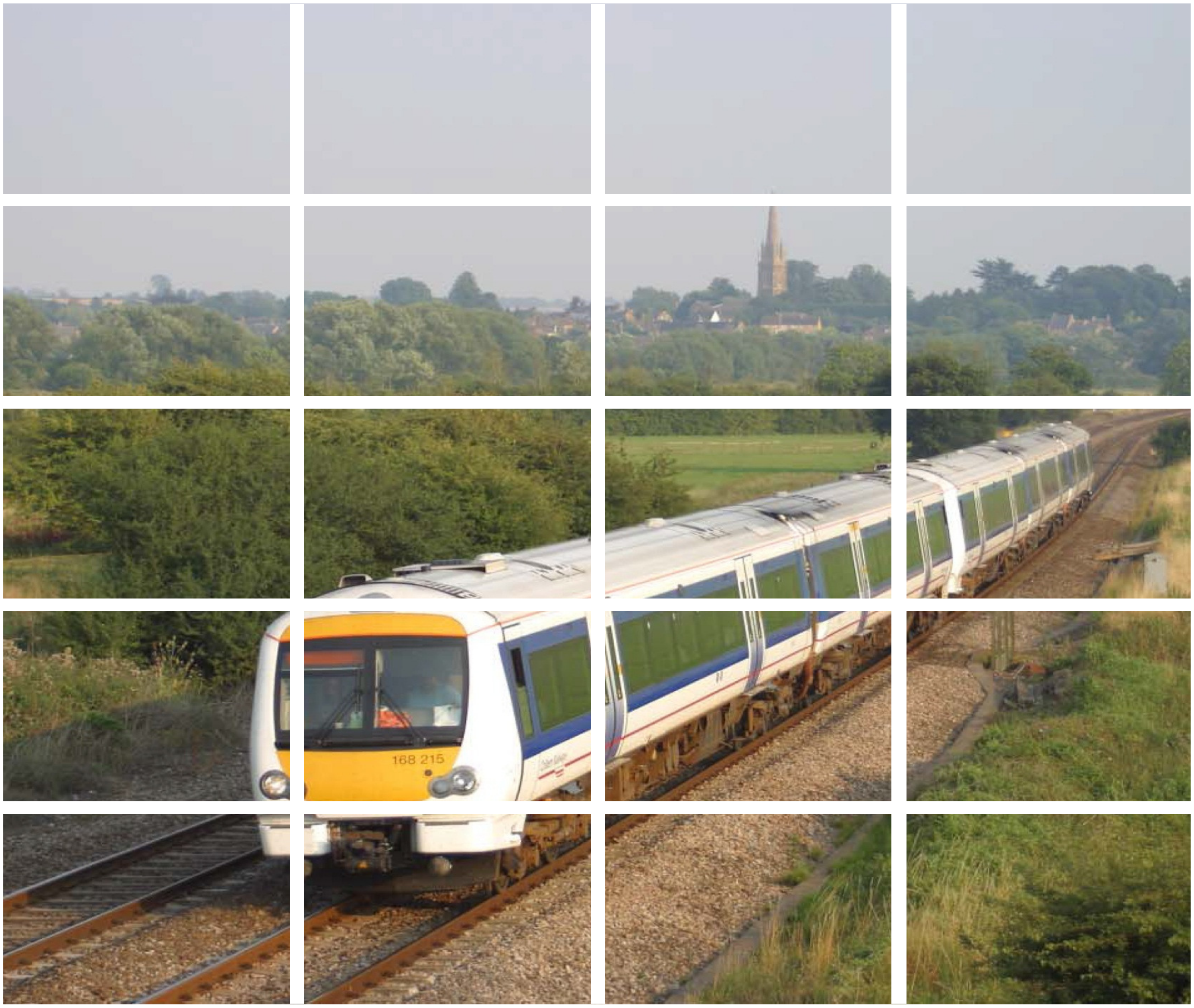

Chiltern Railways

NetworkRail

Conditions 31 and 32: Year One Air Quality Monitoring in relation to Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI

20 April 2020

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For and on behalf of
Environmental Resources Management

Approved by: Ian Gilder

Signed: [redacted]

Position: Technical Director

Date: 20 April 2020

CONTENTS

ACRONYMS AND ABBREVIATIONS

Name	Description
AA	Appropriate Assessment
AADT	Annual Average Daily Traffic
AGL	Above Ground Level
Al	Aluminium
ATC	Automatic Traffic Counts
B	Boron
Ca	Calcium
Cd	Cadmium
CDC	Cherwell District Council
CEH	Centre for Ecology and Hydrology
CRCL	Chiltern Railways Company Limited
Cu	Copper
EA	Environment Agency
ERM	Environmental Resources Management
ES	Environmental Statement
EWR	East West Rail
Fe	Iron
HRSA	Habitat Regulations Screening Assessment
K	Potassium
Mg	Magnesium
Mn	Manganese
N	Nitrogen
NDC	Nationwide Data Collection
NE	Natural England
NHM	Natural History Museum
NO	Nitric Oxide
NO_X	Nitrogen Oxide
NO_2	Nitrogen Dioxide
NR	Network Rail Infrastructure Ltd
NVC	National Vegetation Classification
OCC	Oxford City Council
P	Phosphorous
Pb	Lead
PC	Process Contribution
PEC	Predicted Environmental Concentration
S	Sulphur
SAC	Special Area of Conservation
SSSI	Site of Special Scientific Interest
TRADS	Traffic Flow Data System
TRIS	Transportation Research Information Services
TWA	Transport and Works Act
TWAO	Transport and Works Act Order
W/W	Wet Weight
Zn	Zinc

1 INTRODUCTION

1.1 PURPOSE OF THIS REPORT

This draft report contains the findings of air quality and botanical surveys undertaken in 2017/2018 as part of the approved 'Scheme of Further Assessment of Air Quality'(1)(2) for the Bicester to Oxford Rail Improvements Scheme in relation to Oxford Meadows Special Area of Conservation (SAC) and Hook Meadow and The Trap Grounds Site of Special Scientific Interest (SSSI) during the first year of operation of East West Rail (EWR) Phase 1.

The requirements for reporting the assessment of conditions during Year One of operation of EWR Phase 1 are set out in the Scheme of Further Assessment.

In accordance with the Scheme of Further Assessment, this draft report will be submitted to Natural England (NE), Oxford City Council (OCC) and Cherwell District Council (CDC) prior to a meeting to discuss the findings, any mitigation required, and/or changes to the monitoring approach going forward.

The final version of the report will be formally submitted to NE, OCC and CDC.

1.2 STRUCTURE OF THIS REPORT

The remainder of this report is set out as follows:

- Section 2 Survey and Methods;
- Section 3 Survey Findings, including comparison to baseline survey findings;
- Section 4 Rail and Road Traffic Findings; and
- Section 4 Summary and recommendations.

This report includes the following Annexes:

- Annex A - Condition 31 and Condition 32 of The Chiltern Railways (Bicester to Oxford Improvements) Order 2012;
- Annex B - Survey Programme;
- Annex C - Supporting Air Quality Information;
- Annex D - Lichen and Plant Tissue Analysis;
- Annex E - Soil Analysis;
- Annex F - Plant Root Simulator Analysis; and
- Annex G - Supporting Traffic Information.

(1) Referred to hereafter as the Scheme of Further Assessment.
(2) Conditions 31 and 32: Air Quality Monitoring and Mitigation Report in relation to Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI, October 2015.

1.3 BACKGROUND

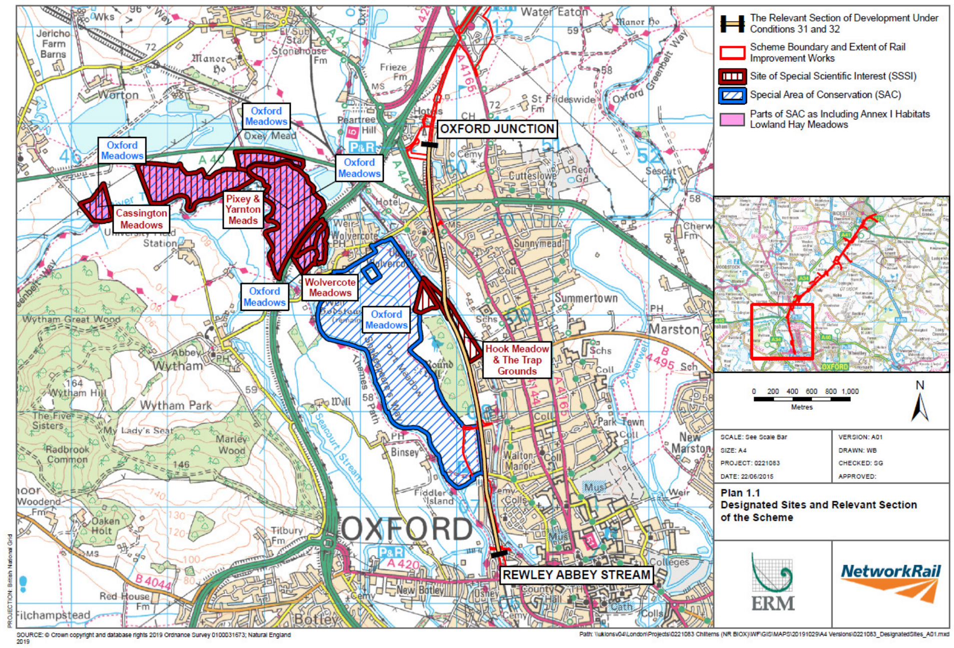
Background to the TWA Scheme

The Chiltern Railway Company Limited (CRCL) was granted a Transport and Works Act Order (TWAO) by the Secretary of State for Transport on 23 October 2012 for improvements works to the Bicester to Oxford railway in accordance with the Order. This scheme, also known as EWR Phase 1, was to construct improvements to the existing railway line between Bicester and Oxford, including a new track alongside the existing mainline between Oxford North Junction and Oxford Station, and a new station at Water Eaton (Oxford Parkway). The Order, granted to CRCL, has been implemented by Network Rail Infrastructure Ltd (NR). Construction works are now complete and the line is operational.

The environmental effects of the Scheme were reported in an Environmental Statement (ES) (December 2009) prepared by Environmental Resources Management (ERM), and submitted with the TWAO application in January 2010. Post-application information on the effects of air emissions due to the proposed Scheme on the Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI was submitted as part of the Transport and Works Act (TWA) Inquiry in November 2010, and the subsequent re-opened TWA Inquiry in May 2012. Conditions 31 and 32 of the deemed planning permission attached to the TWAO contain measures to protect the Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI. The location of these in relation to the Scheme is shown in **Figure 1.1**. The wording of Conditions 31 and 32 was agreed with NE during the course of the re-opened TWA Inquiry and imposed by the Secretary of State on the deemed planning permission.

A Habitat Regulations Screening Assessment (HRSA) was undertaken in 2009 in relation to the Oxford Meadows SAC. In agreement with NE, the HRSA adopted a precautionary approach to avoid any adverse effects, based on a monitoring regime, including that of air emissions, and with the provision for appropriate mitigation to be implemented if required. The Inspector and the Secretary of State, as the Competent Authority, confirmed that the air emissions associated with the Scheme were not likely to have any significant adverse effect on the integrity of the SAC, and that an Appropriate Assessment (AA) was not necessary. A challenge to the TWA Order in the High Court in 2013 was dismissed.

Figure 1.1 **Relationship of EWR Phase 1 to Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI**



The Scheme of Further Assessment of Air Quality

Conditions 31 and 32 required the approval of a Scheme of Further Assessment for the relevant parts of the Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI.

These conditions were included as part of the deemed permission to protect the Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI from harm by virtue of air pollution, in accordance with the precautionary approach advocated by NE at the TWA Inquiry.

The Secretary of State, in his decision, concluded that the development of such a Scheme of Further Assessment would be sufficient to ensure that the operation of the new railway, including the associated road traffic effects, would not be likely to harm the qualifying interests or species for which the SAC and SSSI were designated.

Further details of the requirements of the Scheme of Further Assessment contained in Conditions 31 and 32, are provided in **Annex A.**

The Scheme of Further Assessment detailing the proposed survey methodology was submitted to, and approved by, the Local Planning Authorities (OCC and CDC) and NE as required under Conditions 31 and 32.

The report of the baseline surveys undertaken in 2014/2015[1], in accordance with the Scheme of Further Assessment, was submitted to, and approved by, OCC and CDC.

In November 2015, a report was published and submitted to OCC and CDC which set out the results of an air quality and traffic modelling study as part of the Scheme of Further Assessment [2]. The report contained predictions, based on the air quality monitoring and traffic surveys, for a period of 10 years after opening of the relevant sections of the development to passenger rail traffic.

The Scheme of Further Assessment sets out the operational monitoring and assessment requirements and includes a methodology and programme for:

- assessing the exposure to oxides of nitrogen and inferring nitrogen deposition of the relevant parts of the SAC, including appropriate field observations of nitrogen oxide concentrations; and
- surveys of plant tissues, soil conditions, lichen transplant bio-monitoring and traffic flows including train passenger surveys.

The Year One Operational Assessment reported here covers a 12 month period from September 2017 to September 2018. This does not match exactly with the first calendar year of the new train service, which started operation in December 2016.

(1) Baseline Report of Air Quality in relation to Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI, August 2015.
(2) Conditions 31 item (iii) and 32 item (iv): Air Quality Modelling Report in relation to Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI, November 2016.

2 SURVEY AND METHODS

2.1 INTRODUCTION

The surveys were undertaken to characterise the conditions within the Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI in line with the Scheme of Further Assessment for Year One of operation. This section sets out the survey methodology. Where necessary, it includes details of any survey limitations, and their implications for the approach, or subsequent monitoring and assessment.

The surveys are presented in the following order:

- air quality (diffusion tubes);
- plant tissue collection;
- lichen transplant bio-monitoring;
- soil analysis; and
- traffic flows.

Access to Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI was secured through powers granted under the Chiltern Railways (Bicester to Oxford Improvements) Order 2012.

The survey programme is provided in **Annex B**.

2.2 AIR QUALITY – DIFFUSION TUBES

Overview

NO_2 concentrations were measured at the Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI for a year commencing September 2017 at set distances away from the pollution sources (ie. nearby transport corridors)(1). The measurements were undertaken at the same locations as for the baseline survey. The actual location of the sample points were accurate to within the resolution of GPS (ie. plus or minus three metres) from the original locations. Based on the recorded NO_x concentrations, deposited nitrogen was then calculated (using the Environment Agency (EA) approach(2)).

(1) During the baseline survey total NO_x was measured using a pair of samplers monitoring nitric oxide (NO) and nitrogen dioxide (NO_2) the sum of which provides NO_x. However, between the baseline and Year One surveys the NO tube has been discontinued. As the performance of diffusion tubes is known to vary between laboratories the decision was taken to maintain the same laboratory (Gradko) but monitor only NO_2, as a proxy for total NO_x. The NO_2 results were used to assess the change in concentration between baseline and Year One as a direct comparison. NO_x and nitrogen deposition were calculated in Year One based upon the ratio of NO_x to NO_2 derived from the baseline survey.

(2) AQTAG06 – *Technical Guidance on Detailed Modelling Approach for an Appropriate Assessment for Emissions to Air*, Environment Agency, produced 06/02/04, Version 8.

Diffusion Tubes

The eight transects used were the same ones as those used in the baseline sampling in 2014/15. Four across the Oxford Meadows SAC, and four across Hook Meadow and The Trap Grounds SSSI. Each transect included five sample locations at 10 m, 20 m, 50 m, 100 m and 200 m[(1)] where possible, from the respective road and rail transport corridors (**Figure 2.1** and **Figure 2.2**). The transects were established perpendicular to the transport corridor to assess reductions in the levels of air pollutants with increasing distance from the corridors. The coordinates of each sample location are provided in **Annex C, Tables C.1** and **C.2**.

All transects across the Oxford Meadows SAC covered 200 m. Only one transect (to the west of the Oxford to Birmingham line) across Hook Meadow and The Trap Grounds SSSI covered 200 m, as around the Bicester to Oxford Branch Line the SSSI is narrow and split into smaller areas, only allowing two transects of 50 m, and one of 100 m in those locations. These are the same locations as for the baseline surveys.

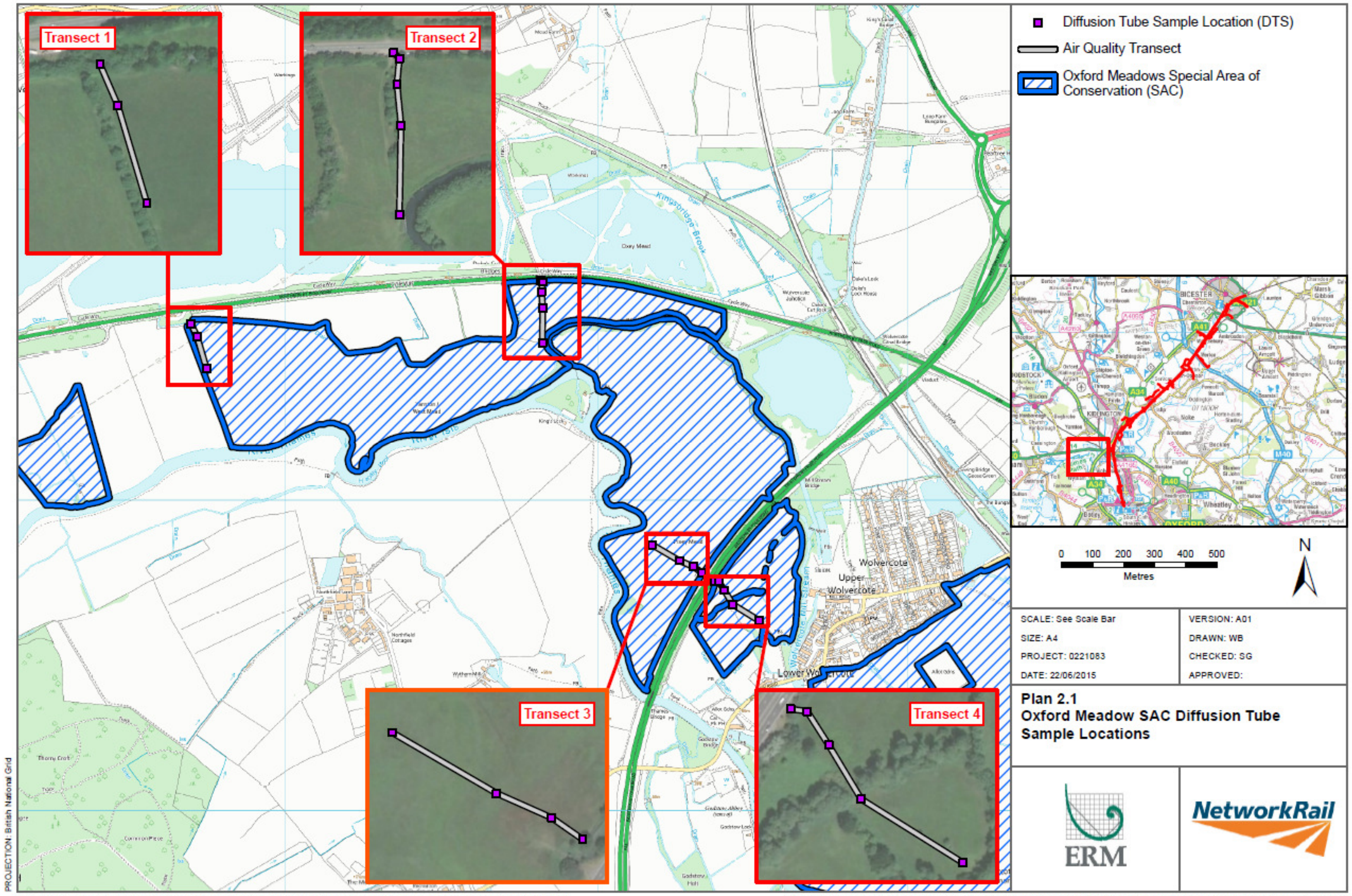
Sampling was undertaken over a 12 month period using Palmes – type diffusion tubes[(2)]. At each sample location, one tube (sampling NO_2 [(3)]) was attached to a wooden post at a height of between 2 m and 4 m above ground level to reduce the risk of theft or disturbance by cattle, and away from bushes or overhanging trees so that air was free to circulate. **Figure 2.3** shows a typical diffusion tube sample location. The tubes were changed monthly, on the first week of the month, to mirror the timings of Defra's UK national diffusion tube studies, which were used in the validation process. The samples were analysed at the Gradko Air Pollution Monitoring laboratory (accredited to ISO 17025) as per the baseline survey to avoid creating a methodological bias.

(1) Observations from the site visit identified that at the closest point, the sites were no less than 10 m from the kerbside of the roads of interest, and railway line. Following guidance provided in the UK Highways Agency (Highways Agency (2007) Design Manual for Roads and Bridges Volume 11, Section 3, Part 1: Air quality), at distances of greater than 200 m from roads, impacts to air quality are anticipated to be negligible.

