functionalities that need to be revised to ensure the application is up-to-date and in accordance with the ever-changing requirements of Google Play and Apple Store. Since the launch of stage 2 version (the previous update) of AQ Scotland App in 2015 it had become apparent that further improvements were required under Stage 3.

In October 2018 Scottish Government commissioned Ricardo to update the Air Quality in Scotland App. As well as update the app, Scottish Government took this opportunity to increase the capabilities of the App by adding new functionality. These functionalities include:

- App Notification Alert Function for elevated site data
- App Notification Alert Function for Local Authority areas with forecast elevated pollution levels
- App Notification Alert Function when entering an AQMA
- Interactive AQMA map and Summary page which provides the location, area covered by the AQMA and supporting information.

In June 2019 the newest version of the Air Quality in Scotland App was released.

10.3.1 App Notification Alert Function for elevated site data

In response to recommendations made in the Air Quality Scotland Enquiry and in consideration of objectives stated within CAFS, Scottish Government are seeking a way to quickly notify the public of when automated monitoring sites within the SAQD measure pollution levels of moderate or above.

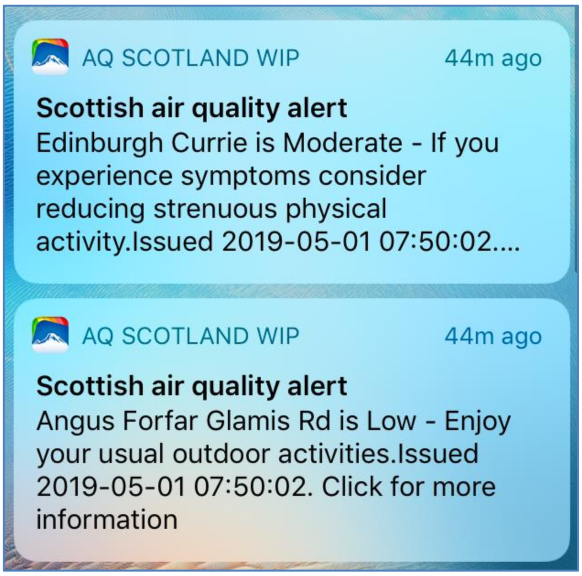
Ricardo facilitated this requirement through the development of a notification alert system on the AQ Scotland App.

The Notification Alert function within the AQ Scotland App works by;

- Providing the user with an option to select areas of interest either through an interactive map selection or table of local authorities.
- When an automate site within the users chosen area goes Moderate/High /Very high, a notification appears on their smart phone or tablet devise informing them of the location and pollutant of concern.
- The notification is colour coded in accordance with the current AQ Index.
- The notification provides an option to find out further information about the health implications of the elevated pollution.
- It is often the case that Erroneous data causes sites to go Moderate/High /Very high, so a checking system has been developed that allows Ricardo to quickly verify the elevated levels before a notification is released.

Figure 10-10 provides an example of how the notification will look on an ios mobile device.