(2) AEA Energy and Environment (2008) Diffusion Tubes for Ambient NO Monitoring: Practical Guidance for Laboratories and Users. AEA

(3) The use of only one tube measuring NO2 was a change from the approach taken during the baseline survey, but was necessary tubes sampling for NO were no longer available.

Figure 2.1 Transect and Sample Locations on the Oxford Meadows SAC



SOURCE: © Crown copyright and database rights 2019 Ordnance Survey 0100031673; Natural England 2019; Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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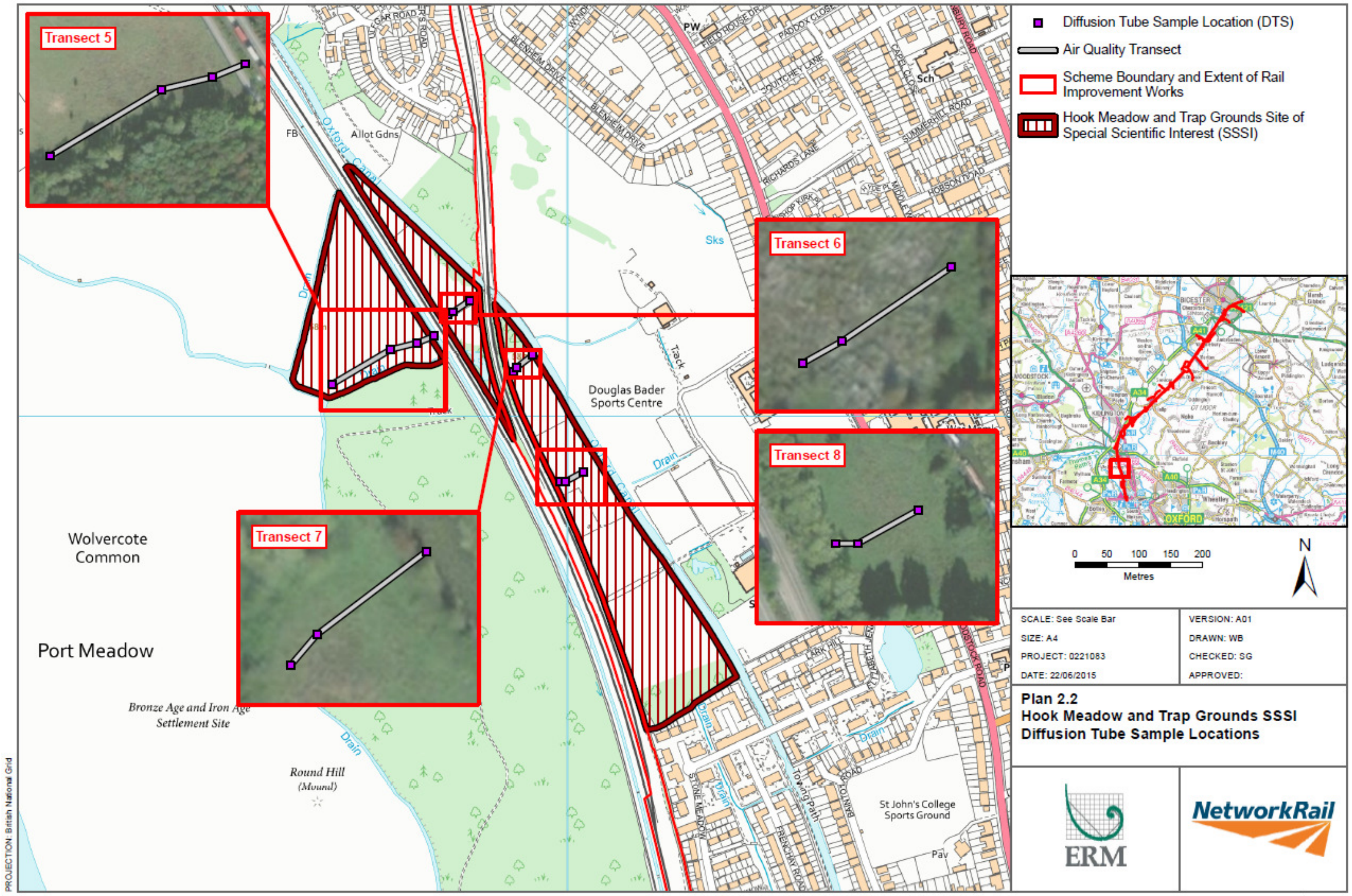
Figure 2.2 Transect and Sample Locations on Hook Meadow and The Trap Grounds SSSI



SOURCE: © Crown copyright and database rights 2019 Ordnance Survey 0100031673; Natural England 2019; Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Figure 2.3 Typical Diffusion Tube Sample Location

2.3 PLANT TISSUE COLLECTIONS

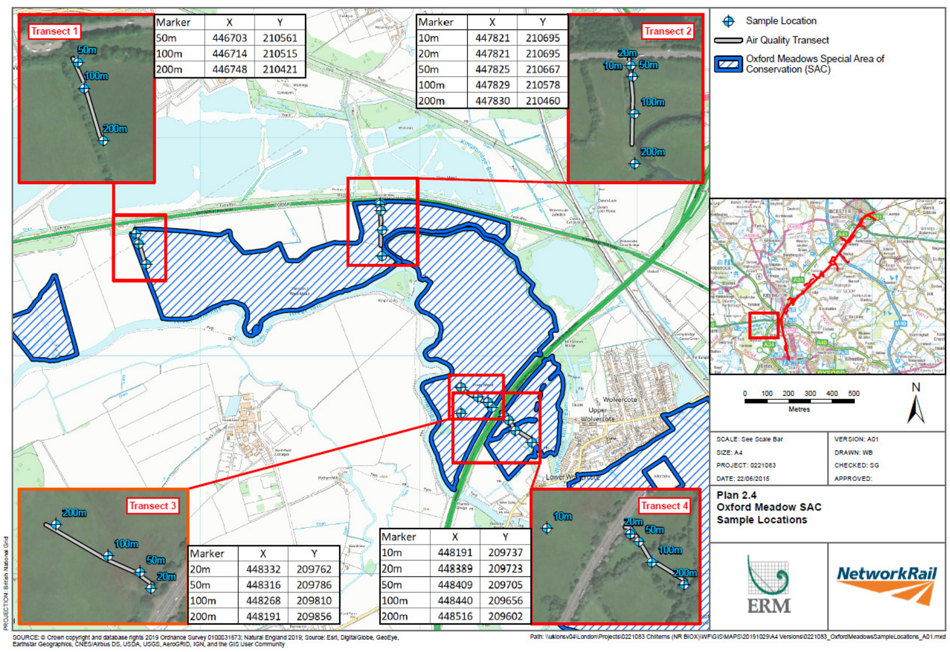
The methods used to sample the nitrogen content in plant tissue followed the approach set out in JNCC Report 356(1). Tissue samples were collected from 30 sample locations in total, along all eight of the survey transects as shown in **Figures 2.4** and **2.5**. The sample locations replicate those of the baseline survey. The samples were collected on 4, 10 and 11 of July 2018.

(1) Sutton M A, Pitcairn C E R, Leith I D, van Dijk N, Tang Y S, Skiba U, Smart S, Mitchell R, Wolseley P, James P *et al* (2004). Bio-indicator and Bio-monitoring Methods for Assessing the Effects of Atmospheric Nitrogen on Statutory Nature Conservation Sites. *JNCC Report* 356.

Samples were taken from three of the main qualifying interest plant species at each sample location (eg. *Alopecurus pratensis* (meadow foxtail), *Festuca rubra* (red fescue), *Holcus lanatus* (Yorkshire fog) and *Sanguisorba officinalis* (great burnet). Where less than three of these species occurred, samples were collected from the more common plant species present. Tissue was collected from leaves exposed to direct sunlight, and newly growing parts of the plants. Two 15 cm x 15 cm ziplock bags were filled with tissue from each plant species, to provide sufficient dried material for analysis. All samples were labelled and couriered to the laboratories in cool boxes.

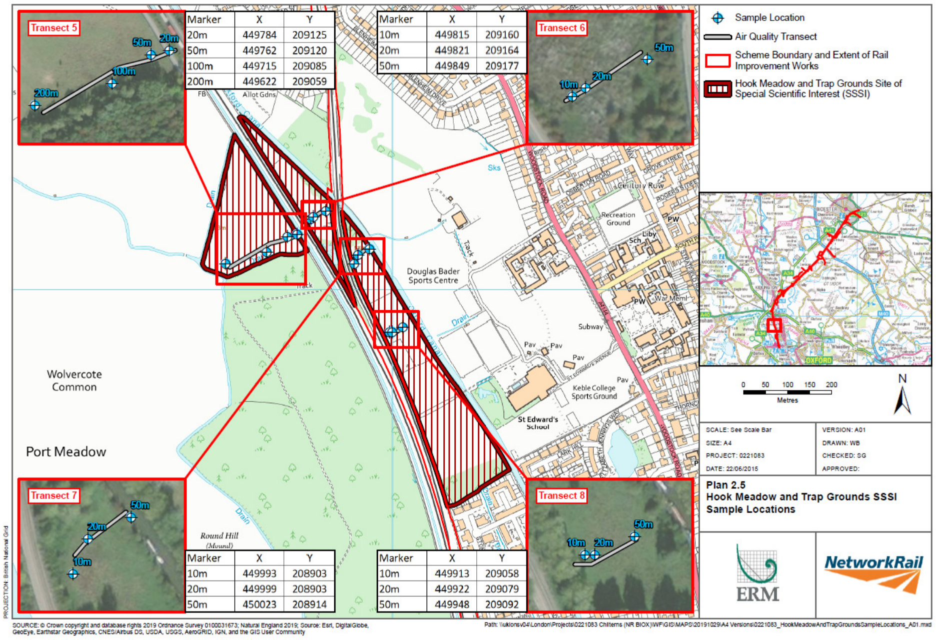
The samples were dried, milled and tested for total nitrogen (% wet weight (w/w)) and $\delta^{15}N$ (%) by the James Hutton Institute[(1)], and for Phosphorous (P) levels (mg/kg) by NRM Laboratories[(2)].

Figure 2.4 Oxford Meadows SAC Plant Tissue Sample Locations



(1) http://www.hutton.ac.uk/
(2) http://www.nrm.uk.com/

Figure 2.5 Hook Meadow and The Trap Grounds SSSI Plant Tissue Sample Locations



2.4 LICHEN TRANSPLANT BIO-MONITORING

The monitoring approach was designed to analyse the effects of air emissions arising from EWR Phase 1 on the habitats of the Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI. As other factors can lead to changes in the site flora (eg. flooding and grazing levels) and hence influence the findings from the analyses of plant tissues, the approach included analyses of lichens, to remove these factors from the assessment.

Transplants of lichen species were used as they are known to be good indicators of air quality(1). Lichens are highly dependent on the atmosphere for nutrients that are absorbed over the whole thallus surface over the whole year (not varying with season). Accumulation of elements, such as nitrogen, is a dynamic process involving uptake and release until an equilibrium is reached with the surrounding environment. Lichens provides information relating to nitrogen accumulation in plant tissue acting as an indicator of exposure to airborne nitrogen.

Two lichen species that are common and widespread within the UK were used (*Xanthoria parietina* and *Evernia prunastri*), based on advice from experts in lichens including at the Natural History Museum (NHM) in London(2). These

(1) Conti M E, Cecchetti G (2001). Biological Monitoring: Lichens as Bio-indicators of Air Pollution Assessment—A Review. *Environmental Pollution* 114, 471–492.

(2) These lichen species were recommended by Pat Wolesley at the NHM (expert in lichens) and Catherine Tregaskes (an experienced lichenologist) and were the species used during the baseline surveys.

species are known to be sensitive to air pollution and were chosen for their different response to environmental conditions. The foliose *Xanthoria* is tolerant of high levels of atmospheric nitrogen and is associated with increasing atmospheric ammonia and NO_x while the fruticose *Evernia* is sensitive to increasing atmospheric nitrogen[(1)].

The lichen samples used, were collected by Catherine Tregaskes (a lichen specialist). *Xanthoria parietina* specimens were obtained from trees around the Oxford Meadows SAC, whilst *Evernia prunastri* samples were collected from a site in Whittlesford, Cambridgeshire on 21 March 2018, as insufficient samples of this species were available locally in Oxford.

The samples collected from the donor sites were cleaned, and their surface pH recorded using a pH meter as advised by NHM. The pH of samples was recorded before and after exposure using the Centre for Ecology and Hydrology (CEH) method.

The samples were halved, with one half attached in mesh bags to the posts supporting the diffusion tubes at a height of 2.6 m above ground level (AGL) (see **Figure 2.6**). The samples were placed in 30 locations in total, along the transects (see **Figures 2.4** and **2.5**) at 10 m, 20 m, 50 m, 100 m and 200 m from the source of pollution on 28 March 2018. The samples were monitored over a six month period, between March and September 2018. The samples were collected on 26 September 2018 and analysed by the James Hutton Institute. A number of samples on Transect T5 were found to be missing at the time of collection.

[(1)] Pinho et al. 2011, Munzi et al. 2014, Nimis & Martellos 2017, Welden et al. 2018.

Figure 2.6 Typical Lichen Monitoring Location

Samples were also used from two control locations (>200 m from the pollution sources), one in the Oxford Meadows SAC (Control 1) and one in Hook Meadow and The Trap Grounds SSSI (Control 2). At the time of collection, the control sample on Oxford Meadows SAC was found to be missing.

The other half of the samples were analysed by the James Hutton Institute for total nitrogen (% N, wet weight (w/w)) and the stable (ie. non-radioactive) nitrogen isotope 15 (δ^{15} N %) contents, to determine their existing levels, against which to compare the findings from exposure of the samples on the site.

2.5 SOIL ANALYSES

Soil pH

On 6 June 2018, single samples (ie. spot samples [(1)]) were collected within a defined 1 m^2 area located within 10 m distance of the air quality sample locations, following the approach in the British Standard BS10175:2001[(2)]. This was the same approach as undertaken in the baseline surveys and in the same locations.

The surface vegetation layer was lifted, and samples collected using a hand trowel from the top 0 cm to 15 cm of the soil profile, the depth likely to be affected by N deposition and comparable to Countryside Survey soil dataset, which also collects from the 0 to 15 cm stratum. Sample jars (provided by AL Control Laboratory) were filled and the vegetation layer replaced. The samples were analysed to determine soil pH.

Soil Plant Available Nutrients

Plant Root Simulator (PRS) probes[(3)] were used following instructions issued by the Western Agg. Laboratory, who undertook the analyses. The probes were used at each sample location to provide data on plant available nutrients within the soil. On average, four cation and four anion PRS probes were buried within a radius of approximately 1.5 m of each of the air quality sample locations, replicating the baseline surveys. Examples of the types of probes and their locations are shown on **Figure 2.7** and **Figure 2.8**. The probes were buried on the 6 June 2018 and retrieved on 1 August 2018 (an eight week period). The probes were analysed by the Western Agg. Laboratory for plant available NO_3^--N, NH_4^+-N, P, K, S, Ca, Mg, Mn, Al, Fe, Cu, Zn, B, Pb, and Cd (µg/10 cm^2/burial length).

(1) Single samples taken as opposed to cluster sampling, as the analyses only covered a limited range of parameters, so less soil was required.

(2) British Standard 10175:2011. *Investigating Potentially Contaminated Sites – Code of Practice*. BSI

(3) http://www.westernag.ca/innovations

Figure 2.7 Oxford Meadows SAC Soil Sample Locations

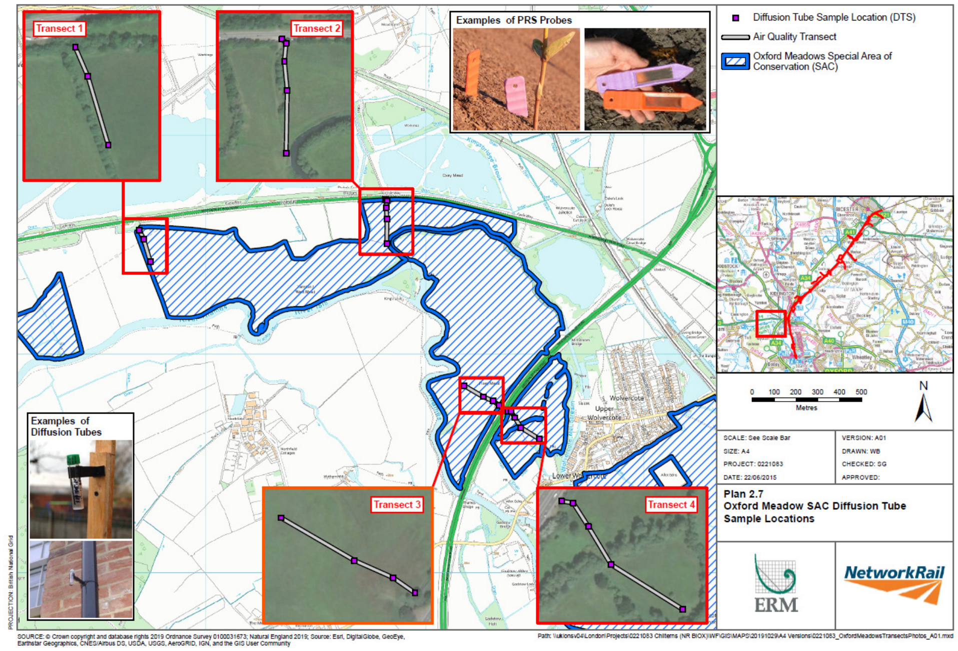
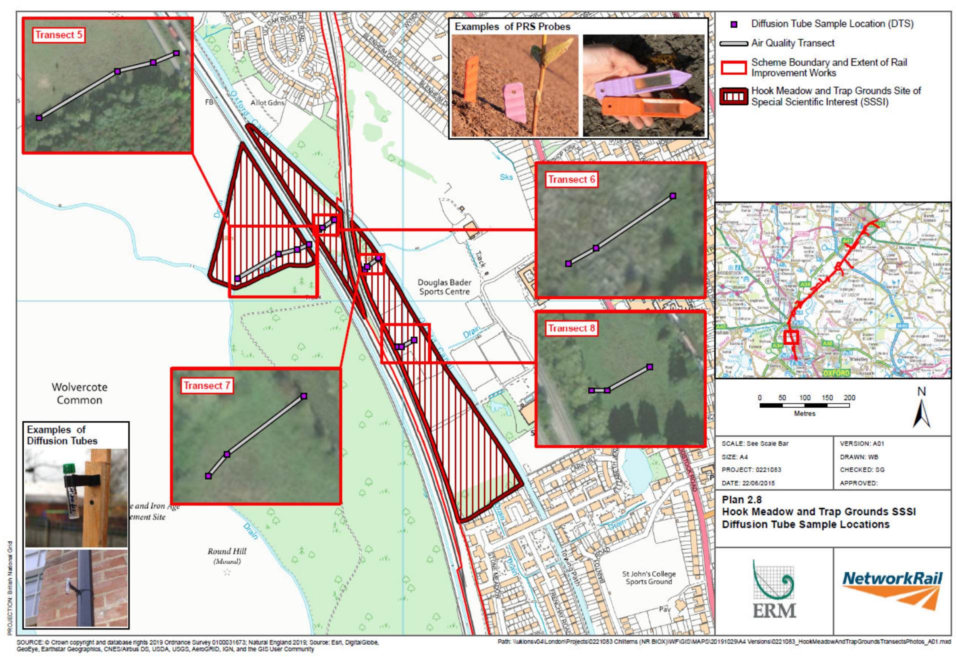


Figure 2.8 Hook Meadow and The Trap Grounds SSSI Soil Sample Locations



2.6 ROAD AND RAIL TRAFFIC FLOWS

Road Traffic Flow Data

Automatic Traffic Counts (ATCs) were undertaken monthly for a period of one year on the A40 from September 2017 to the end of August 2018. The ATCs recorded data for one week at the start of each month. Data for the A34(T), was obtained from the Highways England webTRIS website. The ATCs and Transportation Research Information Services (TRIS) data provide traffic data at the count points to allow comparison with the baseline pre-scheme data.

The counters on the A40 were installed by PFA Consulting approximately 900 m west of the A34(T) overbridge, and approximately 1.6 km west of Wolvercote Roundabout.

Annual Average Daily Traffic (AADT) flows were collated from the data collected, and monthly flow profiles for the roads produced.

The data obtained for daily vehicular travel by rail passengers through the sections of the A34(T) and A40 were then compared with total average daily traffic flow to establish the impact of EWR Phase 1 at these two sections.

Rail Passenger Surveys and Counts

Rail passenger surveys were undertaken on a suitable weekday once every three months on Chiltern Railways rail services between Bicester Village and Oxford stations over a 12 hour survey period (07:00-19:00), at 15 minute survey intervals, on four occasions throughout the year, namely October 2017, January 2018, April 2018 and July 2018. The surveys comprised interviews of passengers travelling on trains between Bicester Village and Oxford stations.

The passenger interviews recorded information about departure station, destination station, journey start postcode, method of travel to the departure station and if they routed along the relevant sections of the A34(T), A40 or both, when travelling to the station. It recorded if passengers had changed their travel arrangements since the re-opening of the railway and how they previously travelled before the railway re-opened. A copy of the survey questionnaire is included at **Appendix G**.