Figure 10-10 Air Quality in Scotland App Elevated Site Data Notifications

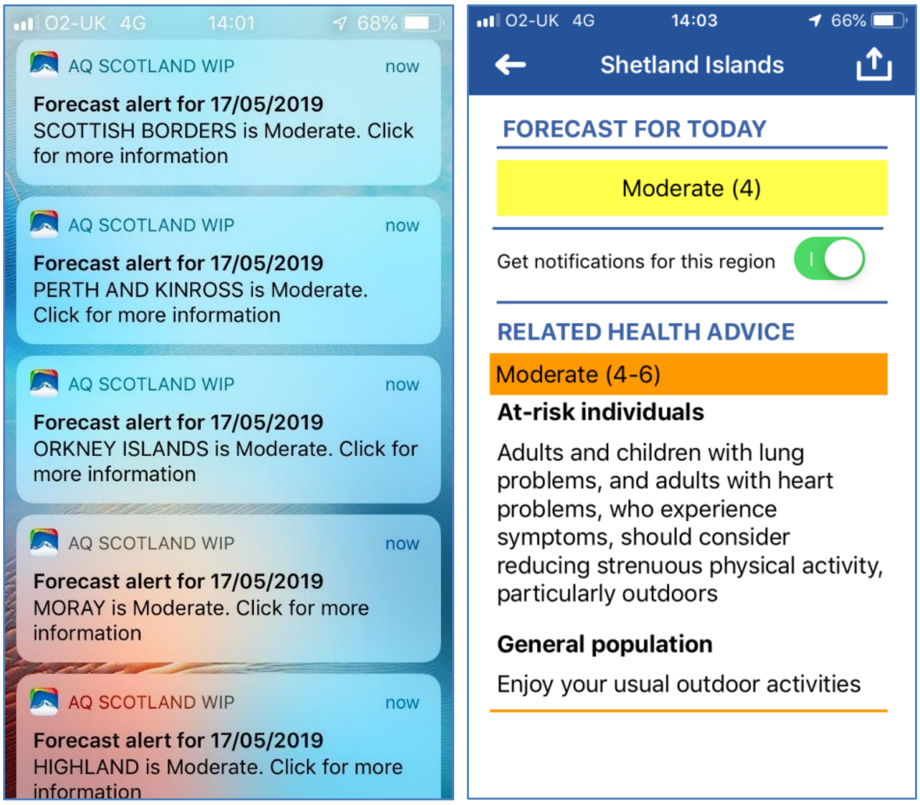


10.3.2 App Notification Alert function for Local Authority areas with forecast elevated pollution levels

Similar to the function described in section 1.3.1, an alert system was developed that notifies the user when the air pollution forecast is moderate or above for chosen local authority areas. The system works in the same way as the alert for elevated sites and in conjunction with the Know and Respond Alerts system.

Figure 10-11 provides an example of what the forecast notification will look like on an ios mobile device and the advice page

Figure 10-11 Air Quality in Scotland App Elevated Forecast Notifications and advice page

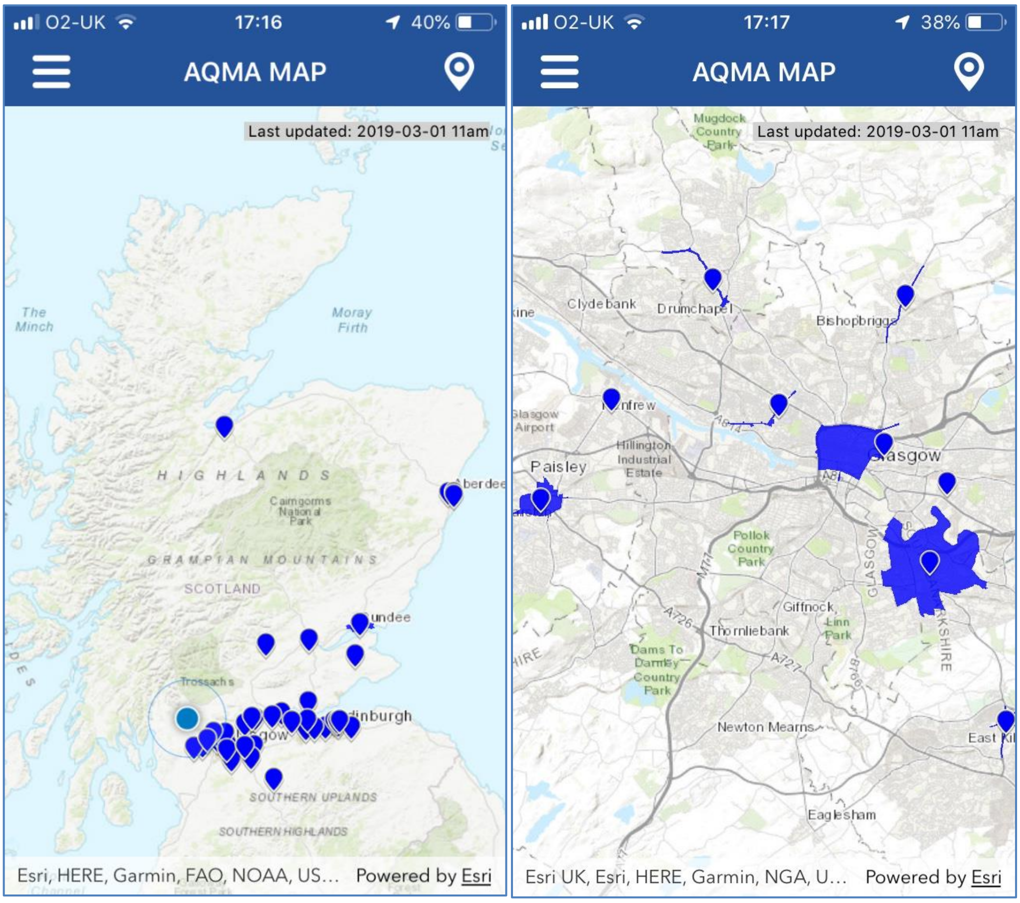


10.3.3 App Notification Alert function when entering an AQMA

To further engage and inform the public about air quality in Scotland, a notification alert system was developed for when the user of the App enters an AQMA. Using GIS data of all AQMAs in Scotland the function sends a notification to the user once they enter an AQMA and then provides them with useful information such as latest data, map of AQMA, nearest monitoring location etc. When AQMAs are added, amended or are revoked, this information will be automatically updated when the information is made available. In addition to this, the App now provides all essential information on AQMAs in Scotland. This includes an interactive map showing the location and boundaries of the AQMAs.

Figure 10-12 shows an image of the new interactive AQMA map on the Air Quality in Scotland App.

Figure 10-12 Air Quality in Scotland App Interactive AQMA map



11 Summary and Conclusions

In April 2007, Ricardo Energy & Environment were commissioned by the Scottish Government to undertake a 3-year project (Apr 2007 – Apr 2010) to develop an Air Quality Database and Website for Scotland. This contract has been renewed in recent years, with the latest contract running from 2016-2019.

This report brings together all the Scottish Air Quality Database data for calendar year 2017 and associated work relating to project deliverables including: data management; QA/QC services; liaison with stakeholders; website development; spatial analysis of air quality data; trend analysis. In addition, the report presents the additional activities and further developments undertaken during the eleventh year of the project, July 2018 – June 2019.

Legislation and Policy

The "Cleaner Air for Scotland – The Road to a Healthier Future" (CAFS) strategy was published by the Scottish Government in November 2015. The purpose of CAFS is to provide a national framework which sets out how the Scottish Government and its partner organisations propose to achieve further reductions in air pollution and fulfil their legal responsibilities as soon as possible. CAFS outlines the contribution that better air quality can make to sustainable development whilst improving health and the natural environment and reducing health inequalities for the citizens of Scotland.

In addition to the six main objectives, CAFS outlines new initiatives to be implemented to compliment the objectives set; these initiatives include a National Modelling Framework and National Low Emissions Framework. CAFS outlines further changes such as the adoption of the WHO guideline value for $PM_{2.5}$; this was transposed by the Air Quality Scotland Amendment Regulations 2016 when the annual mean objective for $PM_{2.5}$ was set at 10ug m^{-3} in April 2016.

The Scottish Government published the NLEF framework in January 2019. The framework provides a methodology for local authorities to undertake air quality assessment to inform decisions on transport related actions.

During the first half of 2019, the Scottish Government carried out an indepth independent review of CAFS and the resulting documents were published in July 2019. The Scottish Government intend to use the information and recommendations made from this review to update CAFS in 2020.

Air Quality Monitoring in Scotland

Air pollution data for 97 automatic monitoring sites throughout Scotland are available in the database for all or part of 2018. All automatic data maintained within the Scottish database are subject to the same QA/QC procedures as at the national network air quality monitoring stations within the UK Automatic Urban and Rural Network. This ensures that all data in the database are quality assured and traceable to UK national calibration standards for the various pollutants.

Analysis shows that data capture rates since 2008 have continued to improve, year on year, for both nitrogen dioxide (NO_2) and Particulate Matter (PM_{10}). A significant improvement in PM_{10} data capture seen between 2016 and 2017 has been attributed to a change in analyser used within the network.

In 2018 six automatic monitoring sites exceeded the annual mean objective for NO_2. However, in 2018, 74 NO_2 diffusion tube monitoring sites exceeded the annual mean objective. The majority of these exceedances were located in and around the 4 cities of Glasgow, Edinburgh, Dundee and Aberdeen.

In 2018, two sites exceeded the PM_{10} annual objective for PM_{10}.

The pattern of measured concentrations is similar to previous years in that where exceedances of the Scottish air quality objectives occur, these are in areas where the relevant local authority has already declared or is in the process of declaring an Air Quality Management Area (AQMA).

In 2018, the Air Quality Strategy Objective the ozone objective was exceeded at 9 out of the 11 sites measuring the pollutant in Scotland. In the same year, no exceedances were observed for the pollutants $PM_{2.5}$, SO_2, CO, benzene, 1,3-butadiene and benzo(a)pyrene.

Air Quality Mapping of Scotland

Ricardo Energy & Environment provide mapped concentrations of modelled background air pollutant concentrations on a 1 km x 1 km basis for the whole of Scotland. Modelled roadside air pollutant concentrations are provided for road links in Scotland. The air pollution maps are derived from a combination of (1) measurements from Scotland's network of air quality monitoring stations, and (2) spatially disaggregated emissions information from the UK National Atmospheric Emissions Inventory (NAEI). This report provides maps modelled using 2017 data, the most recent year for which inventory data is available.