The surveys were undertaken by an independent specialist survey company, Nationwide Data Collection (NDC).

Overall daily passenger data were obtained also for Bicester Village, Oxford Parkway and Oxford stations based on train operators' ticket data. The ticket data was for a full week's data corresponding to the months of the rail passenger surveys. The data provides accurate information on passenger numbers for all movements between specific stations not just total movements from each station.

The passenger interview data were analysed to establish which passengers used car, taxi or motorcycle and routed along the relevant sections of the A34(T), A40 or both, when travelling to Bicester Village, Oxford Parkway and Oxford stations. This sample interview data was factored up to reflect daily passenger numbers using the ticket data. The daily passenger data provides information about which destination station passengers travelled to. This is important as EWR Phase 1 has not affected all rail passengers travelling to and from Oxford.

Since EWR Phase 1 opened, passengers travelling from Oxford to London have had the option to switch to Oxford Parkway for journeys to London Marylebone, or to use the new service from Oxford, and passengers to major stations such as Didcot and Reading have the option to switch to travel from Oxford Parkway to Oxford, and then on to Didcot/Reading. Other stations along the GWR Oxford to London route have been excluded from the analysis as passenger numbers are minimal and travel patterns are likely to have remained unchanged. All stations along the new Oxford to London Marylebone route were included.

Travel patterns change throughout the year, which is why surveys of passengers were undertaken every three months. The passenger interview and daily passenger data were used for the month in which they were undertaken.

Daily vehicular travel by rail passengers using the sections of the A34(T) and A40 were derived from the survey data and compared with the baseline results to establish the impacts of EWR Phase 1 on these two roads in terms of annual average daily traffic flows.

3 YEAR ONE SURVEY FINDINGS AND COMPARISON TO BASELINE SURVEYS

3.1 INTRODUCTION

This section summarises of the findings of the Year One surveys and provides comparisons with the baseline survey results. Further details are contained in the detailed survey reports and supporting information in **Annex C** to **Annex G**.

This section deals with the following survey results, in turn:

- air quality;
- plant tissue analysis;
- lichen transplant bio-monitoring analyses;
- soil conditions;
- road traffic; and
- rail traffic.

3.2 AIR QUALITY

Assessment Criteria

The potential impacts on sensitive habitats are assessed through comparison with relevant critical loads and critical levels. The assessment criteria and significance criteria used in this assessment are set out in this section.

Assessment Criteria for Designated Habitat Sites

The criteria for assessment of impacts at sensitive ecological receptors are derived from:

- UK statutory Air Quality Standards (Critical Levels); and
- Critical Loads estimated by the CEH and set out on the APIS website(1).

Impacts relating directly to atmospheric concentrations of NO_x are not habitat or species specific and are the same for all locations. These are set out in **Table 3.1**. Impacts relating to acid and nutrient nitrogen deposition are habitat and species specific. The site specific critical loads are set out in **Table 3.2** and **Table 3.3** for both the Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI.

(1) Centre for Ecology and Hydrology (2009) Air Pollution Information System [Online] Available from: http://www.apis.ac.uk [Accessed 12th October 2015 and none of the CLs had changed at the time of the assessment in 2018].

Table 3.1 Critical Level for Oxides of Nitrogen (NOx)

Site	Critical Level for NOx (µg/m³)
Oxford Meadows SAC	30 (annual mean)
Hook Meadow and The Trap Grounds SSSI	

Table 3.2 Critical Load for Nutrient Nitrogen Deposition

Site	Relevant Nitrogen Critical Load Class	Empirical Critical Load (kg N/ha/yr)
Oxford Meadows SAC	Low and medium altitude hay meadows	20 - 30
Hook Meadow and The Trap Grounds SSSI		

Table 3.3 Critical Load for Acid Deposition

Site	Acidity Class	Acidity Critical Load (Keq) – Low range		
		MinCLminN	MinCLMaxS	MinCLMaxN
Oxford Meadows SAC	Calcareous grassland (using base cation)	0.856	4.000	4.856
Hook Meadow and The Trap Grounds SSSI				
Note: High Range values are also available, however only the low range values are considered as these are more conservative.				

Significance Criteria

The significance of impacts is based on guidance specified by the EA in its *"Air emissions risk assessment for your environmental permit"* webpage, as defined at the time of Scheme of Further Assessment and also used in baseline assessment(1). It is noted that updated EA guidance has since been published(2), but to ensure consistency with the baseline assessment and direct comparison with the criteria and thresholds set out in the Scheme of Further Assessment, the definition of significance has not been changed.

Significance is determined in terms of:

- Process Contribution (PC), this is the impact associated with emissions from the Scheme only; and
- Predicted Environmental Concentration (PEC), this is the impact associated with PC added to the existing background conditions.

(1) https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit
(2) https://www.gov.uk/guidance/environmental-permitting-air-dispersion-modelling-reports

Impacts of emissions are considered not to have significant effects upon sensitive ecological receptors if:

- the PC <1% of the Long Term Critical Load or Critical Level; or

- if PC> 1%; then the PEC <70% of the Critical Load or Critical Level.

On the basis of this guidance, the following terms have been used in this assessment:

- Insignificant
  - where the PC <1% of the Long Term Critical Load or Critical Level; or
  - where the PC >1% of the Long Term Critical Load or Critical Level but the PEC <70%

- Potentially Significant
  - where the PC >1% of the Long Term Critical Load or Critical Level and the PEC >70%

This approach is used to give clear definition of which effects can be disregarded as insignificant. Where a potentially significant impact is identified, this does not necessarily mean that the effect on the habitat and species of interest will be significant. Instead, it provides an indication of where further investigation of the potential impacts of emissions from the Scheme may be required in order to determine whether there is the potential for significant harm to arise.

Year One Findings

NO_2 Concentrations

The findings of the diffusion tube monitoring of NO_2 levels are summarised in **Figure 3.1** to **Figure 3.8**. They show annual NO_2 levels at each sampling location along each transect for the baseline (blue) and Year One (green) surveys undertaken. A tabulated summary is presented in **Table C.4** in **Annex C**. Details of the monthly concentrations measured during the Year One survey are presented in **Section C1.4** of **Annex C**.

Figure 3.1 Transect T1 – Monitored Annual Mean NO_2 Concentration (µg/m^3)

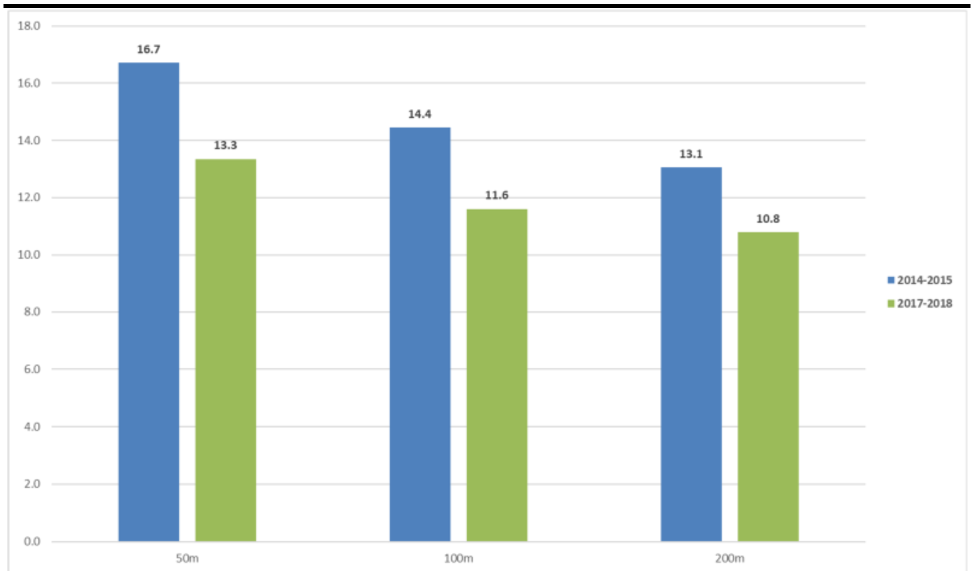


Figure 3.2 Transect T2 – Monitored Annual Mean NO_2 Concentration (µg/m^3)

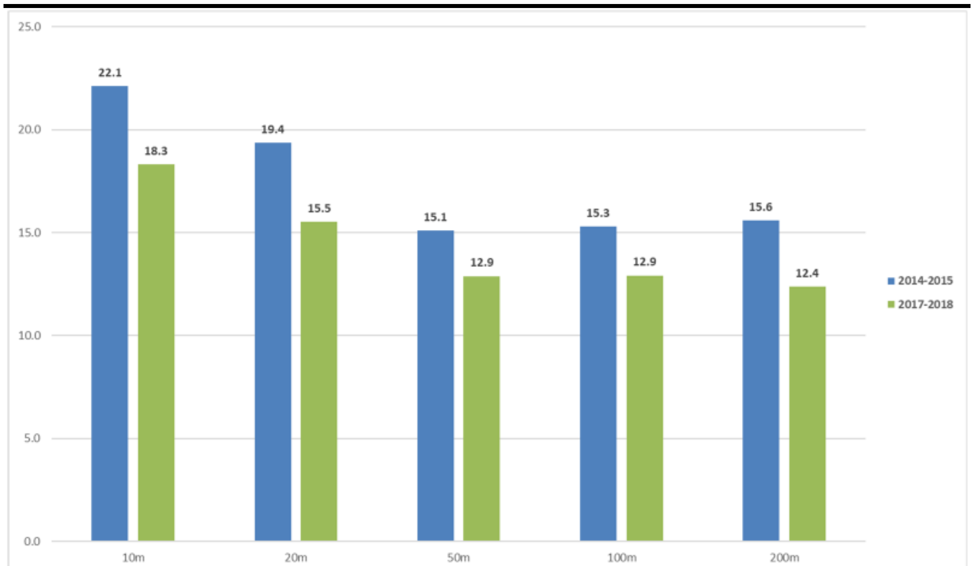


Figure 3.3 Transect T3 – Monitored Annual Mean NO_2 Concentration (µg/m^3)

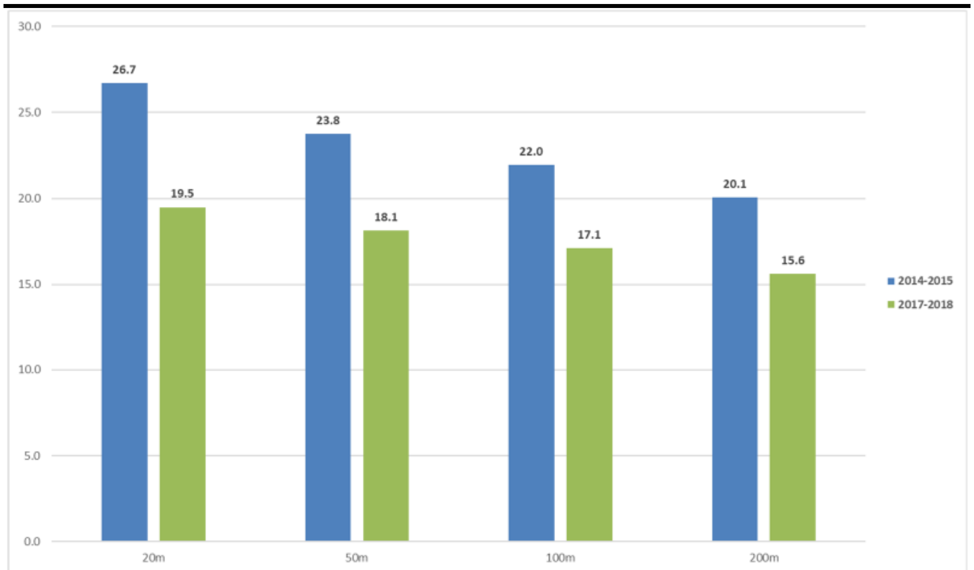


Figure 3.4 Transect T4 – Monitored Annual Mean NO_2 Concentration (µg/m^3)

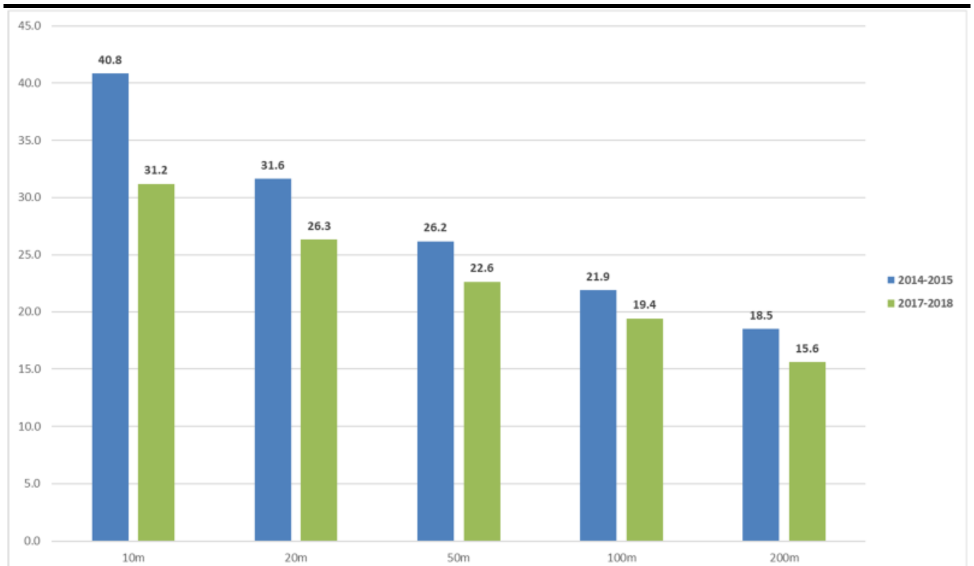


Figure 3.5 Transect T5 – Monitored Annual Mean NO_2 Concentration (µg/m^3)

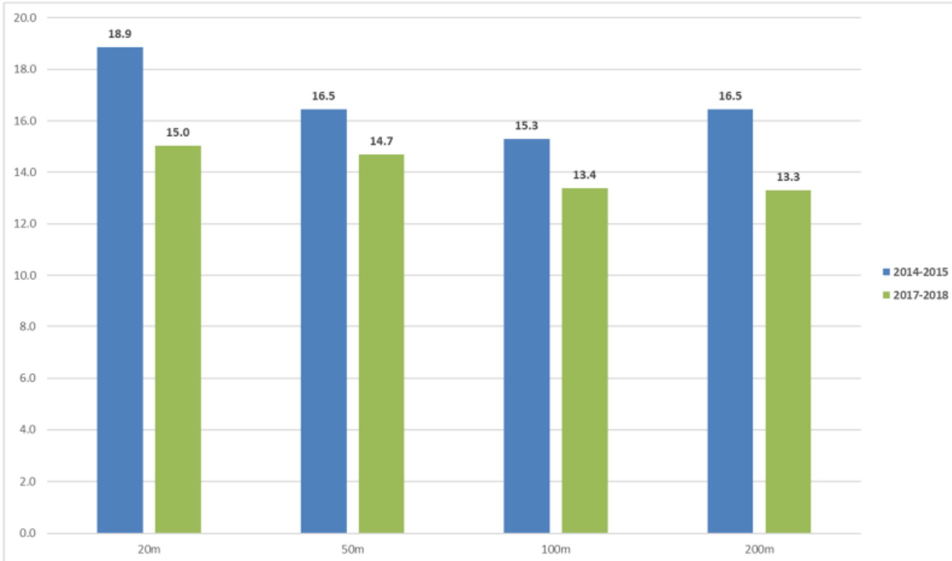


Figure 3.6 Transect T6 – Monitored Annual Mean NO_2 Concentration (µg/m^3)

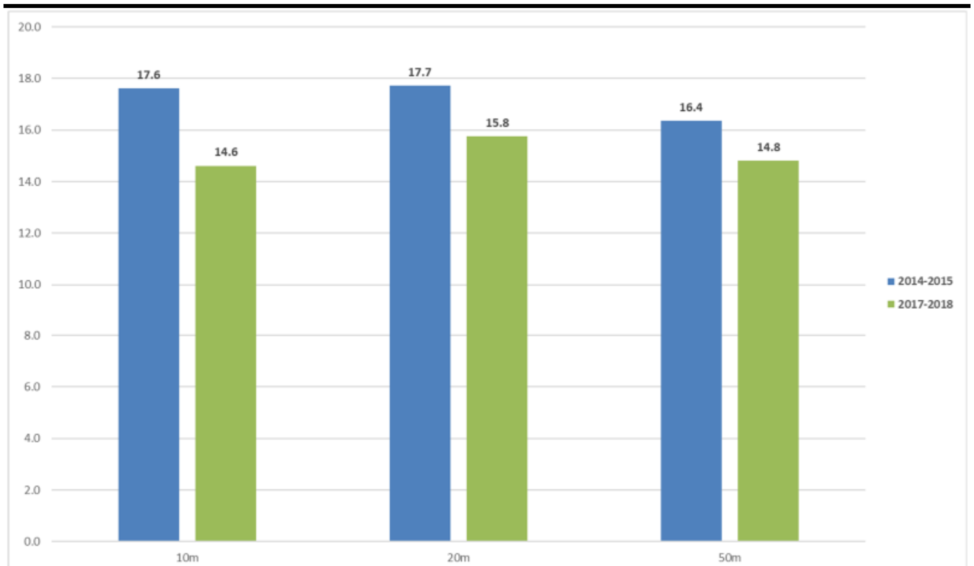


Figure 3.7 Transect T7 – Monitored Annual Mean NO_2 Concentration (µg/m^3)

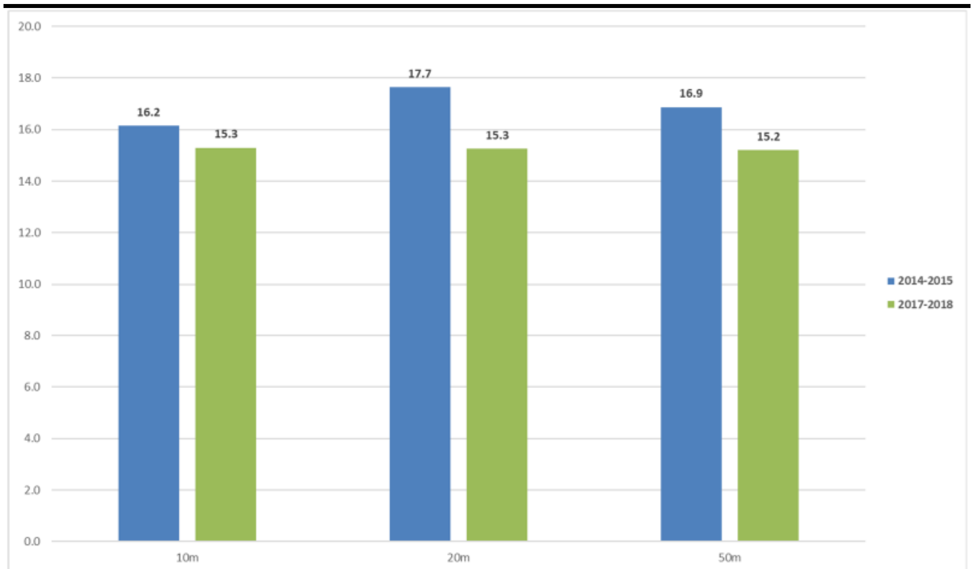
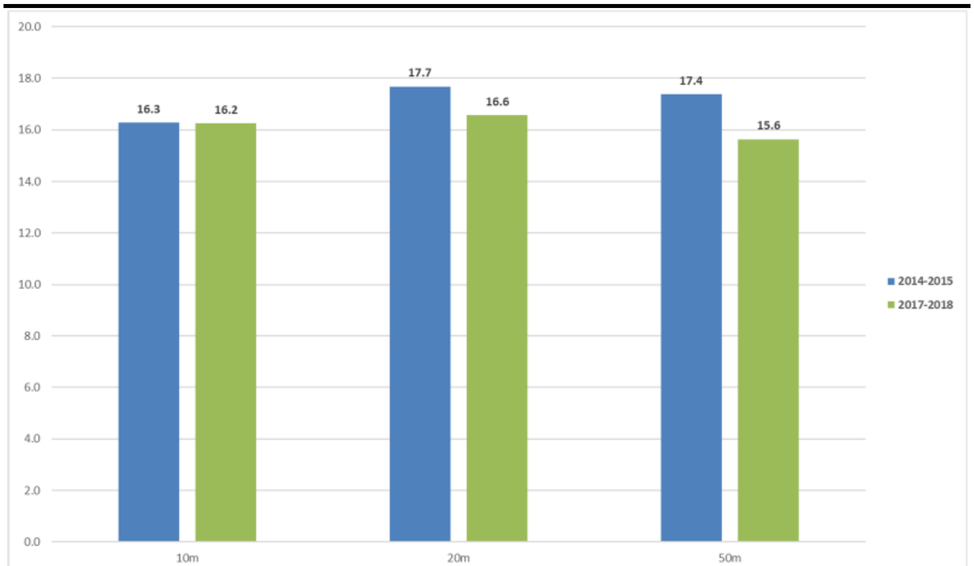


Figure 3.8 Transect T8 – Monitored Annual Mean NO_2 Concentration (µg/m^3)



NO_x Concentrations

As explained in **Section 2.2,** it was only possible to measure NO_2 concentration directly during this survey. Indicative NO_x concentrations have, therefore, been calculated using a 1.44 NO_2 to NO_x conversion ratio, estimated from the average concentrations measured during the baseline survey. Indicative annual mean NO_x concentrations are summarised in **Table 3.4** (and in **Table C.5** in **Annex C**).