For NO_{2}, there were no modelled exceedances of the Scottish annual mean objective of 40 µg m^{-3} at background locations. Exceedances of the annual mean NO_2 objective at roadside locations were modelled at 38 road links (57.5 km of road) in the Glasgow Urban Area and at 11 road links (21.7 km of road) in Central Scotland. In the Edinburgh Urban Area and the North East Scotland zone there were fewer than five road links where exceedances of the Scottish annual mean NO_2 air quality objective were modelled, affecting 4-6 km of roads.

There were no modelled exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} at background locations. Two road links (3.9 km of road) were identified as exceeding the Scottish annual mean PM_{10} air quality objective. Exceedances of the Scottish annual mean PM_{10} objective were modelled in the Glasgow Urban Area only.

Air Quality Trends for Scotland

Data held within the database covering many years have been used to assess possible trends in air pollution throughout Scotland. Air quality trends have been examined on the basis of individual monitoring sites, and subsets of long-running sites, rather than the composite dataset.

NO_2

Trend Analysis of nitrogen dioxide concentrations at Scotland's five long-running urban non-roadside sites suggests that NO_2 concentrations are in general decreasing however not all at the same rate. It also indicates that NO_2 concentrations are decreasing at a greater rate in the larger urban areas.

Nitrogen dioxide concentrations at Scotland's three long-running rural sites showed decreasing trends. Bush Estate and Eskdalemuir showed small but highly significant downward trends. However, this was not the case for Glasgow Waukmillglen Reservoir, where concentrations were decreasing very slightly year-on-year.

Scotland has a large number of urban traffic monitoring sites monitoring NO_2, of which 30 have now been operating for at least 10 years. This trend analysis therefore focussed on eight of these sites that have operated for 10 years and have reported exceedances of the AQS objective in recent years. All these sites showed significant downward trends, with seven of the eight site trends significant at the 0.001 level.

Examination of trends at the same nine sites over the most recent five complete years (2018 to 2018) indicates that the patterns are mostly very similar to the 10-year trends. The exception being N. Lanarkshire Chapelhall where the trend switches from a downwards to an upward trend (though not statistically significant).

PM_{10}

PM_{10} at Scotland's eight long-running urban non-roadside sites showed a significant or highly significant downward trend. PM_{10} at Scotland's nine long-running urban traffic (roadside and kerbside) sites showed statistically significant downward trends at all sites (at the 0.001 level in all but one case).

Examination of trends in PM_{10} at the same nine sites over the most recent five complete years (2014 to 2018) indicates that, at some of these, the decreasing trends have continued but at others they have weakened, levelled off or switched to an increasing trend (Glasgow Byres Road). For Edinburgh Queensferry Road analysis indicates a highly significant increasing trend. However, this may have been influenced by ongoing construction works close to the monitoring location.

Only four sites in Scotland have 10 years or more particulate matter 2.5 ($PM_{2.5}$) data. Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth sites show slight but highly statistically significant downward trends. Contrary to this, the rural site Auchencorth Moss shows a slight upward trend however not statistically significant.

$PM_{2.5}$

At the time of writing this report there are 63 sites monitoring $PM_{2.5}$ in Scotland. However, the vast majority of these sites started monitoring in the last 3 years with the introduction of the $PM_{2.5}$ objective and the requirement for local authorities to measure the pollutant. By the end of 2018 there were four sites with 10 consecutive years of $PM_{2.5}$ data. Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth sites show slight but highly statistically significant (at the 0.001 level) downward trends for $PM_{2.5}$. Contrary to this, the rural site Auchencorth Moss shows a slight upward trend however not statistically significant.

Ozone

Ozone has been measured at three rural sites in Scotland for thirty years. All three sites showed small positive trends over this very long period, highly statistically significant at two of the three sites. Ozone has been measured for the past 10 years at six rural sites. Over this more recent period only one site (Lerwick) showed a significant trend (positive)– so trends over this more recent period are less consistent. Ozone concentrations showed no significant trends at one of the two urban background sites which have monitored this pollutant for the past 10 years, while the other site showed a slightly positive trend.

Emissions of Pollution Species

Scotland NOx emissions have declined by 73% since 1990 and were estimated to be 93kt in 2017 representing 11% of the UK total. This decline is driven by the continued introduction of tighter vehicle emissions standards over the last decade. Since 2008, emissions from passenger cars have further decreased. This has been mainly driven by improvements in catalyst repair rates resulting from the introduction of regulations controlling the sale and installation of replacement catalytic converters and particle filters for light duty vehicles. However, the increasing number of diesel cars partly offsets these emissions reductions, because diesel cars emit higher NO_x relative to their petrol counterparts (88% of 2017 passenger car emissions is due to diesel cars).

Emissions of PM_{10} have declined by 63% since 1990 and in 2017 and were estimated to be 15kt (9% of the UK total). PM_{10} exhaust emissions from diesel vehicles have been decreasing due to the successive introduction of tighter emission standards over time. The decline in PM_{10} emissions has basically stopped across all sectors over the past few years with some, such as Industrial Processes increasing. This has been attributed to an increased quantity of wood fuel use. In addition, almost all other emissions sources have remained stable since 2011. Though PM_{10} emissions have reduced since 1990, overall there has been no significant reduction in PM_{10} emissions since 2013.

Emissions of $PM_{2.5}$ have declined by 68% since 1990 and in 2017 were estimated to be 8kt (8% of the UK total). For $PM_{2.5}$, the residential, commercial and public sector combustion category accounts for 42% of 2017 emissions. The decline in emissions has significantly reduced over the past few years with no significant decrease since 2013. One of the reasons for this slowing has been attributed to the increase in emissions from the residential sector and in particular the combustion of wood.

SAQD Developments and Websites Updates

Expansion of the $PM_{2.5}$ Network

The $PM_{2.5}$ network continues to expand with 14 new sites added to the network by the end of 2018. At the time of writing this report there were 63 sites.

Air Quality in Scotland App

In October 2018 Scottish Government commissioned Ricardo to update the Air Quality in Scotland App. As well as update the app, Scottish Government took this opportunity to increase the capabilities of the App by adding new functionality. These functionalities included:

- App Notification Alert Function for elevated site data
- App Notification Alert Function for Local Authority areas with forecast elevated pollution
- App Notification Alert Function when entering an AQMA
- Interactive AQMA map and Summary page which provides the location, area covered by the AQMA and supporting information on each AQMA in Scotland.

In June 2019 the newest version of the Air Quality in Scotland App was released.

Development of NO_2 Diffusion Tube Map

In October 2018 Scottish Government commissioned Ricardo to develop a NO_2 diffusion tube database and Map similar to what is already provided for the automated site data. The map was release live on the Air Quality in Scotland website in June 2019. The Map provides bias corrected annual mean data previously published in the local authorities' annual progress report and has the following features:

- Due to the large number of diffusion tube sites compared to automatic sites, a cluster format will be applied (i.e. when the user is zoomed out and can see the full map of Scotland each local authority will display the number of diffusion tube sites available rather than individual sites. When selected the map zooms in to display the individual sites) enabling the user to easily select specific sites whilst at the same time having a map easy to use, isn't overly busy and is visually aesthetic.
- The colour of each site markers will be related to the NO_2 annual mean concentration (i.e. displayed red when the annual mean exceeds 40 µg m^{-3}).
- A Year Selector will enable the user to view historical data from current and closed sites.
- A Local Authority drop down list will provide the user an alternative way to specify which local authority and site they wish to obtain data from rather than using the map.
- When the user selects a site, specific site details will appear giving information such as, site type, location coordinates, historical data, graphing capabilities.

Interactive Pollution Plots

Scottish Government commissioned Ricardo to update pollution graphs to a more interactive, visually more attractive plotting format and they were release on the website in June 2019. The new graphing format allows the user to obtain actual concentrations, zoom in on certain dates and times, print and download (to various formats) individual graphs. In addition, a new site comparison functionality has been included enabling the user to compare their site data to any other site in Scotland on the same plot.

Appendices

Appendix 1: National Monitoring Networks in Scotland 2018
Appendix 2: Ratification Procedures