Table 3.4 Measured (Baseline) and Calculated (Year One) Annual Mean NO_x Concentrations (µg m^{-3}) Summary

Transect	10m	20m	50m	100m	200m	Average
Transect T1 – A40 – Oxford Meadows SAC						
Baseline (Measured)	*n/a*	*n/a*	23.6	21.0	20.7	21.8
Year One (Calculated)	*n/a*	*n/a*	19.3	16.8	15.6	17.2
Change	*n/a*	*n/a*	-4.3	-4.2	-5.1	-4.6
Transect T2 – A40 – Oxford Meadows SAC						
Baseline (Measured)	31.2	27.3	23.3	23.2	22.3	25.4
Year One (Calculated)	26.4	22.4	18.6	18.7	17.9	20.8
Change	-4.8	-4.9	-4.7	-4.5	-4.4	-4.6
Transect T3 – A34(T) – Oxford Meadows SAC						
Baseline (Measured)	*n/a*	39.8	33.3	30.6	27.9	32.9
Year One (Calculated)	*n/a*	28.1	26.2	24.7	22.5	25.4
Change	*n/a*	-11.7	-7.1	-5.9	-5.4	-7.5
Transect T4 – A34(T) – Oxford Meadows SAC						
Baseline (Measured)	55.4	45.2	35.9	32.4	27.3	39.2
Year One (Calculated)	45.0	38.0	32.7	28.0	22.5	33.3
Change	-10.4	-7.2	-3.2	-4.4	-4.8	-5.9
Transect T5 – Oxford/Birmingham Train Line – Hook Meadow and The Trap Grounds SSSI						
Baseline (Measured)	*n/a*	28.8	25.2	22.8	24.6	25.4
Year One (Calculated)	*n/a*	21.7	21.2	19.3	19.2	20.3
Change	*n/a*	-7.1	-4.0	-3.5	-5.4	-5.1
Transect T6 – Both Train Lines – Hook Meadow and The Trap Grounds SSSI						
Baseline (Measured)	28.0	29.3	25.7	*n/a*	*n/a*	27.7
Year One (Calculated)	21.1	22.7	21.4	*n/a*	*n/a*	21.7
Change	-6.9	-6.6	-4.3	*n/a*	*n/a*	-6.0
Transect T7 – Oxford/Bicester Train Line – Hook Meadow and The Trap Grounds SSSI						
Baseline (Measured)	25.2	26.7	20.6	*n/a*	*n/a*	24.2
Year One (Calculated)	22.1	22.0	21.9	*n/a*	*n/a*	22.0
Change	-3.1	-4.7	+1.3	*n/a*	*n/a*	-2.2
Transect T8 – Oxford/Bicester Train Line – Hook Meadow and The Trap Grounds SSSI						
Baseline (Measured)	29.0	27.9	27.3	*n/a*	*n/a*	28.1
Year One (Calculated)	23.5	23.9	22.6	*n/a*	*n/a*	23.3
Change	-5.5	-4.0	-4.7	*n/a*	*n/a*	-4.8

The NO_x levels on the Oxford Meadows SAC in Year One are all below the 30 µg m^{-3} critical level, except for the points on Transect T4 within 100 m of the A34(T). On Hook Meadow and The Trap Grounds SSSI, all the estimated NO_x levels are below the critical level.

Deposited Nitrogen

The loads of deposited nitrogen were calculated at each location from the estimated NO_x concentrations. A summary of the results is presented in **Table C.6** in **Annex C**.

The threshold value of 70% of the critical load is 14 kg N ha^{-1} yr^{-1}, and the nutrient nitrogen deposition on the Oxford Meadows SAC is well below this value. The maximum deposition predicted to occur on Transect T4 is at 10 m from the A34(T), with a load representing 32% of the critical load, and hence is insignificant on the Oxford Meadows SAC.

On Hook Meadow and The Trap Grounds SSSI, the levels are also well below 70% of the critical load. The maximum deposition predicted to occur on Transect T8, represents 17% of the critical load. Nutrient nitrogen deposition is therefore insignificant on Hook Meadow and The Trap Grounds SSSI.

Acid Deposition

Nitrogen deposition, as a function of total acid deposition, was calculated for each location using the methodology provided on APIS[(1)] from the calculated NO_x concentrations. The levels were compared to the critical load for calcareous grassland used in the baseline survey, with:

- MinCLminN = 0.856 Keq;
- MinCLMaxS = 4.000 Keq; and
- MinCLMaxN = 4.856 Keq.

The calculated acid deposition levels for both Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI, did not reach 0.1% of the MinCLminN critical load and are, therefore, insignificant.

Comparison to Baseline

NO_2 Concentrations

The NO_2 levels on the Oxford Meadows SAC (Transects T1 to T4) (**Figure 2.1**) were on average 4 µg m^{-3} (ie. 19%) lower than the levels measured during the baseline survey. This is consistent with the overall 20% decrease in NO_2 concentrations in the Oxford area over recent years[(2)]. A gradual decline in NO_2 levels with increasing distance from the pollution source, which mirrors the baseline survey findings.

On Hook Meadow and The Trap Grounds SSSI (Transect T5 to Transect T8) (**Figure 2.2**), the NO_2 levels were on average 1.8 µg m^{-3} (ie. 18%) lower than the levels measured during the baseline survey. There were some variations between the levels at the closest and furthest points from the source on

(1) http://www.apis.ac.uk/indicative-critical-load-values

(2) https://www.oxford.gov.uk/news/article/798/significant_reduction_in_oxford_s_air_pollution_after_cleaner_buses_introduced_%E2%80%93_but_city_still_has_toxic_air_in_some_streets

Transects T6, T7 and T8, where levels were generally higher at 20 m from the source than at 10 m, but this was recorded also in the baseline surveys.

Local baseline data (Oxford Centre and St Ebbes AURN monitors, **Tables C.45** and **C.48** in **Annex C**) showed the results from the diffusion tube survey followed the seasonal variations in NO_2 in line with changing meteorological conditions.

The data suggest (as they did from the baseline surveys) that exhaust emissions from traffic are having an impact on ambient concentrations of ground level NO_2 up to 50 m from the road, and the impacts related to train emissions are less than those associated with road traffic.

NO_x Concentrations

The NO_x levels on the Oxford Meadows SAC are all below the 30 µg m^{-3} critical level, except for the point on Transect T4 within 100 m of the A34(T). This was an improvement on the baseline survey, where concentrations above the critical level were recorded also at Transects T2 and T3.

On Hook Meadow and The Trap Grounds SSSI, all the estimated NO_x levels were below the critical level, as they were during the baseline survey.

Detailed data and comparison with the baseline survey levels and the 30 µg m^{-3} critical level are shown in **Section C1.4** of **Annex C.**

Deposited Nitrogen

The calculated nutrient nitrogen deposition levels were compared with the 20 kg N ha^{-1} yr^{-1} critical load (lower end of the range) as used in the baseline survey for low and medium altitude hay meadows. In line with airborne NO_x concentrations (used to calculate the nutrient nitrogen deposition), the levels of nitrogen deposition:

- were all below 35% of the critical load;
- averaged 17% of the critical load across all transects (ie. well below the 70% of the critical load threshold); and
- decreased compared to the baseline survey, that had recorded a maximum of 40% and an average across all transects of 21%.

Detailed results and comparison with the baseline survey levels are in **Section C1.4** of **Annex C**.

Acid Deposition

In line with airborne NO_x concentrations (used to calculate the acid deposition), the acid deposition loads have decreased across all transects compared to the baseline survey, and are insignificant (ie. below the 70% of the critical load threshold).

Detailed results and comparison with the baseline survey levels are in **Section C1.4** of **Annex C.**

Conclusion

The overall level of reduction in the actual levels measured in Year One reflects a regional lowering in NO_x in the background levels, greater than that experienced elsewhere in the UK. There has been a regional impact on measured levels at Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI as a result of extensive measures implemented in Oxford City to reduce emissions. For example, OCC has invested £3.25m in reducing NO_x and NO_2 levels which were exceeding the air quality standards in the city centre. As a result, NO_2 levels decreased by 22.7% on average across the city as a whole between 2016 and 2017(1).

Given the magnitude of the overall changes to the background levels compared with the small changes in road and rail traffic associated with EWR Phase 1, the extent to which EWR Phase 1 has, in itself, contributed to any changes in NO_2/NO_x levels on the Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI will have been marginal.

It is also anticipated that due to further improvements planned in Oxford, including lower emissions from both trains and road vehicles, there will continue to be substantial improvements in the background concentrations in future years.

3.3 PLANT TISSUE ANALYSES

Nitrogen can accumulate in plant tissue when its availability exceeds the growth demands and when growth is restricted. This excess can be estimated from nitrogen concentrations in plant tissue. The foliar nitrogen concentration of many plants has been found to be related to atmospheric inputs, and thus can be used as an indicator of nitrogen deposition. In addition, the ratio (δ15N) of the two naturally occurring stable isotopes of nitrogen (14N and 15N) may help identify the source type of the nitrogen found, as it varies according to the source of the fixed nitrogen. For example, combustion processes are typically 15N positive (railway and roads) and those from agricultural processes being 15N negative (livestock) (http://www.apis.ac.uk/node/1214). The levels of δ15N within the plant tissue collected, when assessed in conjunction with the air pollutant findings from the diffusion tube surveys, may help identify the source of the nitrogen accumulating in the plant tissue (ie. from transport or agricultural sources), however, it can be difficult in agricultural and urban areas as there can be much variability.

(1) https://www.oxford.gov.uk/news/article/798/significant_reduction_in_oxford_s_air_pollution_after_cleaner_buses_introduced_%E2%80%93_but_city_still_has_toxic_air_in_some_streets

Year One Findings

N%, δ15N and P values were obtained from analysis of the tissue of plant samples taken from the locations where National Vegetation Classification (NVC) quadrats were undertaken as part of the baseline surveys (see **Annex D** Lichen and Plant Tissue Analyses).

The total nitrogen content ranged between 0.5% to 3.3% (wet weight), $\delta^{15}N$ values ranged from approximately -2 to +11, and total phosphorus levels (mg kg^{-1}) ranged from approximately 500 to 4,300. However, there were no consistent patterns across species and/or transects (see **Table 3.7** and **Table 3.8).**

Table 3.7 Year One Plant Tissue Analyses Oxford Meadows SAC

Transect Sample Location	Grid Reference	Plant Species	N (%, w/w)	$\delta^{15}N$ (%)	Total Phosphorus mg kg^{-1}
T1 - 50 m	SP 46703 10561 (+ 5.5m)	*Filipendula ulmaria*	2.02	7.19	2475
		Arrhenatherum elatius	1.22	3.64	1302
		Sanguisorba officinalis	1.68	4.4	1827
T1 - 100 m	SP 46714 10515 (+ 5.5m)	*Sanguisorba officinalis*	1.53	5.3	1671
		Arrhenatherum elatius	1.13	5.75	1397
		Centaurea debeauxii	1.03	4.62	1197
T1 - 200 m	SP 46748 10421 (+ 5.2m)	*Filipendula ulmaria*	1.87	5.45	2280
		Arrhenatherum elatius	0.98	2.12	1167
		Sanguisorba officinalis	1.82	4.1	1946
T2 - 10 m	SP 47819 10706 (+ 7.3m)	*Arrhenatherum elatius*	1.24	4.42	1636
		Arctium lappa	1.83	5.73	3031
		Urtica dioica	2.81	6.65	4272
T2 - 20 m	SP 47821 10695 (+ 7.3m)	*Sanguisorba officinalis*	2.54	5.08	2350
		Arrhenatherum elatius	1.33	4.19	1531
		Urtica dioica	2.61	5.31	1939
T2 - 50 m	SP 47825 10667 (+ 7.3m)	*Filipendula ulmaria*	2.63	5.24	1943
		Hordeum secalinum	1.06	9.28	828
		Sanguisorba officinalis	2.70	4.15	2213
T2 - 100 m	SP 47829 10578 (+ 7.3m)	*Filipendula ulmaria*	1.87	4.28	2381
		Arrhenatherum elatius	1.26	4.21	2222
		Urtica dioica	2.29	8.04	2563
T2 - 200 m	SP 47830 10460 (+ 7.3m)	*Hordeum secalinum*	0.80	3.30	1009
		Sanguisorba officinalis	1.52	-0.07	1963
		Filipendula ulmaria	1.86	3.19	2043
T3 - 20 m	SP 48332 09762 (+ 5.5m)	*Phragmites australis*	2.73	9.54	2390
		Galium aparine	1.64	1.89	3195
		Urtica dioica	2.40	5.92	3957
T3 - 50 m	SP 48316 09786 (+ 5.5m)	*Deschampsia cespitosa*	0.92	7.61	1379
		Holcus lanatus	0.69	-1.28	816
		Juncus acutiflorus	1.38	6.92	1587
T3 - 100 m		*Sanguisorba officinalis*	2.16	-1.72	1660
		Holcus lanatus	0.85	2.19	874

Transect Sample Location	Grid Reference	Plant Species	N (%, w/w)	δ15N (%)	Total Phosphorus mg kg-1
	SP 48268 09810 (+ 5.5m)	*Succisa pratensis*	1.58	-1.21	1279
T3 - 200 m	SP 48191 09856 (+ 5.5m)	*Sanguisorba officinalis*	2.30	2.92	2251
		Filipendula ulmaria	2.47	4.83	2187
		Holcus lanatus	0.76	0.53	705
T4 - 10 m	SP 48191 09737 (+ 6m)	*Filipendula ulmaria*	2.28	2.01	1778
		Thalictrum flavum	2.26	-0.11	2139
		Phragmites australis	1.73	6.26	2173
T4 - 20 m	SP 48389 09723 (+ 6m)	*Urtica dioica*	2.83	4.03	2862
		Filipendula ulmaria	2.66	6.04	2999
		Phragmites australis	2.31	8.96	2041
T4 - 50 m	SP 48409 09705 (+ 6m)	*Phragmites australis*	1.85	4.31	1839
		Filipendula ulmaria	2.60	2.94	2399
		Holcus lanatus	0.56	-0.89	1313
T4 - 100 m	SP 48440 09656 (+ 5.5m)	*Phragmites australis*	2.76	10.85	2724
		Holcus lanatus	0.87	0.85	1673
		Urtica dioica	3.17	7.85	3169
T4 - 200 m	SP 48516 09602 (+ 5.5m)	*Filipendula ulmaria*	2.67	5.90	2552
		Phragmites australis	2.41	8.58	2456
		Angelica sylvestris	3.28	3.53	3901

Table 3.8 Year One Plant Tissue Analyses Hook Meadow and The Trap Grounds SSSI

Transect Sample Location	Grid Reference	Plant Species	N (%, w/w)	$\delta^{15}N$ (%)	Total Phosphorus mg kg^{-1}
T5 - 20 m	SP 49784 09125 (+ 4.3m)	*Filipendula ulmaria*	2.17	3.65	2834
		Arrhenatherum elatius	1.79	4.62	2991
		Sanguisorba officinalis	1.87	4.5	2228
T5 - 50 m	SP 49762 09120 (+ 4.3m)	*Sanguisorba officinalis*	1.90	2.85	1985
		Arrhenatherum elatius	2.17	3.27	2158
		Centaurea debeauxii	0.46	1.84	721
T5 - 100 m	SP 49715 09085	*Filipendula ulmaria*	1.83	-0.21	2002
		Holcus lanatus	0.69	2.71	523
		Centaurea debeauxii	1.26	1.65	1592
T5 - 200 m	SP 49622 09059 (+ 4.3m)	*Filipendula ulmaria*	1.78	4.71	2141
		Holcus lanatus	0.77	4.08	697
		Centaurea debeauxii	1.63	3.51	2192
T6 - 10 m	SP 49815 09160 (+ 4.3m)	*Filipendula ulmaria*	2.20	8.49	1940
		Aster x salignus	2.28	3.92	2468
		Centaurea debeauxii	1.79	5.55	2141
T6 - 20 m	SP 49821 09164 (+ 4.3m)	*Filipendula ulmaria*	1.99	1.47	1536
		Aster x salignus	1.61	3.01	1987
		Centaurea debeauxii	1.66	4.38	1989
T6 - 50 m	SP 49849 09177 (+ 6.1m)	*Filipendula ulmaria*	2.16	4.81	2044
		Aster x salignus	1.96	3.16	2768
		Holcus lanatus	2.00	1.94	1409
T7 - 10 m	SP 49913 09058 (+ 4.3m)	*Filipendula ulmaria*	0.77	3.39	3797
		Juncus effusus	3.27	4.98	2169
		Carex otrubae	1.23	4.85	1375
T7 - 20 m	SP 49922 09079 (+ 4.3m)	*Filipendula ulmaria*	1.92	8.59	2964
		Juncus effusus	0.97	3.64	852
		Holcus lanatus	1.72	2.73	1653
T7 - 50 m	SP 49948 09092 (+ 4.3m)	*Filipendula ulmaria*	2.56	3.87	3470
		Holcus lanatus	0.81	0.43	2776
		Juncus effusus	2.32	6.50	1175
T8 - 10 m	SP 49993 08903 (+ 9.8m)	*Filipendula ulmaria*	1.27	8.95	3314
		Urtica dioica	1.22	-0.36	1669
		Holcus lanatus	1.14	3.23	1547
T8 - 20 m	SP 49999 08903 (+ 11.9m)	*Filipendula ulmaria*	2.54	-0.62	2914
		Holcus lanatus	1.30	2.93	1665
		Ranunculus acris	2.42	1.74	2387
T8 - 50 m	SP 50023 08914 (+ 4.3m)	*Filipendula ulmaria*	2.37	4.46	2564
		Holcus lanatus	1.34	3.87	972
		Deschampsia cespitosa	1.71	5.00	1446

Comparison to Baseline

A comparison of the two data sets, shows that the total nitrogen (N) content percentage (wet weight) were largely similar at both the Oxford Meadows SAC and at Hook Meadow and The Trap Grounds SSSI (see **Table 3.9**). There was no consistent pattern between the baseline and Year One findings for the total phosphorus, or for the $\delta^{15}N$ values.

Table 3.9 Baseline and Year One, Plant Tissue Analyses

Transect Sample Location	Plant Species	N (%, w/w)		$\delta^{15}N$ (%)		Total Phosphorus mg kg^{-1}	
		Baseline	Year One	Baseline	Year One	Baseline	Year One
Oxford Meadows SAC							
T1 - 50 m	*Filipendula ulmaria*	1.60	2.02	5.81	7.19	2161	2475
T1 - 100 m	*Sanguisorba officinalis*	1.29	1.53	4.33	5.30	1100	1671
T1 - 200 m	*Sanguisorba officinalis*	1.08	1.82	4.86	4.10	1061	1946
T2 - 10 m	*Arrhenatherum elatius*	1.44	1.24	4.04	4.42	2501	1636
T2 - 20 m	*Sanguisorba officinalis*	1.12	2.54	6.16	5.08	1584	2350
T2 - 50 m	*Hordeum secalinum*	0.77	1.06	1.4	9.28	901	828
	Sanguisorba officinalis	1.26	2.70	2.77	4.15	1191	2213
T2 - 100 m	*Filipendula ulmaria*	1.85	1.87	5.66	4.28	1969	2381
T2 - 200 m	*Hordeum secalinum*	0.93	0.80	2.65	3.3	1491	1009
	Sanguisorba officinalis	1.44	1.52	5.56	-0.07	1942	1963
T3 - 20 m	*Galium aparine*	1.64	1.64	10.14	1.89	3697	3195
T3 - 50 m	*Deschampsia cespitosa*	0.84	0.92	7.78	7.61	1045	1379
	Juncus acutiflorus	1.50	1.38	7.65	6.92	1367	1587
T3 - 100 m	*Sanguisorba officinalis*	2.68	2.16	2.11	-1.72	2641	1660
T3 - 200 m	*Sanguisorba officinalis*	1.79	2.3	3.48	2.92	1493	2251
	Holcus lanatus	1.12	0.76	4.45	0.53	1258	705
T4 - 10 m	*Filipendula ulmaria*	2.04	2.28	3.94	2.01	1795	1778
	Thalictrum flavum	2.38	2.26	4.02	-0.11	3029	2139
T4 - 50 m	*Holcus lanatus*	1.17	0.56	3.84	-0.89	1382	1313
T4 - 100 m	*Holcus lanatus*	1.49	0.87	3.64	0.85	1990	1673
T4 - 200 m	*Filipendula ulmaria*	1.86	2.67	1.97	5.9	2121	2552

Transect Sample Location	Plant Species	N (%, w/w)		δ15N (%)		Total Phosphorus mg kg-1	
		Baseline	Year One	Baseline	Year One	Baseline	Year One
Hook Meadow and The Trap Grounds SSSI							
T5 - 20 m	*Filipendula ulmaria*	2.16	2.17	7.55	3.65	4262	2834
T5 - 100 m	*Filipendula ulmaria*	2.18	1.83	4.45	-0.21	1454	2002
T5 - 200 m	*Filipendula ulmaria*	1.53	1.78	4.51	4.71	2255	2141
T6 - 10 m	*Filipendula ulmaria*	1.71	2.2	3.93	8.49	2306	1940
T6 - 20 m	*Filipendula ulmaria*	1.72	1.99	3.66	1.47	1654	1536
T6 - 50 m	*Filipendula ulmaria*	1.71	2.16	4.4	4.81	2310	2044
T7 - 10 m	*Filipendula ulmaria*	2.03	0.77	4.93	3.39	1914	3797
	Juncus effusus	1.03	3.27	7.35	4.98	1197	2169
	Carex otrubae	1.42	1.23	7.87	4.85	1395	1375
T7 - 20 m	*Filipendula ulmaria*	1.79	1.92	4.94	8.59	2039	2964
	Juncus effusus	1.11	0.97	6.05	3.64	1051	852
	Holcus lanatus	1.23	1.72	5.48	2.73	1707	1653
T7 - 50 m	*Filipendula ulmaria*	2.41	2.56	4.88	3.87	2091	3470
	Holcus lanatus	1.29	0.81	5.16	0.43	2350	2776
T8 - 10 m	*Filipendula ulmaria*	2.14	1.27	3.2	8.95	2397	3314
	Holcus lanatus	1.05	1.14	5.5	3.23	2655	1547
T8 - 20 m	*Filipendula ulmaria*	2.04	2.54	4.07	-0.62	1783	2914
	Holcus lanatus	1.07	1.30	3.53	2.93	1823	1665
	Ranunculus acris	0.65	2.42	2.74	1.74	1166	2387
T8 - 50 m	*Filipendula ulmaria*	1.83	2.37	3.61	4.46	2060	2564
	Holcus lanatus	1.18	1.34	4.34	3.87	1914	972

3.4 LICHEN TRANSPLANT BIO-MONITORING ANALYSES

The following sections summarise the findings from the analyses of the lichen samples from the Year One monitoring. **Tables 3.10** and **3.11** list the findings for each lichen species at each transect location for Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI respectively. The tables list the pH, range of N% and δ15N in the tissue at the start and at the end of the sampling period (see also **Annex D** Lichen and Plant Tissue Analyses).

Year One Findings

General Trends

As expected, NO_2 decreases with distance from the A40 and the A34(T) according to a logarithmic function[(1)]. The average NO_2 levels for the months March to September (when the lichen samples were on site) from Transect T2 and Transect T4 show that changes in NO_2 levels are more pronounced in the sampling locations close to the source in each transect (0-50 m) than in those further away (50-200 m). This is more evident in Transect T2 than in Transect T4. This is reflected also in the N% values.

NO_2 levels in Transect T6 and Transect T7 are equivalent to the lowest levels in Transect T2 and Transect T4 and there are smaller changes between NO_2 at distances below 50 m.

Surface pH

The surface pHs of the *Xanthoria parietina* samples after six months' exposure were found to be between 4 and 6, apart from one sample below 5. The pHs prior to exposure on the sites were similar. The findings were similar for *Evernia prunastri* with pHs of the samples before and after exposure both between 4 and 5.

Only the control samples for *Xanthoria parietina* and *Evernia prunastri* in Hook Meadow and The Trap Grounds SSSI (Control Site 2) could be analysed, as the control samples at the Oxford Meadows SAC control site (Control Site 1) were lost. The pH of the *Xanthoria parietina* sample in the SSSI was approximately 5.5 before and after the six months exposure. The initial *Evernia prunastri* pH was approximately 4.5, with a slight increase after exposure to 5.

Little change occurred in the surface pH values of the lichens after the six month exposure at the transect sample locations. Most values were similar, or had shown a slight decrease in pH. This differed from the control sample (>200 m from the pollution source) which the pH slightly increasing for both *Xanthoria parietina* and *Evernia prunastri* following exposure.

Table 3.10 shows the findings of the lichen sample analysis for the Oxford Meadows SAC and **Table 3.11** those for Hook Meadow and The Trap Grounds SSSI.

(1) Frati L., Caprasecca E., Santoni S., Gaggi C., Guttova A., Gaudino S., Pati A., Rosamilia S., Pirintsos S.A., Loppi S., 2006. Effects of NO_2 and NH_3 from road traffic on epiphytic lichens. Environ. Pollut. 142(1), 58-64

Table 3.10 Year One Findings from Lichen Sample Analyses, Oxford Meadows SAC

Sample Reference/ Location	Lichen Species	Original Samples			Exposed Samples		
		pH	N%	δ15N	pH	N%	δ15N
T2 - 10 m	*Xanthoria*	5.75	2.41	-9.86	5.73	2.40	-9.07
	Evernia	5.22	1.17	-11.70	4.48	1.42	-9.20
T2 - 20 m	*Xanthoria*	5.89	2.14	-10.60	5.32	2.57	-7.22
	Evernia	4.54	1.40	-15.20	4.03	1.84	-10.44
T2 - 50 m	*Xanthoria*	5.41	1.60	-11.80	5.00	2.39	-5.68
	Evernia	4.88	1.14	-17.80	4.32	2.37	-8.27
T2 - 100 m	*Xanthoria*	5.63	2.05	-11.30	5.74	3.04	-4.33
	Evernia	4.74	1.42	-15.40	4.14	2.80	-3.80
T2 - 200 m	*Xanthoria*	5.58	2.32	-10.00	5.90	3.25	-4.56
	Evernia	4.45	1.70	-14.90	4.79	2.76	-6.85
T4 - 10 m	*Xanthoria*	5.58	2.40	-10.20	5.50	2.32	-9.01
	Evernia	4.74	1.36	-17.00	4.53	1.90	-9.25
T4 - 20 m	*Xanthoria*	5.54	1.94	-13.00	5.46	2.61	-8.22
	Evernia	5.00	1.60	-14.60	4.38	1.72	-11.31
T4 - 50 m	*Xanthoria*	5.38	1.71	-9.48	5.32	2.52	-7.16
	Evernia	4.37	0.97	-18.00	4.01	2.00	-11.76
T4 - 100 m	*Xanthoria*	5.67	2.04	-11.00	5.32	3.68	-1.80
	Evernia	4.63	1.70	-13.20	4.16	2.49	-6.40
T4 - 200 m	*Xanthoria*	5.41	2.30	-11.70	5.08	2.38	-9.82
	Evernia	4.99	1.40	-11.70	4.49	1.79	-8.35
Control 1	*Xanthoria*	5.38	2.12	-13.40	*	*	*
	Evernia	4.37	1.61	-14.30	*	*	*
* No recordings collected due to sample being destroyed							

Table 3.11 Year One Findings from Lichen Sample Analyses, Hook Meadow and The Trap Grounds SSSI

Sample Reference/ Location	Lichen Species	Original Samples			Exposed Samples		
		pH	N%	δ15N	pH	N%	δ15N
T5 - 20 m	*Xanthoria*	5.37	1.81	-10.2	*	*	*
	Evernia	4.41	1.46	-11.7	*	*	*
T5 - 50 m	*Xanthoria*	5.58	2.13	-7.6	5.53	3.13	-2.04
	Evernia	4.55	1.55	-13.5	*	*	*
T5 - 100 m	*Xanthoria*	5.72	1.90	-12.5	*	*	*
	Evernia	4.16	1.37	-18.9	*	*	*
T5 - 200 m	*Xanthoria*	5.41	2.32	-11.5	5.59	3.00	-6.76
	Evernia	4.72	1.67	-12.1	4.70	2.95	-4.54
T6 - 10 m	*Xanthoria*	5.61	2.42	-10.8	5.01	2.49	-8.71
	Evernia	4.65	1.73	-15.4	4.23	2.11	-9.50
T6 - 20 m	*Xanthoria*	5.64	2.30	-10.1	5.18	2.56	-8.15
	Evernia	4.31	1.28	-14.9	4.24	1.92	-8.75
T6 - 50 m	*Xanthoria*	5.24	2.34	-10.5	5.04	2.92	-4.34
	Evernia	4.54	1.66	-14.2	4.49	2.12	-7.48
T7 - 10 m	*Xanthoria*	5.88	2.15	-12.7	4.63	2.34	-9.82

Sample Reference/ Location	Lichen Species	Original Samples			Exposed Samples		
		pH	N%	δ^{15}N	pH	N%	δ^{15}N
	Evernia	4.72	1.45	-11.8	4.22	1.65	-10.27
T7 - 20 m	*Xanthoria*	5.69	2.43	-9.9	5.34	3.23	-4.59
	Evernia	4.33	1.41	-14.2	4.16	1.90	-6.84
T7 - 50 m	*Xanthoria*	5.52	2.20	-12.5	5.24	2.44	-10.65
	Evernia	5.10	1.56	-13.6	4.49	1.67	-11.15
Control 2	*Xanthoria*	5.42	2.30	-11.1	5.64	2.67	-11.65
	Evernia	4.61	1.30	-14.8	5.05	1.92	-9.41
* No recordings collected due to sample being destroyed							

Total Nitrogen (%N, w/w)

Background N values of 1.6 - 2.43% and 0.97-1.73% in *Xanthoria parietina* (Xp) and in *Evernia prunastri* (Ep) respectively are in line with values in samples of the same species collected in UK (1.2-1.5%)(1), or in other studies from anthropized(2) areas (1 - 3.2% for Xp)(3); 3.3% *Xanthoria parietina* and 0.7% *Evernia prunastri*(4)). In particular, a maximum thallus N concentration of 2.3%, was found in saturated samples by Olsen *et al* (5) and of 2.5% in *Xanthoria parietina* and 2.2% in *Evernia prunastri* by Munzi *et al*(6). Other maximum thallus nitrogen contents of *Xanthoria parietina* reported in the literature range from 3.4% to 5.5%(7)(8). Much less data are available for *Evernia prunastri*.

After exposure, the total nitrogen content of *Xanthoria parietina* was between 2.32% and 3.68%, and *Evernia prunastri* was between 1.42% and 2.95%. The content in both the *Xanthoria parietina* and *Evernia prunastri* control samples from the Hook Meadow and The Trap grounds SSSI increased after

(1) Munzi S., Branquinho C., Cruz C., Máguas C., Leith I.D., Sheppard L.J., Sutton M.A., 2019. δ^{15}N of lichens reflects the isotopic signature of ammonia source. Sci. Tot. Environ. 653, 698-704.

(2) Conversion of open spaces, landscapes, and natural environments by human action.

(3) Boltersdorf S., Werner W., 2013. Source attribution of agriculture-related deposition by using total nitrogen and δ^{15}N in epiphytic lichen tissue, bark and deposition water samples in Germany. Isotopes Environ Health Stud. 49(2), 197-218.

(4) Gaio-Oliveira G., Dahlman L., Palmqvist K., Martins-Loução M.A., Máguas C., 2005. Planta 220, 794.

(5) Olsen H.B., Berthelsen K., Andersen H.V., Søchting U., 2010. *Xanthoria parietina* as a monitor of ground-level ambient ammonia concentrations. Environ. Pollut. 158, 455–461.

(6) Munzi S., Branquinho C., Cruz C., Máguas C., Leith I.D., Sheppard L.J., Sutton M.A., 2019. δ^{15}N of lichens reflects the isotopic signature of ammonia source. Sci. Tot. Environ. 653, 698-704.

(7) GaioOliviera G., Branquinho C., Máguas C., Martins-Loução M.A., 2001. The concentration of nitrogen in nitrophilous and non-nitrophilous lichen species. Symbiosis 31, 187-199.

(8) Pitcairn C.E.R., Leith I.D., Sheppard L.J., van Dijk N., Tang S.Y., Wolseley P., James P., Sutton M.A., 2004. Appendix I: field inter-comparison of different bio-indicator methods to assess the impacts of atmospheric nitrogen deposition. In: Pitcairn C.E.R., Leith I.D., Sheppard L.J., van Dijk N., Tang S.Y., Skiba U., Smart S., Mitchell R., Wolseley P., James P., Purvis W., Fowler D., Sutton M.A. (Eds.), Bioindicator and Biomonitoring Methods for Assessing the Effects of Atmospheric Nitrogen on Statutory Nature Conservation Sites. JNCC report no. 356.

exposure (*Xanthoria parietina* from 2.3% to 2.67% and *Evernia prunastri* from 1.3% to 1.92%).

The difference in %N accumulation was similar in both lichen species with lowest %N in samples at 10 m and 20 m from the source in both species. The highest accumulation is in *Evernia* in Transect T2 at 100 m, but in Transect T4 there was a rapid decrease in the samples located over 50 m from the source. The response was similar in Transect T6 and Transect T7, with a threshold at 20 m for both species. In Transect T6, *Evernia* showed a greater difference in %N accumulation than *Xanthoria*.

The difference in %N content and average NO_2 in Transect T2 showed a strong correlation in both species (*Xanthoria* r^2=0.968 and *Evernia* r^2= 0.8323)(1). In Transect T4 the correlation was not strong for *Evernia,* but was evident for *Xanthoria* if the sample at 200 m (where NO_2 was lowest was excluded).

Even though Transects T6 and T7 are only 50 m long and had only three samples sites (10 m, 20 m and 50 m), the difference in %N accumulation was significantly lower for both *Xanthoria* and *Evernia* than in Transects T2 and T4. The pattern is similar in Transect T6 with a greater difference in %N accumulation in *Evernia* than in *Xanthoria* (as in Transects T2 and T4). Transect T6 is situated between the two railway lines so that the sample at 50 m is affected by the mainline as well as EWR Phase 1. Transect T7, adjacent to playing fields of St Edward's School, has a different pattern with a conspicuous increase in %N in *Xanthoria*.

The findings show (using the reduced data points) that there is a low correlation between NO_2 and the %N accumulation in the lichens. The most conspicuous difference is between the effect of road and rail transport on %N accumulation in both species of lichen, with the highest %N accumulations recorded in Transect T2 (likely to be due to the road traffic on the A40) and lowest along Transect T7 (that is close to the EWR Phase 1 line).

Data from the diffusion tube surveys showed that the annual mean for NO_2 had decreased from 22.1 µg m^{-3} in the baseline, to 17.6 µg m^{-3} in Year One. In Year One, the highest monthly means for NO_2 were over the winter months and especially in February and March 2018. The lichens were, however, exposed over the six month period between March and September 2018.

(1) r2 is the square of the correlation. It measures the proportion of variation in the dependent variable that can be attributed to the independent variable.

Lichens have been shown to be sensitive to atmospheric ammonia at 1 µg m^{-3} [(1)(2)]. There is no equivalent scale for their sensitivity to NO_2 although it has been shown to be highly toxic to other organisms. Different nitrogen forms affect different metabolic pathways in lichens. The responses of lichens to high levels of NO_2 is different to the response to NH_3, and it is thought that the phytotoxic effects of NO_2 are more influential, as the concentrations of NH_3 are relatively low[(3)]. Using OPAL citizen science data for *Xanthoria* and *Evernia*[(4)], a difference in their sensitivities to NO_x deposition from road traffic is evident (ie. Evernia is more sensitive). This is supported by the abundance of nitrogen tolerant *Xanthoria* in the Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI, and the absence of the nitrogen sensitive *Evernia*, which suggests that historical air pollution has already caused the disappearance of *Evernia* on trees in the region of the SAC and SSSI.

This is supported further by the calculated nitrogen depositions for the transects (see **Annex C**, Table C1.3.3) during the Year One surveys, with loads between a high of 6.48 kg N ha yr at 10 m (T4) and a low of 2.24 kg N ha yr at 200 m (T1). Whilst these loads are lower than the baseline loads, they remain above the critical load for sensitive species such as Evernia[(5)].

Differences in Responses to NO_2 between Xanthoria and Evernia

The higher surface/volume ratio of the fruticose species *Evernia,* that has a bushy growth structure, contributes to the higher %N uptake in *Evernia* than *Xanthoria*. Research[(6)] suggests that *Xanthoria* is able to convert N to nitrate, allowing it to tolerate higher levels of N in the atmosphere. In contrast, *Evernia* is adapted to low nutrient conditions and cannot tolerate high atmospheric N deposition as ammonia. The use of stable isotopes in order to track N deposition in different forms[(7)] showed that *Evernia* was most sensitive to ammonia, then NH_4^+ and least sensitive to NO_3^-. Other mechanisms used

(1) Sutton M.A., Wolseley P.A., Leith I.D., Van Dijk N., James P.W., Theobald M.R., Whitfield C., 2009. Estimation of ammonia critical level for epiphytic lichens based on observations at the farm, landscape and national scales. In Sutton M.A., Reis S., Baker S.M.H. (eds) Atmospheric Ammonia– detecting emission changes and environmental impacts. Springer Science pp. 71-86.

(2) Wolseley, P.A., Leith, I.D., Van Dijk, N. & Sutton, M.A. (2009). Macrolichens on twigs and trunks as indicators of Ammonia Concentrations across the UK – a practical method. In In Sutton, M.A., Reis, S. & Baker, S.M.H. (eds) Atmospheric Ammonia – detecting emission changes and environmental impacts. Springer Science pp. 101-108.

(3) Gadsdon S.R., Dagley, J., Wolseley, P.A., Power S.A. 2010. Relationships between lichen community composition and concentrations of NO_2 and NH_3. Environ. Pollut. 158(8), 2553-60.

(4) Welden N.A., Wolseley P.A., Ashmore M.R., 2018. Citizen science identifies the effects of nitrogen deposition, climate and tree species on epiphytic lichens across the UK. Environ. Pollut. 232, 80-89.

(5) The critical load of 1µg m-3 NH3 for lichens and bryophytes was published in Sutton et al. 2009 Estimation of the Ammonia Critical level for Epiphytic lichens based on observations at Farm, Landscape and National Scales and accepted by the UNECE.

(6) Gaio-Oliveira G., Dahlman L., Palmqvist K., Martins-Loução M.A., Máguas C., 2005. Planta 220, 794.

(7) Munzi S., Branquinho C., Cruz C., Máguas C., Leith I.D., Sheppard L.J., Sutton M.A., 2019. $\delta^{15}N$ of lichens reflects the isotopic signature of ammonia source. Sci. Tot. Environ. 653, 698-704.

by *Xanthoria,* that allow it to tolerate higher N may include the production of polyamines(1) and storage of nitrogen in form of chitin(2).

High levels of NO_2 are toxic and affect the metabolism by causing oxidative stress(3). Although there is very little published information available on the effects on lichens, this could prevent the incorporation of N for protein production and explain the strong linear correlation between the NO_2 concentration and the differences in %N. It could explain also the differences in %N, as *Xanthoria* has higher antioxidant activity than *Evernia* and could cope better with oxidative stress.

The lichen depends on the health of its photobiont (a green alga). However in Transect T2 the loss of %C w/w was greatest at the 10 m sample in *Xanthoria* and in *Evernia*, and proportional to the increase in %N w/w. In Transect T4 the loss of %C in *Evernia* correlated with increasing NO_2, but not with increasing %N. It appeared that the C/N balance was affected by increasing NO_2 and that total C decreased with increasing N in *Evernia.* Previous measurements of lichen vitality using lichen Fv/Fm ratios (measurements of photosynthetic efficiency) have supported such linkages(4). Although no Fv/Fm data were collected for the lichen samples, the loss of C appeared to correlate with increasing NO_2 in Transect T4.

Other Factors Affecting N Accumulation

Samples of *Xanthoria* and *Evernia* from Transects T2 and T4 showed an increasing difference in %N with distance from the source. This is an inverse correlation to NO_2 and suggests that there are contributions other than the road / rail transport to %N in both lichen species.

The management regimes for the constituent parts of Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI in the locations of all of the transects, except Transect T7, allow for grazing in the summer months which coincided with the period of lichen exposure. No records of differential grazing levels across each transect were available, nor any records of NH_3 deposition during this period. The surface pH data showed a general tendency to acidification. It is expected that, in a humid environment, NH_3 reacts in the atmosphere to form NH_4^+ and that if taken up by the lichen, could result in the release of H^+ ions, causing acidification(5). Tissue pHs were typically lower (ie. more acidic) in *Evernia* than *Xanthoria*, due to its higher cation exchange capacity (CEC) (a measure of positive cations retained).

(1) Pirintsos S.A., Munzi S., Loppi S., Kotzabasis K., 2009. Do polyamines alter the sensitivity of lichens to nitrogen stress? Ecotox. Environ. Safe. 72, 1331-1336.

(2) Munzi S., Cruz C., Maia R., Máguas C., Perestrello-Ramos M.M., Branquinho C., 2017a. Intra- and inter-specific variations in chitin in lichens along a N-deposition gradient. Environ. Sci. Pollut. Res. 24(36), 28065-28071.