Appendix 1 – National Monitoring Networks in Scotland 2018

Table A1.1. AURN Measurement Sites in Scotland 2018

Aberdeen	URBAN BACKGROUND	NO NO_2 NO_X O_3 PM_{10}, $PM_{2.5}$	394416,807408
Aberdeen Union St Roadside	ROADSIDE	NO NO_2 NO_X	396345,805947
Aberdeen Wellington Road	ROADSIDE	NO NO_2 NO_X	394397, 804779
Auchencorth Moss	RURAL	O_3 PM_{10}(grav) $PM_{2.5}$(grav)	322167, 656123
Bush Estate	RURAL	NO NO_2 NO_X O_3	324626,663880
Dumbarton Roadside	ROADSIDE	NO NO_2 NO_X	240234,675193
Dumfries	ROADSIDE	NO NO_2 NO_X	297012,576278
Dundee Mains Loan	URBAN BACKGROUND	NO NO_2 NO_X	340971, 731892
Edinburgh Nicolson St	ROADSIDE	NO NO_2 NO_X	326150, 673046
Edinburgh St Leonards	URBAN BACKGROUND	CO NO NO_2 NO_X O_3 PM_{10} $PM_{2.5}$ SO_2	326265, 673136
Eskdalemuir	RURAL	NO NO_2 NO_X O_3	323552,603018
Fort William	RURAL	NO NO_2 NO_X O_3	210830,774410
Glasgow Great Western Road	ROADSIDE	NO NO_2 NOx	258007,666651
Glasgow High Street	URBAN TRAFFIC	NO NO_2 NO_X PM_{10}, $PM_{2.5}$	260014,665349
Glasgow Kerbside	KERBSIDE	NO NO_2 NO_X PM_{10}, $PM_{2.5}$	258708,665200
Glasgow Townhead	KERBSIDE	NO NO_2 NO_X PM_{10}, $PM_{2.5}$	259692,665899
Grangemouth	URBAN INDUSTRIAL	NO NO_2 NO_X PM_{10}, $PM_{2.5}$, SO_2	293840,681032
Grangemouth Moray	URBAN BACKGROUND	NO NO_2 NOx	296436,681344
Greenock A8 Roadside	ROADSIDE	NO NO_2 NO_X	229332, 675715
Inverness	ROADSIDE	PM_{10}(grav), $PM_{2.5}$(grav), NO NO_2 NO_X	265720,845680
Lerwick	RURAL	O_3	445337,113968
Peebles	SUBURBAN	NO NO_2 NO_X O_3	324812,641083
Strath Vaich	REMOTE	O_3	234787,875022

Table A1.2 Automatic Hydrocarbon Network Sites in Scotland 2018

Auchencorth Moss	RURAL	Benzene and 1,3-butadiene and 24 other ozone precursor hydrocarbon species*	322167, 656123

Table A1.3 Non-Automatic Hydrocarbon Network Sites in Scotland 2018

Glasgow Kerbside$^{\alpha}$	KERBSIDE	Benzene	258708, 665200
Grangemouth	URBAN INDUSTRIAL	Benzene	293840,681032

EU requirement and part of the EMEP long-range transboundary air pollution monitoring programme.
$^{\alpha}$Non-Automatic Monitoring of Benzene started at this site on 01/09/10.

Table A1.3 PAH Monitoring Sites in Scotland 2018

Auchencorth Moss	Rural site in Scotland, South of Edinburgh	322167, 656123
Edinburgh	145 Pleasance Edinburgh EH8 9RU	326265, 673136

Glasgow Townhead	Townhead Glasgow G4 0PH	259692, 665899
Kinlochleven 2	Electrical Substation Kinlochleven	219280, 761986

Table A1.4 Heavy Metals Monitoring Network Sites in Scotland 2018

Auchencorth Moss	Rural	As, Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb, Se, V, Zn	322167, 656123
Eskdalemuir	Rural	As, Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb, Se, V, Zn	323552,603018

Table A1.6 Rural Metal Deposition Monitoring sites in Scotland 2018

Site	Location Grid Ref.	Heavy metals			Mercury	
		In Particles	In Rain	In Cloud	In Air	In Rain
Inverpolly	218776,908833		✓			
Banchory	367694,798519	✓	✓		✓	✓
Bowbeat	328289,647302		✓	✓		
Auchencorth Moss	322167, 656123	✓	✓		✓	✓

United Kingdom Eutrophying & Acidifying Network (UKEAP)

Table A1.7 The Precipitation Network (PrecipNet) Sites in Scotland 2018

Auchencorth Moss	322167, 656123	Na^+, Ca^{2+}, Mg^{2+}, K^+, PO_4^{3-}, NH_4^+, NO_3, SO_4^{2-}, Cl^-
Allt a'Mharcaidh	287691, 805223	
Balquhidder 2	254465, 720706	
Eskdalemuir	323552, 603018	
Forsinard RSPB	289309, 942826	
Glensaugh	366329, 780027	
Loch Dee	246907, 577768	
Polloch	179244, 768951	
Strath Vaich	234787, 875022	
Whiteadder	366180, 663116	

Table A1.8 Acid Gas and Aerosol Network (AGANet) and Ammonia Network (NAMN) Sites in Scotland 2018