(3) Sheng Q., Zhu Z., 2019. Effects of nitrogen dioxide on biochemical responses in 41 garden plants. Plants 8, 45.

(4) Munzi S., Pisani T., Paoli L., Renzi M., Loppi S., 2013. Effect of nitrogen supply on the C/N balance in the lichen *Evernia prunastri* (L.) Ach. Turkish J. Biol. 37(2), 165-170.

(5) Munzi S., Sheppard L.J., Leith I.D., Cruz C., Branquinho C., Bini L., Gagliardi A., Cai G., Parrotta L., 2017b. The cost of surviving nitrogen excess: energy and protein demand in the lichen *Cladonia portentosa* as revealed by proteomic analysis. Planta 245(4), 819-833.

Nitrogen Isotope 15 (δ15 N %)

The δ15N values of the control samples prior to exposure for *Xanthoria* (-13.4 and -11.1) and *Evernia* (-14.3 and -14.8) are similar to values found in UK samples(1). Isotopic N signatures of agricultural areas and of urban areas are extremely variable and it may not be possible to detect whether the changes in isotopic values of δ15N are due to NO_2 emissions or agriculture (2)(3).

The negative δ15N values of the lichen samples for both species reduced in all viable samples in the transect areas following exposure. However, the *Xanthoria* control sample at Hook Meadow and The Trap Grounds SSSI, did not follow this trend and δ15N became more negative. The reduced negativity of most of the samples may reflect the influence of emissions from roads / railway given the positive effects on the δ15N ratios along the transects, contrasting with the slight increase in the negativity in the *Xanthoria* in the control sample over 200 m from road/rail transport sources.

The increase in δ15N coincided with high values of total N (%N) in the lichens and not with the highest values of NO_2 recorded in the diffusion tubes. Using stable isotopes in order to track N deposition in different forms has shown that *Evernia* was most sensitive to ammonia, then NH_4^+ and least sensitive to NO_3^- (4).

Comparison to Baseline

In order to present a comparison between the baseline and Year One recordings, the percentage change after exposure was calculated for surface pH, total nitrogen and the nitrogen isotope (see **Tables 3.12** to **3.14**) using the formula below:

$$\%\ change = \left(\frac{Exposed}{original} x\ 100\right) - 100$$

Surface pH

For both Year One and the baseline, little change occurred to the surface pH values of the lichens after the six months exposure. However, the two datasets differed slightly. The baseline data showed a slight increase (5.43%) in pH, whereas the Year One recordings displayed a minor decrease (5.16%), in particular for *Evernia* (see **Figures 3.9** and **3.10**). A similar trend was observed for both the baseline and Year One control sites (see **Table 3.12**).

(1) Munzi S., Branquinho C., Cruz C., Máguas C., Leith I.D., Sheppard L.J., Sutton M.A., 2019. δ15N of lichens reflects the isotopic signature of ammonia source. Sci. Tot. Environ. 653, 698-704.

(2) Miller D.J., Wojtal P.K., Clark S.C., Hastings M.G., 2017. Vehicle NO_x emission plume isotopic signatures: Spatial variability across the eastern United States. J. Geophys. Res. Atmos. 122, 4698–4717.

(3) Ti C., Gao B., Luo Y., Wang X., Wang S., Yan X., 2018. Isotopic characterization of NH_x-N in deposition and major emission sources. Biogeochemistry 138, 85–102.

(4) Munzi S., Branquinho C., Cruz C., Máguas C., Leith I.D., Sheppard L.J., Sutton M.A., 2019. δ15N of lichens reflects the isotopic signature of ammonia source. Sci. Tot. Environ. 653, 698-704.

The baseline pH for *Xanthoria* on average, increased for both the SAC (14.18%) and SSSI (8.82%), whereas, for Year One the pH on average for decreased after exposure (SAC by 2.62% and SSSI by 6.59%) (see **Figure 3.9**). There was a similar trend for *Evernia* in the SAC, with an increase of 1.83 (baseline) and a reduction of 8.71% for the Year One data. For the SSSI, the initial baseline showed a reduction in pH after the six months exposure (5.18%) a similar, but smaller reduction in pH (4.83%), in the Year One samples (see **Figure 3.10**).

Figure 3.9 Baseline and Year One, Percentage Change in Surface pH for *Xanthoria parietina* after Six Months of Exposure

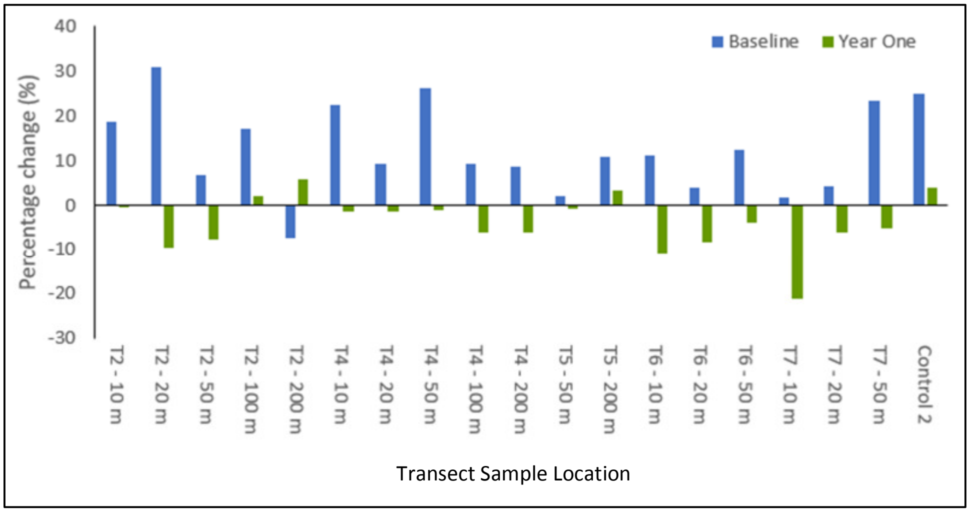


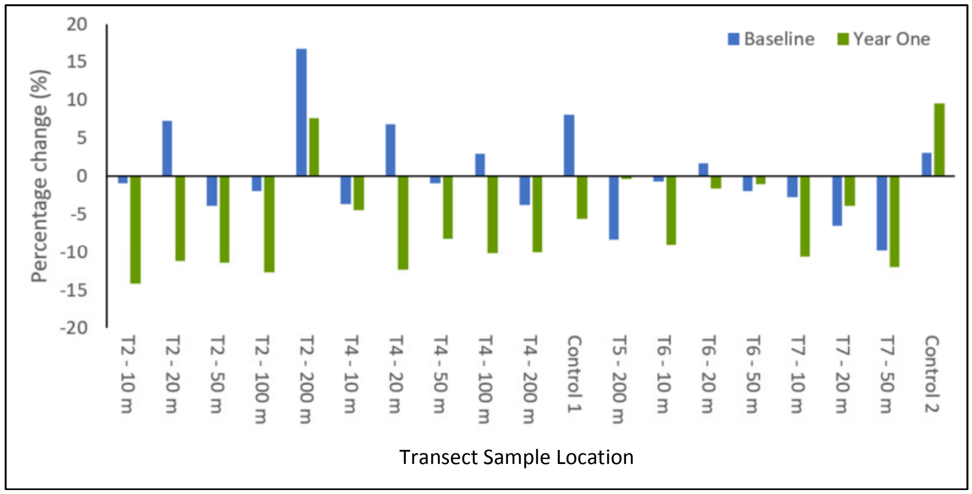
Table 3.12 Baseline and Year One, Percentage Change in Tissue pH after Exposure

Transect Sample Location	Lichen Species	Baseline Tissue pH			Year One Tissue pH		
		Original	Exposed	% Change	Original	Exposed	% Change
T2 - 10 m	*Xanthoria*	5.34	6.34	18.73	5.75	5.73	-0.35
	Evernia	4.04	4.00	-0.99	5.22	4.48	-14.18
T2 - 20 m	*Xanthoria*	5.09	6.66	30.84	5.89	5.32	-9.68
	Evernia	3.72	3.99	7.26	4.54	4.03	-11.23
T2 - 50 m	*Xanthoria*	5.5	5.87	6.73	5.41	5.00	-7.58
	Evernia	4.05	3.89	-3.95	4.88	4.32	-11.48
T2 - 100 m	*Xanthoria*	5.52	6.46	17.03	5.63	5.74	1.95
	Evernia	4.02	3.94	-1.99	4.74	4.14	-12.66
T2 - 200 m	*Xanthoria*	5.64	5.22	-7.45	5.58	5.9	5.73
	Evernia	3.95	4.61	16.71	4.45	4.79	7.64
T4 - 10 m	*Xanthoria*	5.32	6.52	22.56	5.58	5.50	-1.43
	Evernia	4.05	3.90	-3.70	4.74	4.53	-4.43
T4 - 20 m	*Xanthoria*	5.46	5.97	9.34	5.54	5.46	-1.44
	Evernia	3.81	4.07	6.82	5.00	4.38	-12.40
T4 - 50 m	*Xanthoria*	5.02	6.34	26.29	5.38	5.32	-1.12
	Evernia	3.99	3.95	-1.00	4.37	4.01	-8.24
T4 - 100 m	*Xanthoria*	5.75	6.28	9.22	5.67	5.32	-6.17
	Evernia	3.75	3.86	2.93	4.63	4.16	-10.15

Transect Sample Location	Lichen Species	Baseline Tissue pH			Year One Tissue pH		
		Original	**Exposed**	**% Change**	**Original**	**Exposed**	**% Change**
T4 - 200 m	*Xanthoria*	5.29	5.74	8.51	5.41	5.08	-6.10
	Evernia	4.18	4.02	-3.83	4.99	4.49	-10.02
Control 1	*Xanthoria*	5.51	*	*	5.38	*	*
	Evernia	4.26	*	*	4.37	*	*
T5 - 20 m	*Xanthoria*	5.36	6.46	20.52	5.37	*	*
	Evernia	4.05	3.72	-8.15	4.41	*	*
T5 - 50 m	*Xanthoria*	5.50	5.61	2.00	5.58	5.53	-0.90
	Evernia	4.29	3.86	-10.02	4.55	*	*
T5 - 100 m	*Xanthoria*	5.98	5.88	-1.67	5.72	*	*
	Evernia	3.74	*	*	4.16	*	*
T5 - 200 m	*Xanthoria*	5.69	6.31	10.90	5.41	5.59	3.33
	Evernia	4.09	3.75	-8.31	4.72	4.7	-0.42
T6 - 10 m	*Xanthoria*	5.82	6.47	11.17	5.61	5.01	-10.70
	Evernia	4.02	3.99	-0.75	4.65	4.23	-9.03
T6 - 20 m	*Xanthoria*	5.52	5.74	3.99	5.64	5.18	-8.16
	Evernia	4.05	4.12	1.73	4.31	4.24	-1.62
T6 - 50 m	*Xanthoria*	5.63	6.32	12.26	5.24	5.04	-3.82
	Evernia	4.01	3.93	-2.00	4.54	4.49	-1.10
T7 - 10 m	*Xanthoria*	5.64	5.73	1.60	5.88	4.63	-21.26
	Evernia	3.99	3.88	-2.76	4.72	4.22	-10.59
T7 - 20 m	*Xanthoria*	5.25	5.47	4.19	5.69	5.34	-6.15
	Evernia	3.95	3.69	-6.58	4.33	4.16	-3.93
T7 - 50 m	*Xanthoria*	5.08	6.26	23.23	5.52	5.24	-5.07
	Evernia	4.38	3.95	-9.82	5.10	4.49	-11.96
Control 2	*Xanthoria*	5.52	6.89	24.82	5.42	5.64	4.06
	Evernia	3.99	4.11	3.01	4.61	5.05	9.54

* No recordings collected due to sample error

Figure 3.10 Baseline and Year One, Percentage Change in Surface pH for *Evernia prunastri* after Six Months of Exposure



Total Nitrogen (%N, w/w)

Throughout the transect sample locations, the %N content for *Xanthoria* and *Evernia* increased for Year One (as it did for the baseline) after the six month exposure on site (see **Table 3.13** and **Figures 3.11** and **3.12)**. The average percentage change for *Xanthoria* in Year One was an increase of approximately 27% (lower than the percentage increase after exposure during the baseline survey of approximately 47%). However, the reverse was true for *Evernia* with an increase of approximately 46% (higher than the percentage increase after exposure during the baseline survey of approximately 29%).

The average percentage changes in the baseline total nitrogen were greater for both lichen species at Hook Meadow and The Trap Grounds SSSI than the Oxford Meadows SAC. However, the reverse was true for the Year One data, with a greater percentage increase for both *Xanthoria* and *Evernia* at the SAC (approximately 32% and 55% respectively) than the SSSI (approximately 21% and 29% respectively).

Figure 3.11 Baseline and Year One, Percentage Change in the Total Nitrogen (%N, w/w) for *Xanthoria parietina* after Six Months of exposure

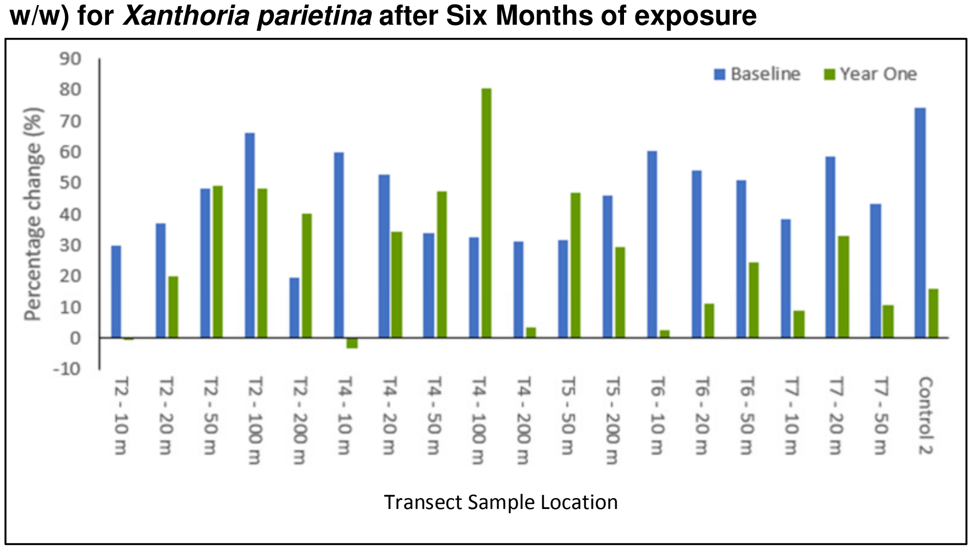


Figure 3.12 Baseline and Year One, Percentage Change in the Total Nitrogen (w/w) for *Evernia prunastri* after Six Months of Exposure

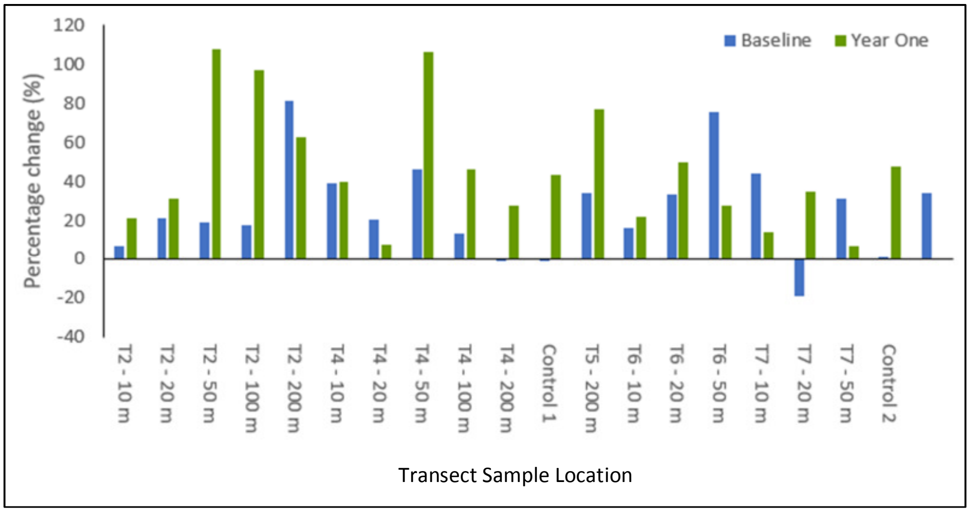


Table 3.14 Baseline and Year One, Percentage Change in Total Nitrogen after Exposure

Transect Sample Location	Lichen Species	Baseline N%			Year One N%		
		Original	Exposed	% Change	Original	Exposed	% Change
T2 - 10 m	*Xanthoria*	1.36	1.77	30.15	2.41	2.40	-0.41
	Evernia	1.47	1.57	6.80	1.17	1.42	21.37
T2 - 20 m	*Xanthoria*	1.29	1.77	37.21	2.14	2.57	20.09
	Evernia	1.40	1.70	21.43	1.40	1.84	31.43
T2 - 50 m	*Xanthoria*	1.34	1.99	48.51	1.60	2.39	49.38
	Evernia	1.31	1.56	19.08	1.14	2.37	107.89
T2 - 100 m	*Xanthoria*	1.39	2.31	66.19	2.05	3.04	48.29
	Evernia	1.39	1.63	17.27	1.42	2.80	97.18
T2 - 200 m	*Xanthoria*	1.73	2.07	19.65	2.32	3.25	40.09
	Evernia	1.42	2.57	80.99	1.70	2.76	62.35
T4 - 10 m	*Xanthoria*	1.54	2.46	59.74	2.40	2.32	-3.33
	Evernia	1.33	1.85	39.10	1.36	1.90	39.71
T4 - 20 m	*Xanthoria*	1.29	1.97	52.71	1.94	2.61	34.54
	Evernia	1.19	1.43	20.17	1.60	1.72	7.50
T4 - 50 m	*Xanthoria*	1.52	2.04	34.21	1.71	2.52	47.37
	Evernia	1.28	1.87	46.09	0.97	2.00	106.19
T4 - 100 m	*Xanthoria*	1.25	1.66	32.80	2.04	3.68	80.39
	Evernia	1.31	1.48	12.98	1.70	2.49	46.47
T4 - 200 m	*Xanthoria*	1.46	1.92	31.51	2.30	2.38	3.48
	Evernia	1.42	1.40	-1.41	1.40	1.79	27.86
Control 1	*Xanthoria*	1.50	*	*	2.12	*	*
	Evernia	1.45	*	*	1.61	*	*
T5 - 20 m	*Xanthoria*	1.54	2.48	61.04	1.81	*	*
	Evernia	1.49	2.45	64.43	1.46	*	*
	Xanthoria	1.67	2.20	31.74	2.13	3.13	46.95

Transect Sample Location	Lichen Species	Baseline N%			Year One N%		
		Original	Exposed	% Change	Original	Exposed	% Change
T5 - 50 m	*Evernia*	1.16	1.66	43.10	1.55	*	*
T5 - 100 m	*Xanthoria*	1.46	2.12	45.21	1.9	*	*
	Evernia	1.02	*	*	1.37	*	*
T5 - 200 m	*Xanthoria*	1.70	2.48	45.88	2.32	3.00	29.31
	Evernia	1.23	1.43	16.26	1.67	2.95	76.65
T6 - 10 m	*Xanthoria*	1.66	2.66	60.24	2.42	2.49	2.89
	Evernia	1.45	1.93	33.10	1.73	2.11	21.97
T6 - 20 m	*Xanthoria*	1.44	2.22	54.17	2.30	2.56	11.30
	Evernia	1.31	2.30	75.57	1.28	1.92	50.00
T6 - 50 m	*Xanthoria*	1.35	2.04	51.11	2.34	2.92	24.79
	Evernia	1.29	1.86	44.19	1.66	2.12	27.71
T7 - 10 m	*Xanthoria*	1.53	2.12	38.56	2.15	2.34	8.84
	Evernia	1.67	1.35	-19.16	1.45	1.65	13.79
T7 - 20 m	*Xanthoria*	1.47	2.33	58.50	2.43	3.23	32.92
	Evernia	1.15	1.51	31.30	1.41	1.90	34.75
T7 - 50 m	*Xanthoria*	1.56	2.24	43.59	2.20	2.44	10.91
	Evernia	1.33	1.34	0.75	1.56	1.67	7.05
Control 2	*Xanthoria*	1.32	2.30	74.24	2.30	2.67	16.09
	Evernia	1.44	1.93	34.03	1.30	1.92	47.69
* No recordings collected due to sample error							

Nitrogen Isotope 15 (δ^{15} N %)

The negative δ15N values of the lichen samples (both species) for Year One reduced (ie. became more positive) for the majority of the samples, as it did during the baseline survey (**Figures 3.13** and **3.14** and **Table 3.15**). However, the negative values reduced on average more for both *Xanthoria* and *Evernia* samples in Year One (approximately 36% and 40%), compared with the baseline survey (approximately 32% and 30%).