Allt a Mharcaidh	289184, 804320	✓	
Auchencorth Moss	322188, 656202	✓	✓
Auchencorth Moss	322188, 656202	✓	
Auchincruive	238018, 623382	✓	
Bush	324629, 663891	✓	✓
Carradale	179870, 637801	✓	✓
Carradale	179870, 637801	✓	
Dumfries Grannoch	254650, 565848	✓	
Edinburgh St Leonards	326265, 673136	✓	
Ellon	394689, 830322	✓	
Eskdalemuir	323588, 602997	✓	✓
Eskdalemuir	323588, 602997	✓	

Forsinard RSPB	289309, 942826	✓	
Glen Shee	312187, 769016	✓	
Glensaugh	366329, 780027	✓	✓
Glensaugh	366329, 780027	✓	
Green Cabin	324646, 663902	✓	
Halladale	290285, 948838	✓	
Inverpolly	218695, 908820	✓	
Lagganlia	285684, 803720	✓	✓
Lagganlia	28568, 403720	✓	
Oldmeldrum	383297, 827323	✓	
Polloch	179244, 768951	✓	✓
Polloch	179244, 768951	✓	
Rannoch	260380, 753315	✓	
Sourhope	386796 621798	✓	
Strathvaich	234787, 875022	✓	✓
Strathvaich Dam	234787, 875022	✓	
Tummel	274483, 761116	✓	

Appendix 2 - Ratification Procedures

A2.1 Intercalibration and Audit procedures

The audit and intercalibration procedures adopted by Ricardo Energy & Environment rely upon the principle that a set of recently certified gas cylinders (called "audit gas") is taken to all the stations in a monitoring network. This gas is certified at the Ricardo Energy & Environment Gas Calibration Laboratory. At each station, analyser response to audit gas is recorded to check if the expected concentration (i.e. the certified value for the cylinder) is obtained. The analyser response to audit gas is obtained using calibration factors obtained from the site operator. The audit procedure checks the validity of the provisional data, the correct overall operation of the analyser and the reliability of calibrations undertaken routinely at that station. These site audit procedures are compliant with the requirements of the CEN standard methods of measurement and are used throughout the UK AURN network.

The results of the audit exercises form an integral part of the data management system and are fed directly into the data ratification process. After the audit exercise, data from all the stations visited are traceable to recently calibrated UKAS accredited gas calibration standards (the audit gas).

A2.1.1 Detailed instrumentation checks

The following instrument functional checks are undertaken at an audit:

- Analyser accuracy and precision, as a basic check to ensure reliable datasets from the analysers.
- Instrument linearity, to check that doubling a concentration of gas to the analyser results in a doubling of the analyser signal response. If an analyser is not linear, data cannot be reliably scaled into concentrations.
- Ozone analyser calibration against a traceable ozone photometer
- Instrument signal noise, to check for a stable analyser response to calibration gases.
- Analyser response time, to check that the analyser responds quickly to a change in gas concentrations.
- Leak and flow checks, to ensure that ambient air reaches the analysers, without being compromised in any way.
- NO_X analyser converter efficiency, via gas phase titration, to ensure reliable operation. The converter must be more than 95% efficient to ensure that the NO_2 data are of the required accuracy.
- TEOM k_0 evaluation. The factor is used to calculate particulate mass concentrations.
- Particulate analyser flowrates. Any error in the flow through these particulate analysers is directly reflected in an error in the final measure of particulate concentration.
- SO_2 analyser hydrocarbon interference, certain hydrocarbons are known to interfere with the SO_2 detector.
- Evaluation of site cylinder concentrations, with reference to the certified audit gas taken to the stations. This procedure allows for the correction of data from stations where the site calibration cylinder concentration is slowly changing and for identification of any unstable cylinders that require replacement.
- Assessing changes in local site environment. During the visit, a record of any changes in the site environment, for example any increase or decreased traffic flow due to road layout changes, construction activity, encroachment of the site by vegetation etc.
- Assessment of station infrastructure and operational procedures. Any deficiencies in site infrastructure or operational procedures, which may affect data quality or safe operation of the site, are noted.

- Ensure Local Site Operators (LSO) understand calibration procedures correctly. It is the calibrations by the LSOs that are used to scale pollution datasets and hence, it is important to check that these are undertaken reliably.