The Year One reductions in the negative δ15N values of both lichen species, were greater at the Oxford Meadows SAC, than at Hook Meadow and The Trap Grounds SSSI and compared with the baseline surveys. The Hook Meadow and The Trap Grounds SSSI Year One findings were similar to the baseline findings. The greater reduction in negative δ15N values after exposure at the Oxford Meadows SAC, suggests that the lichen absorbed less nitrogen from airborne sources in Year One than during the baseline survey.

Figure 3.13 Baseline and Year One, Percentage Change in the Nitrogen Isotope 15 (δ15 N %) for *Xanthoria parietina* after Six Months of Exposure

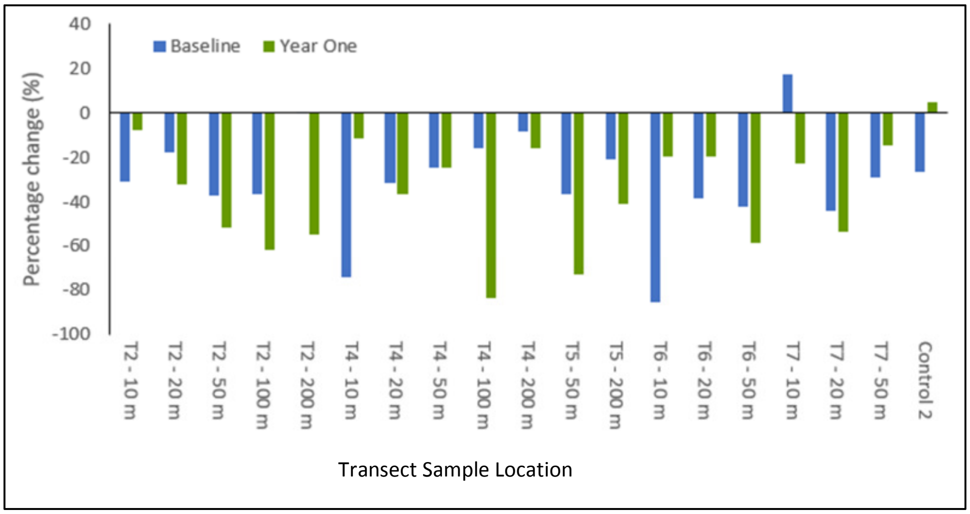


Figure 3.14 Baseline and Year One, Percentage Change in the Nitrogen Isotope 15 (δ15 N %) for *Evernia prunastri* after Six Months of Exposure

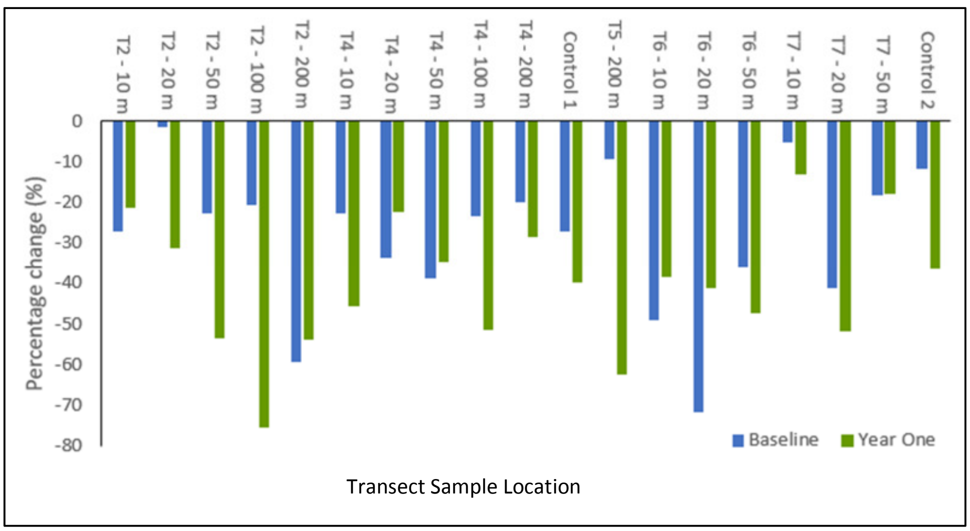


Table 3.15 Baseline and Year One, Percentage Change in Nitrogen Isotope after Exposure

Transect Sample Location	Lichen Species	Baseline δ15N			Year One δ15N		
		Original	Exposed	% Change	Original	Exposed	% Change
T2 - 10 m	*Xanthoria*	-11.30	-7.80	-30.97	-9.86	-9.07	-8.01
	Evernia	-14.40	-10.50	-27.08	-11.70	-9.20	-21.37
T2 - 20 m	*Xanthoria*	-8.69	-7.14	-17.84	-10.60	-7.22	-31.89
	Evernia	-12.80	-12.60	-1.56	-15.20	-10.44	-31.32
T2 - 50 m	*Xanthoria*	-11.20	-7.07	-36.88	-11.80	-5.68	-51.86
	Evernia	-15.90	-12.30	-22.64	-17.80	-8.27	-53.54
T2 - 100 m	*Xanthoria*	-7.93	-5.05	-36.32	-11.30	-4.33	-61.68
	Evernia	-14.90	-11.80	-20.81	-15.40	-3.80	-75.32
T2 - 200 m	*Xanthoria*	-7.31	-7.33	0.27	-10.00	-4.56	-54.40
	Evernia	-13.90	-5.67	-59.21	-14.90	-6.85	-54.03
T4 - 10 m	*Xanthoria*	-10.10	-2.60	-74.26	-10.20	-9.01	-11.67
	Evernia	-16.30	-12.60	-22.70	-17.00	-9.25	-45.59
T4 - 20 m	*Xanthoria*	-9.26	-6.35	-31.43	-13.00	-8.22	-36.77
	Evernia	-17.00	-11.30	-33.53	-14.60	-11.31	-22.53
T4 - 50 m	*Xanthoria*	-11.40	-8.57	-24.82	-9.48	-7.16	-24.47
	Evernia	-16.80	-10.30	-38.69	-18.00	-11.76	-34.67
T4 - 100 m	*Xanthoria*	-11.50	-9.65	-16.09	-11.00	-1.80	-83.64
	Evernia	-15.80	-12.10	-23.42	-13.20	-6.40	-51.52
T4 - 200 m	*Xanthoria*	-8.01	-7.33	-8.49	-11.70	-9.82	-16.07
	Evernia	-16.00	-12.80	-20.00	-11.70	-8.35	-28.63
Control 1	*Xanthoria*	-9.49	*	*	-13.40	*	*
	Evernia	-14.80	*	*	-14.30	*	*
T5 - 20 m	*Xanthoria*	-9.10	-4.16	-54.29	-10.20	*	*
	Evernia	-15.50	-6.61	-57.35	-11.70	*	*
T5 - 50 m	*Xanthoria*	-8.34	-5.27	-36.81	-7.60	-2.04	-73.16
	Evernia	-14.50	-11.40	-21.38	-13.50	*	*
T5 - 100 m	*Xanthoria*	-11.10	-7.88	-29.01	-12.50	*	*
	Evernia	-14.30	*	*	-18.90	*	*
T5 - 200 m	*Xanthoria*	-7.98	-6.31	-20.93	-11.50	-6.76	-41.22
	Evernia	-15.10	-13.70	-9.27	-12.10	-4.54	-62.48
T6 - 10 m	*Xanthoria*	-8.52	-1.26	-85.21	-10.80	-8.71	-19.35
	Evernia	-16.10	-8.19	-49.13	-15.40	-9.50	-38.31
T6 - 20 m	*Xanthoria*	-11.80	-7.25	-38.56	-10.10	-8.15	-19.31
	Evernia	-15.60	-4.44	-71.54	-14.90	-8.75	-41.28
T6 - 50 m	*Xanthoria*	-11.50	-6.66	-42.09	-10.50	-4.34	-58.67
	Evernia	-15.60	-9.97	-36.09	-14.20	-7.48	-47.32
T7 - 10 m	*Xanthoria*	-5.22	-6.13	17.43	-12.70	-9.82	-22.68
	Evernia	-15.10	-14.30	-5.30	-11.80	-10.27	-12.97
T7 - 20 m	*Xanthoria*	-12.70	-7.13	-43.86	-9.90	-4.59	-53.64
	Evernia	-15.50	-9.10	-41.29	-14.20	-6.84	-51.83
T7 - 50 m	*Xanthoria*	-8.01	-5.70	-28.84	-12.50	-10.65	-14.80
	Evernia	-15.40	-12.60	-18.18	-13.60	-11.15	-18.01
Control 2	*Xanthoria*	-9.10	-6.67	-26.70	-11.10	-11.65	4.95
	Evernia	-17.00	-15.00	-11.76	-14.80	-9.41	-36.42

Transect Sample Location	Lichen Species	Baseline δ15N			Year One δ15N		
		Original	Exposed	% Change	Original	Exposed	% Change
* No recordings collected due to sample error Note: A negative percentage change demonstrates that the lichen absorbed less nitrogen, which is a positive outcome.							

3.5 SOIL CONDITIONS

The following sections provide a summary of the findings from the soil condition analyses for Year One and compares them to the baseline findings.

Year One Findings

The Year One findings for each soil sample at each transect location are listed in **Table 3.16** for Oxford Meadows SAC and **Table 3.17** for Hook Meadow and The Trap Grounds SSSI and in **Annex E** (Soil Analyses), and show the pH and total nitrogen content. Total N is the amount of mineral nitrogen in the soil available for use by plants, and is the sum of Nitrate -N (NO_3 -N) and Ammonium -N (NH_4+ -N).

Table 3.16 Year One Soil Analyses, Oxford Meadows SAC

Transect Sample Location	Soil pH (0 – 15 cm depth)	Total N #	Nitrate -N (NO_3 -N) #	Ammonium -N (NH_4^+-N) #
T1 - 50m	7.80	118.60	116.32	2.28
T1 - 100m	7.07	84.28	81.06	3.22
T1 - 200m	7.21	123.68	120.22	3.46
T2 - 10m	7.81	386.77	363.79	22.98
T2 - 20m	7.58	284.26	276.76	7.50
T2 - 50m	7.18	136.64	133.00	3.64
T2 - 100m	7.67	69.80	68.22	1.58*
T2 - 200m	7.46	37.04	34.24	2.80
T3 - 20m	7.90	199.86	197.06	2.80
T3 - 50m	7.19	47.92	35.60	12.32
T3 - 100m	6.29	73.46	37.36	36.10
T3 - 200m	7.31	270.96	129.86	141.10
T4 - 10m	7.35	30.28	26.06	4.22
T4 - 20m	7.22	40.92	38.98	1.94*
T4 - 50m	7.39	14.14	12.28	1.86*
T4 - 100m	7.77	100.04	94.88	5.16
T4 - 200m	7.66	68.34	65.82	2.52
# PRS™ probe supply rate (µg/10 cm2/burial length) * Highlighted values are below method detection limits (mdl), but provided as measured.				

Table 3.17 Year One Soil Analyses, Hook Meadow and The Trap Grounds SSSI

Transect Sample Location	Soil pH (0 – 15 cm depth)	Total N #	Nitrate -N (NO_3 -N) #	Ammonium -N (NH_4^+-N) #
T5 - 20m	7.18	52.92	51.04	1.88*
T5 - 50m	7.15	17.14	12.36	4.78
T5 - 100m	7.55	34.60	31.18	3.42
T5 - 200m	7.47	45.34	43.10	2.24
T6 - 10m	7.18	206.86	200.02	6.84
T6 - 20m	6.92	27.44	25.04	2.40
T6 - 50m	6.32	67.42	64.40	3.02
T7 - 10m	6.69	36.58	34.34	2.24
T7 - 20m	6.08	38.32	9.62	28.70
T7 - 50m	7.57	157.92	148.90	9.02
T8 - 10m	7.20	117.56	108.58	8.98
T8 - 20m	6.48	31.88	21.08	10.80
T8 - 50m	6.03	37.32	28.02	9.30

PRS™ probe supply rate (µg/10 cm2/burial length)
* Highlighted values are below method detection limits (mdl), but provided as measured.

Soil pH

The soil pH was as expected for neutral grasslands with pH levels ranging between 6 and 8 at both Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI.

Total Nitrogen

At the Oxford Meadows SAC, the highest levels of nitrogen in the soil were in Transect T2 and the lowest in Transect T4.

- Transect T1: 84 - 124 (variable with highest at 200 m and lowest at 100 m);
- Transect T2: 37 - 387 (gradual reduction from 10 m to 200 m);
- Transect T3: 48 - 271 (variable with highest at 200 m and lowest at 50 m); and
- Transect T4: 14 - 100 (variable with highest at 100 m and lowest at 50 m).

At Hook Meadow and The Trap Grounds SSSI, Transect T6 displayed the highest levels of nitrogen, with Transect T5 displaying the lowest.

- Transect T5: 17 - 53 (variable with highest at 20 m and lowest at 50 m);
- Transect T6: 27 - 207 (variable with highest at 10 m and lowest at 20 m);

- Transect T7: 37 - 158 (10 m and 20 m very similar, with large increase at 50 m); and

- Transect T8: 32 - 118 (variable with highest at 10 m and lowest at 20 m).

Both Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI are in floodplains and are susceptible to flooding which alongside changeable grazing regimes can influence the levels of nitrogen in the soil. This makes it difficult to define a clear relationship between the impact of EWR Phase 1 on soil conditions compared with other contributing factors.

Other Elements

The ranges of the main elements analysed are listed below (all figures are rates in µg/10cm^2/burial depth):

- Calcium – c1,123 to 3,571, but 24/30 samples had values of <3,000;
- Magnesium – c48 to 174;
- Potassium – c68 to 1,007, but 17/30 samples had values of <250;
- Iron – c3 to 125, but 25/30 samples had values of <20;
- Manganese – c0 to 12, but 29/30 samples had values <9;
- Copper – c0 to 7, but 21/30 samples had values <2;
- Zinc – c1 to 12, but 25/30 samples had values <4;
- Sulphur – c25 to 274, but 26/30 samples had values <200;
- Lead – c0 to 45; and
- Aluminium – c4 to 22.

The findings for each element by transect are listed in **Table 3.18** and in **Annex F (**Plant Root Simulator Analyses).

The findings are largely within the expected ranges for grassland based on information available from Western Agg. Laboratory[(1)], although the calcium and potassium values were generally high and the magnesium values generally low. High levels of magnesium can, however, be typical of lowland meadows (Wilson & Wheeler, 2016[(2)]).

(1) https://www.westernag.ca/innovations/customer/interpretation

(2) Wilson P J & Wheeler B R (2016) *A Survey and Assessment of Soil pH and Nutrient Status on Sites of High Botanical Value*.

Table 3.18 Year One PRS Analysis – Other Elements

						PRS™-Probe Supply Rate (µg/10cm²/burial length)																
WAL	Sample ID	Burial Date	Retrieval Date	Anion	Cation	Total N	NO_3^--N	NH_4^+-N	Ca	Mg	K	P	Fe	Mn	Cu	Zn	B	S	Pb	Al	Cd
Method Detection Limits (mdl):						2	2	2	2	4	4	0.2	0.4	0.2	0.2	0.2	0.2	2	0.2	0.4	0.2
175133	T1 50 m	06/05/18	01/08/18	4	4	118.60	116.32	2.28	2064.02	85.99	716.79	26	6	1	2	12	0*	68.78	0*	6	0*
175134	T1 100 m	06/05/18	01/08/18	4	4	84.28	81.06	3.22	2396.46	90.34	535.41	23	6	1	3	1	0*	73.39	0	7	0*
175135	T1 200 m	06/05/18	01/08/18	4	4	123.68	120.22	3.46	2485.98	76.70	181.53	24	4	1	2	1	0*	77.71	0*	6	0*
175136	T2 10 m	06/05/18	01/08/18	3	4	386.77	363.79	22.98	1657.88	91.76	936.46	21	5	12	1	5	0*	53.25	3	7	0*
175137	T2 20 m	06/05/18	01/08/18	4	4	284.26	276.76	7.50	2233.10	82.11	231.12	6	5	1	0	1	0*	42.85	0	8	0*
175138	T2 50 m	06/05/18	01/08/18	4	4	136.64	133.00	3.64	2935.28	88.40	122.26	15	7	1	1	1	0	202.52	0	8	0*
175139	T2 100 m	06/05/18	01/08/18	4	4	69.80	68.22	1.58*	3299.48	78.82	149.44	10	15	1	2	2	0	111.14	1	8	0*
175140	T2 200 m	06/05/18	01/08/18	4	4	37.04	34.24	2.80	3571.38	97.11	184.10	19	50	3	1	3	0*	194.91	2	7	0*
175141	T3 20 m	06/05/18	01/08/18	4	4	199.86	197.06	2.80	2642.56	85.52	366.03	19	7	1	0	3	1	128.37	1	10	0*
175142	T3 50 m	06/05/18	01/08/18	4	4	47.92	35.60	12.32	2794.32	95.91	134.97	26	14	3	2	1	0*	209.27	1	7	0*
175143	T3 100 m	06/05/18	01/08/18	4	4	73.46	37.36	36.10	1574.34	101.16	228.44	19	13	4	2	2	0*	190.04	0	6	0*

PRS™-Probe Supply Rate (µg/10cm^2/burial length)																					
WAL	**Sample ID**	**Burial Date**	**Retrieval Date**	**Anion**	**Cation**	**Total N**	**NO_3^--N**	**NH_4^+-N**	**Ca**	**Mg**	**K**	**P**	**Fe**	**Mn**	**Cu**	**Zn**	**B**	**S**	**Pb**	**Al**	**Cd**
Method Detection Limits (mdl):						**2**	**2**	**2**	**2**	**4**	**4**	**0.2**	**0.4**	**0.2**	**0.2**	**0.2**	**0.2**	**2**	**0.2**	**0.4**	**0.2**
175144	T3 200 m	06/05/18	01/08/18	4	4	270.96	129.86	141.10	2575.78	174.20	476.18	30	22	4	2	2	0*	125.03	1	5	0*
175145	T4 10 m	06/05/18	01/08/18	4	4	30.28	26.06	4.22	2179.18	113.63	251.49	6	46	2	2	10	1	76.97	5	9	0*
175146	T4 20 m	06/05/18	01/08/18	4	4	40.92	38.98	1.94*	1492.00	68.52	465.40	13	18	1	7	3	0	46.74	1	9	0*
175147	T4 50 m	06/05/18	01/08/18	4	4	14.14	12.28	1.86*	1123.34	48.28	345.30	9	5	1	1	1	0	53.98	0	4	0*
175148	T4 100 m	06/05/18	01/08/18	4	4	100.04	94.88	5.16	1710.97	63.43	313.71	22	4	0	0	1	1	46.06	0*	8	0*
175149	T4 200 m	06/05/18	01/08/18	4	4	68.34	65.82	2.52	2246.34	117.29	1006.53	15	3	0	0	1	0*	26.64	0*	8	0*
175150	T5 20 m	06/05/18	01/08/18	4	4	52.92	51.04	1.88*	3212.94	108.88	126.59	21	13	1	4	1	1	51.31	0	17	0*
175151	T5 50 m	06/05/18	01/08/18	4	4	17.14	12.36	4.78	3048.00	97.21	176.32	11	11	2	1	1	1	58.13	0	22	0*
175152	T5 100 m	06/05/18	01/08/18	4	4	34.60	31.18	3.42	3016.00	85.39	71.91	12	7	1	1	1	1	45.94	0	11	0*
175153	T5 200 m	06/05/18	01/08/18	4	4	45.34	43.10	2.24	2545.14	100.31	316.64	21	5	1	2	1	0	77.01	0	7	0*
175154	T6 10 m	06/05/18	01/08/18	4	4	206.86	200.02	6.84	2776.14	115.16	183.82	9	11	1	1	1	1	50.52	1	11	0*
175155	T6 20 m	06/05/18	01/08/18	4	4	27.44	25.04	2.40	2845.00	122.58	183.28	8	6	1	0	1	0	24.90	0*	8	0*
175156	T6 50 m	06/05/18	01/08/18	5	4	67.42	64.40	3.02	2823.19	106.18	323.75	22	14	1	1	1	1	119.11	0	9	0*

PRS™-Probe Supply Rate (μg/10cm²/burial length)																						
WAL	**Sample ID**	**Burial Date**	**Retrieval Date**	**Anion**	**Cation**	**Total N**	**NO_3^--N**	**NH_4^+-N**	**Ca**	**Mg**	**K**	**P**	**Fe**	**Mn**	**Cu**	**Zn**	**B**	**S**	**Pb**	**Al**	**Cd**
Method Detection Limits (mdl):						**2**	**2**	**2**	**2**	**4**	**4**	**0.2**	**0.4**	**0.2**	**0.2**	**0.2**	**0.2**	**2**	**0.2**	**0.4**	**0.2**
175157	T7 10 m	06/05/18	01/08/18	4	3	36.58	34.34	2.24	3570.12	94.69	68.14	16	125	7	4	7	2	273.99	5	13	0*
175158	T7 20 m	06/05/18	01/08/18	4	4	38.32	9.62	28.70	2236.90	127.22	154.37	17	15	3	2	1	0*	94.85	0	5	0*
175159	T7 50 m	06/05/18	01/08/18	4	4	157.92	148.90	9.02	2840.06	100.87	127.98	55	10	3	2	1	1	96.23	0	10	0*
175160	T8 10 m	06/05/18	01/08/18	4	4	117.56	108.58	8.98	2963.10	137.33	264.81	13	82	3	3	12	0	224.54	45	7	0*
175161	T8 20 m	06/05/18	01/08/18	4	4	31.88	21.08	10.8	2495.14	141.26	182.44	18	9	2	3	2	1	151.78	4	11	0*
175162	T8 50 m	06/05/18	01/08/18	4	4	37.32	28.02	9.30	2702.20	80.36	125.27	9	12	2	2	1	0*	70.88	2	7	0*
* Highlighted values are below method detection limits (mdl), but provided as measured.																					