The procedures used to determine instrument performance are documented in Ricardo Energy & Environment Work Instructions. These methods are regularly updated and improved and have been evaluated by the United Kingdom Accreditation Service (UKAS). Tests are performed on the analysers, cylinders and ambient air inlet systems. Checks are made on the environment around the site, including the continued representative nature of the site and safety assessments. The data collected from the instrument and cylinder tests are collated on site, using a controlled and protected Excel spreadsheet, which automatically undertakes all calculations and alerts the audit staff to any unusual results. The completed spreadsheets are then returned for further checking, before being used within the data management process and in production of accredited Certificates of Calibration.

A2.1.2 UKAS Accreditation

Ricardo Energy & Environment holds UKAS accreditation to ISO 17025 for the on-site calibration of the gas analysers (NO_X, CO, SO_2, O_3), for flow rate checks on particulate (PM_{10}) analysers and for the determination of the spring constant, k_0, for the TEOM analyser.
ISO17025 accreditation provides complete confidence that the analyser calibration factors are traceable to national metrology standards, that the calibration methods are sufficient and fit for purpose, and that the uncertainties are appropriate for data reporting purposes. Ricardo Energy & Environment also holds ISO17025 accreditation for laboratory certification of NO, NO_2, CO and SO_2 gas cylinders.

A2.1.3 Zero air

The reliability of the zero air supply at each station is of fundamental importance in the determination of ambient concentrations. A reference zero air source is held at the Ricardo Energy & Environment Gas Calibration Laboratory, which is traceable to international standards. A transfer standard, checked against this standard, is used to evaluate the site zero sources at the QA/QC audits. The zero air supply at a site will be either:

- A zero air cylinder.
- A series of chemical scrubbers connected to a pumped delivery system.
- A pollutant specific chemical scrubber system to connect directly into the analyser.

A2.1.4 Ozone Photometers

Ozone photometers are calibrated every six months against the NIST Reference Photometer, held at NPL, before use at the station audits.

A2.2 Data Acquisition and Processing

The Scottish local authority monitoring stations are polled three times a day to retrieve 15-minute averages of raw output from instruments. This is a balance between regular updating of the database and web site yet minimising the associated telecoms costs. UK National network stations are polled hourly as these data are used for the air quality forecast system.
The data are transmitted via MODEM or internet connection, depending on type of logging system used at the site, and automatically appended to the air quality site database. The results of automatic overnight autocalibration checks are also retrieved and databased. Appropriate scaling factors based on the most recent calibration information are applied to the pollutant measurements to produce concentrations in the relevant units.
From the 15-minute values, the hourly averaged results are calculated. This is the averaging period used for the reporting of both validated and ratified data for all pollutants. Additionally, the 15-minute data files are provided for SO_2 to allow direct comparison with the 15-minute objective. Once the raw data from the stations has been acquired the next step in the data management process is data validation.

A2.2.1 Validation of Data

All incoming data from the monitoring station are automatically screened prior to the release of validated data sets. Experienced staff will check the data daily, to monitor satisfactory data acquisition and to investigate instances of suspect data. This daily checking ensures rapid diagnosis of any instrument malfunctions.

The automatic screening procedures, and many years' experience of our staff, enables us to ensure that only the highest quality data are released to the Scottish Air Quality Database and Website as validated data.

Should equipment or site problems be identified, it is possible for data management staff to contact the monitoring station manually, in order to access further information. If necessary, the relevant LSO is contacted to undertake further investigation.

A2.3 Data Ratification

This section provides details of the procedures and the software tools we use for data ratification.

Our software runs a number of protocols to automatically flag data anomalies in the provisional data received from the stations, these are examined in detail during the ratification process. These include identifying the following:

- Negative data
- High data peaks
- Calibrations which are more than 5% different from previous values
- Peaks with a maximum 15-minute concentration significantly above the hourly mean value
- Measurements which are outside the normal range of expected data e.g. elevated ozone concentrations during the winter months
- Long periods of constant or zero concentrations
- Data gaps of more than six hours.

A2.3.1 Ratification tasks and output

When ratifying data, the following are closely examined:

- Issues that have been flagged up automatically by the software
- zero and sensitivity factors used on each day
- General review of the result to make sure that there are no other anomalies.

A2.3.2 Ratified Data Checking

Once the data have been initially ratified proforma reports is produced and passed to the data checker The role of the data checker is to:

- Assess if there are any station problems if not the data can be marked as ratified.
- Return the station to the data ratifier if there are any issues requiring further action by the data ratifier.
- Forward the report to the project Quality Circle if there are data quality issues which require a group discussion to resolve.

Following the Quality Circle meeting the data are then corrected if required and uploaded as ratified to the database and web site.

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