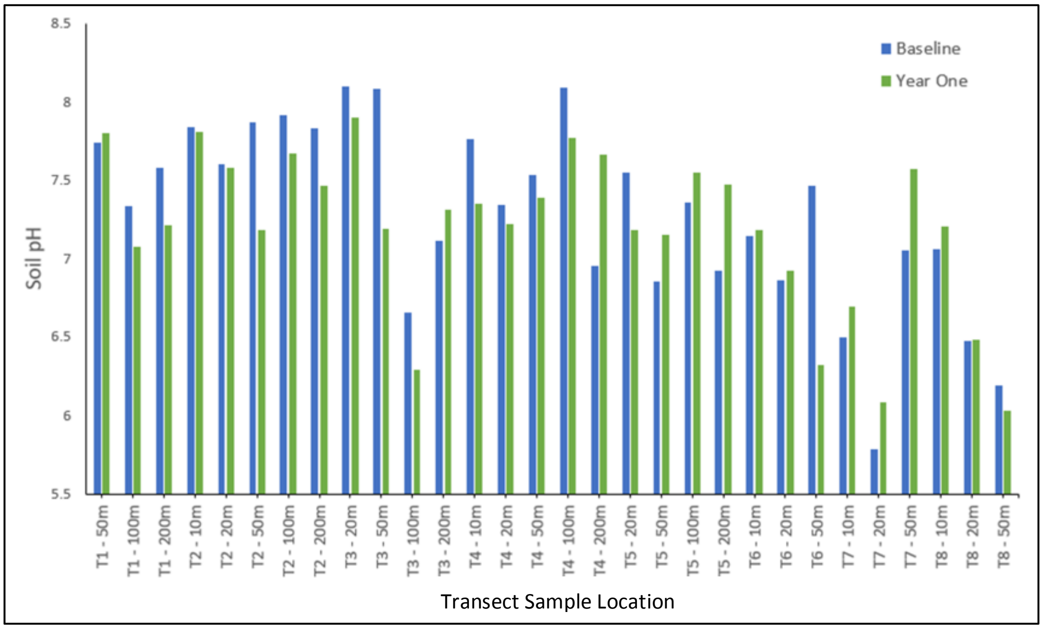
Comparison to Baseline

Soil pH

The pH of the soils were as expected for a neutral grassland habitat in both the Baseline and Year One, with little variation between the two sample years.

For the Oxford Meadows SAC sites (Transects T1 to T4) the pH for the 2018 samples reduced on average by 0.2 compared with the baseline recordings (**Figure 3.15**). Minimal change was observed between the baseline and Year One at Hook Meadow and The Trap Grounds SSSI (**Figure 3.15**), with an average increase in pH of 0.05 in Year One from the baseline.

Figure 3.15 Baseline and Year One, Comparison of Soil pH at Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI



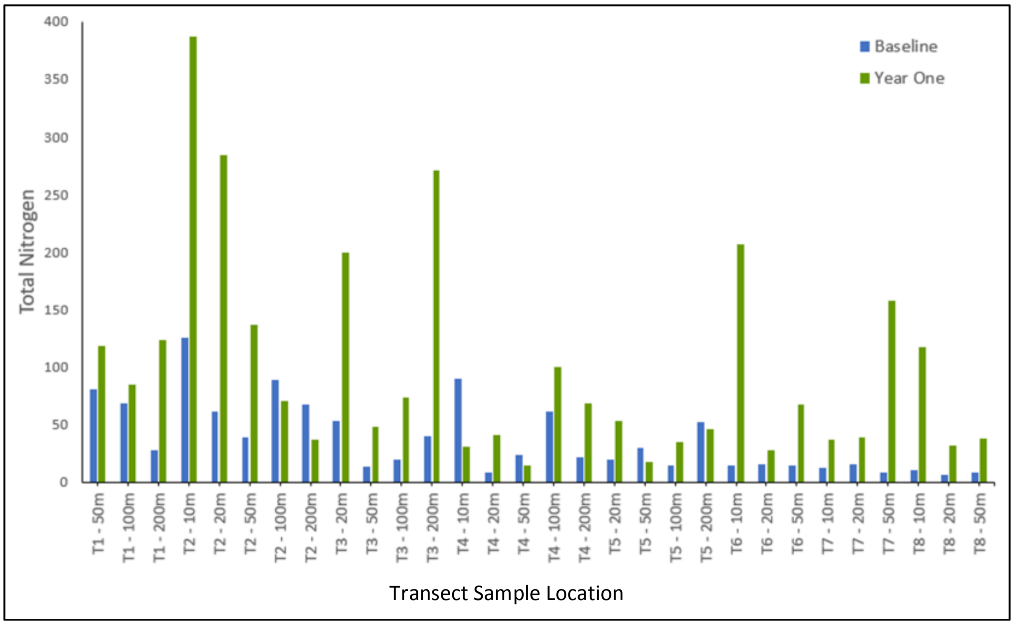
Total Nitrogen

There was no clear relationship between sample distance from source and levels of nitrogen in the soil, in either year of survey. At the Oxford Meadows SAC for both Year One and the baseline, Transect T2 experienced the highest levels of total nitrogen in the soil and Transect T4 the lowest levels (**Figure 3.16**). At Hook Meadow and The Trap Grounds SSSI the findings were more varied, Transect T6 experienced the highest levels in Year One, whereas they were in Transect T1 in the baseline. Transect T5 experienced the lowest levels in Year One, whilst they were in Transect T8 during the baseline survey.

The levels for Year One exceeded those recorded in the baseline at most sample points particularly along Transects T2 and T3 (Oxford Meadows SAC) and Transects T6, T7 and T8 (Hook Meadow and The Trap Grounds SSSI (see **Figure 3.16**).

Overall, total nitrogen levels for both the baseline and Year One are lower for the Hook Meadow and The Trap Grounds SSSI than for the Oxford Meadows SAC.

Figure 3.16 Baseline and Year One, Total Nitrogen Levels within the Soil



Other Elements

The findings were broadly similar across the two sample years, as listed below (all figures are rates in µg/10cm²/burial depth), although calcium levels decreased and magnesium levels increased, and the range of potassium increased.

- **Calcium** – Went from 21 of the 30 samples in the baseline having values of >3,000 to 24/30 samples being <3,000 in Year One.
- **Magnesium** – c48 to 174. Levels have slightly increased from: c46 – 108 in the baseline to c48 – 174 in Year One.
- **Potassium** – Range significantly increased with a maximum value of 192 in the baseline to 1,007 in Year One, and with 15/30 samples in Year One > 192.
- **Iron** – The maximum value had reduced from 394 in the baseline to 125 in Year One, with 18/30 samples having values of 20 or less in the baseline, to 25/30 samples with values of <20 in Year One.
- **Manganese** – the Year One levels showed a slight increase from the baseline, in which values did not exceed 6. However, 29/30 of the Year One samples had values <9.

- **Copper** – The overall range of values in copper ranged from 0 to 9 in the baseline compared to 0 to 7. However, the number of locations with values of <2 reduced to 21 in Year One from 25/30 in the baseline.

- **Zinc** – levels reduced with 25/30 samples with values of <4 in Year One, compared to 23 in the baseline.

- **Sulphur** – The maximum reduced from 1034 in the baseline to 274 in Year One, with values <200 for 26/30 sites in Year One.

- **Lead** – levels increased from 0 to 20 in the baseline to 0 to 45 in Year One, although with the exception of the higher value on Transect 8), many of the other levels were lower than the baseline.

- **Aluminium** – the range shortened between sites and the maximum values decreased (38 in the baseline and 22 in Year One).

Differences in rates between the years may reflect the substantial variation in rainfall between the two survey years(1)(2) as soil moisture can affect solubility of soil minerals and diffusivity of irons in soil solution. The rainfall during May of both years exceeded the long term average of 57.1mm. The rainfall for June 2018 (2.5 mm) was substantially lower than 2014 (36.9mm) and in both years was lower than the long term June average of 48.0 mm. The reverse was true in July 2018, with 23.2 mm of rainfall compared with 3.4 mm in July 2014, both less than the long term July average of 48.9 mm.

For example, the higher potassium rates may reflect the drier conditions in 2018, with displacement of potassium by more strongly held elements such as calcium and magnesium occurring in wetter conditions (Hartsock & Bremer, 2018(3)), such as those in 2014. Similarly, less iron is taken up by plants in wetter conditions (as water traps carbon dioxide and bicarbonates) and iron is therefore, retained in the soil, hence the higher rates in 2014. Sulphur can also be higher under saturated conditions.

(1) https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcpn7mp10
(2) https://www.metoffice.gov.uk/pub/data/weather/uk/climate/stationdata/oxforddata.txt
(3) Hartsock, J, A. and Bremer. E., (2018) *Nutrient supply rates in a boreal extreme-rich fen using ion exchange membranes*, Ecohydrology, Vol 11, No. 7

4 RAIL AND ROAD TRAFFIC FINDINGS

4.1 INTRODUCTION

The overarching purpose of the road and rail traffic analysis is allow for the attribution of the relevant proportions of the recorded nitrogen deposition as a result of the operation of EWR Phase 1 and its associated traffic effects.

The form of Condition 31 takes a precautionary approach based on the assumption that the operation of the railway and changes to road traffic movements on the A34(T) and A40 would occur as a result of the opening of Oxford Parkway Station, which could lead to a reduction in air quality on Oxford Meadows SAC. As Hook Meadow and The Trap Grounds SSSI is bordered by the railway but not close to major roads, road traffic information is not relevant to Condition 32.

4.2 RAIL PASSENGER YEAR ONE FINDINGS

Rail Passenger Services

Based on the December 2017 timetable there were typically up to 81 passenger trains a day used the Bicester to Oxford line, with an additional six freight trains. The number of passenger trains using the Bicester to Oxford line represents only a small proportion of the total train movements on the Oxford to Banbury mainline, which carries both passenger and freight trains. The mainline line runs adjacent to Hook Meadow and Unit 1 of The Trap Grounds and parallel to the EWR Phase 1 line along much of the length of Unit 2 of The Trap Grounds.

There has been little change to the service levels and patterns between 2017 and 2020 and it is reasonable to assume there will be no further significant increases in services in future years. The current service pattern, as of January 2020, is 83 passenger services and six freight services per day. This is considerably lower than the projections made, when the planning conditions were imposed, which were that, from 2020 onwards, EWR Phase 2 services would also be running on the line (1).

The assessment also assumed that there is unlikely to be any future change to the currently available DMU and locomotive fleet using the Bicester to Oxford railway. This is a cautious assumption, since over time, there are likely to be new diesel designs brought into service, which are either more fuel efficient and lower emissions or will incorporate ammonia abatement. In the longer term, there is the prospect of diesel-electric hybrids or hydrogen powered units.

(1) The predictions provided in evidence at the public inquiry were for 146 passenger trains and six freight trains in 2020 with freight numbers increasing from 2027 to 25 per day.

In accordance with the Scheme of Further Assessment emissions from mainline train operations are considered to be part of the background air quality and the assumption is that the mainline traffic is unchanged from the baseline survey.

Rail Passenger Surveys

Rail passenger surveys were undertaken on Chiltern Railways' services between Bicester Village and Oxford in order to determine how train passengers had travelled to their departure station ie. mode of travel and the proportion travelling to the stations via either the A34(T) or the A40 or both. The surveys when combined with operators' ticket data provided accurate information on daily passenger movements on the A34(T) and A40. The surveys also determined whether rail passengers had changed their travel arrangements since the opening of EWR Phase 1 and how they previously travelled before it opened.

The surveys were undertaken from October 2017, two years after Oxford Parkway station opened and 10 months after services started running into Oxford. As such, they reflect the full extent of likely post-scheme changes in travel habits.

The greatest impact of rail passengers on the A34(T) and A40 is from those EWR Phase 1 passengers using Oxford Parkway station.

The survey methodology is described in detail in Section 2.6 and supporting rail passenger survey information is provided in **Annex G**.

Rail Passenger Numbers

Table 4.1 sets out the daily passenger numbers for the days when passenger surveys were undertaken and the annual average of daily passenger numbers. These were extracted from ticket sales data provided by the train operators. The ticket data for Oxford station covers both GWR and Chiltern Railways services, while that for other stations is just for Chiltern Railways. **Table 3.19** shows an annual average of daily rail passengers of around 2,430 using Oxford Parkway station and 2,690 daily passengers using Bicester Village.

Table 4.1 Year One Daily Passenger Numbers, Ticket Data Summary

Station	19 October 2017	9 January 2018	17 April 2018	5 July 2018	Annual Average Daily Rail Passengers
Oxford	5,733	6,434	5,723	5,937	**5,957**
Oxford	2,366	2,290	2,329	2,742	**2,432**
Bicester	2,394	2,954	2,631	2,794	**2,693**
Note: Oxford data is just for London/Reading/Didcot trips on GWR service, and all stations on Chiltern London Route, Oxford Parkway/Bicester data is for all stations on London Route.					

Rail Passenger Travel Patterns

A34(T) and A40 Impact

Figure 4.1 shows the origins of passengers who accessed stations by car and routed along the relevant sections of the A34(T) and A40. This data is summarised in **Table 4.2**.

Figure 4.1 Home Locations of Rail Passengers Routeing via the A34(T) and A40

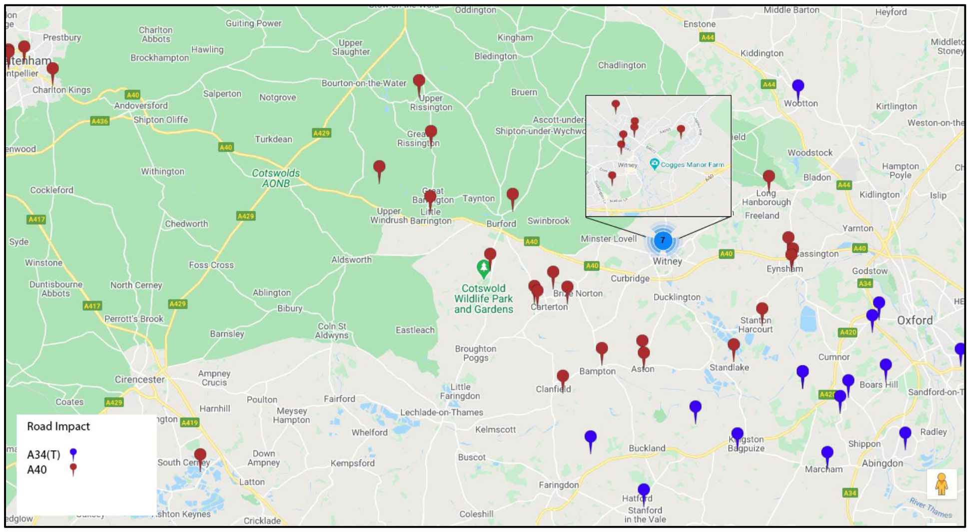


Table 4.2 Year One Origins of Passengers who Travelled to the Station by Car on the A34(T) and A40

Station	A34(T)	A40
Oxford	North of Oxford	West of Oxford
Oxford Parkway	South of Oxford, South east Oxfordshire	West of Oxford
Bicester Village	-	-

Table 4.3 shows the percentage of rail passenger trips for each station travelling by car, taxi or motorcycle using the relevant sections of the A34(T) and A40.

Table 4.3 Year One – Proportion of Rail Passengers Interviewed using the A34(T) and A40

Station Start	Number of Interviews	Total Traveling by Car/ Taxi/MC	Routeing along A34(T)	% of All Trips	Routeing along A40	% of All Trips
Oxford	2063	313	2	0.10%	9	0.44%
Oxford Parkway	559	265	16	2.86%	27	4.83%
Bicester Village	712	203	0	0.00%	0	0.00%

The greatest impact of rail passengers on the A34(T) and A40 is from those passengers using Oxford Parkway station, even then they only account for 2.9% of all trips on the A34(T) and 4.8% of all trips on the A40. The impact on the A34(T) and A40 from those passengers using Oxford station is minimal accounting for less than 0.5% of all passenger movements. EWR Phase 1 passengers using Bicester Village station have no impacts on the A34(T) or A40.

The small number of passengers at Oxford, who identified travelling by car and impacting on the A34(T), had journeys and locations that would allow them to use Oxford Parkway. In the future such passengers could switch from Oxford to Oxford Parkway, resulting in a slightly reduced impact on the A34(T).

Passengers using Oxford Parkway who used the A34(T) either previously used Didcot Station, routed from south of Oxford, used the Bus (X90 or P&R), or used Bicester Station. Some rail passengers who previously drove to Oxford Station from the south of the City now drive to Oxford Parkway via the A34(T).

Passengers using Oxford Parkway who route via the A40 either previously used Oxford Station from destinations to the west of Oxford; other stations, including Cheltenham and Didcot; or previously travelled to their destination by car.

Comparison of Year One with Baseline

Table 4.8 in **Annex G** sets out a summary of the change in travel habits of interviewed passengers. Passengers using Oxford Parkway in Year One, who travel on the A34(T) had either previously used Didcot station (instead of Oxford station), used the bus or used Bicester station. The passengers who previously drove to Oxford station from areas outside of Oxford now drive to Oxford Parkway station instead.

Passengers using Oxford Parkway in Year One, who have changed their travel patterns either previously used Oxford station travelling from the west (46%), used other stations including Cheltenham, Didcot and local stations or used a bus or cycled (32%), or previously travelled direct to their destination by car (9%).

4.3 ROAD TRAFFIC

The botanical and air monitoring surveys were designed to assess the effects of pollution from the A40 and A34(T), as these are the two main sources of road traffic pollution. Absolute counts of traffic were obtained for both roads to show the traffic flows that pass the designated sites.

The purpose of the surveys is to estimate the change in road traffic movements that has occurred on the A34(T) and A40 adjacent to Oxford Meadows SAC following the introduction of the new station at Oxford Parkway which could potentially have a bearing on air quality within the relevant parts of the SAC.

Supporting road traffic information is provided in **Annex G.**

Year One Findings of Daily Traffic using A34(T) and A40 from Rail Passengers

The number of rail passengers who travelled to/from Oxford, Oxford Parkway or Bicester Village Stations by car, taxi or motorcycle who routed along the A34(T) or A40, has been calculated by applying the percentages derived from the rail passenger interviews to the estimated annual average daily passenger numbers for each station.

The annual average daily traffic flows (two way) from rail passengers using either Oxford or Bicester Stations is 152 vehicles on the A34(T) and 286 vehicles on the A40.

The passenger surveys identified that a proportion of the above rail passenger trips which passed along the A34(T) and A40 had previously travelled by car for their entire journey. These trips can reasonably be discounted from the above totals to reflect the true impact on the two roads as a result of EWR Phase 1. **Table 4.4** shows the true impact on the A34(T) and A40 of the EWR Phase 1 discounting those who had previously driven.

Table 4.4 Year One, Rail Passenger Average Daily Traffic Flows on A34(T) & A40 (two-way) following discount of those that had previously driven

	Annual Average Daily Traffic Flows (two-way)
A34(T)	143
A40	255

Comparison of Year One to Baseline

Table 4.5 shows the impact of EWR Phase 1 on traffic flows on the A34(T). Annual average daily traffic flows on the A34(T) can be seen to reduce by 59 vehicles with EWR Phase 1 compared to the baseline. Annual average daily traffic flows on the A40 can be seen to increase by 91 vehicles with EWR Phase 1 over the baseline.

Table 4.5 Traffic Impact of EWR Phase 1 on A34(T) and A40 Traffic Flows

	Rail Passenger Average Daily Traffic Flows		Change
	Baseline	Year One	
A34(T)	202	143	-59
A40	164	255	+91
Note: Calculated from values in Tables 3.13 and 4.14 in **Annex G**			

The increase in traffic flows on the A40 is significantly lower than had been predicted at the time of the public inquiry of an increase in traffic on the A40 of some 750 vehicles (two-way) as a consequence of EWR Phase 1.

Tables 4.6 and **4.7** show the 2017/2018 AADT traffic flows on the A34(T) and A40 for both with and without EWR Phase 1. The percentage impacts of EWR Phase 1 are also identified.

Table 4.6 2017/ 2018 AADT Traffic Flows on the A34(T) With and Without EWR Phase 1

Direction	AADT Traffic Flow without EWR Phase 1	AADT Traffic Flow with EWR Phase 1	Difference	% Impact
Northbound	37,579	37,549	-30	-0.08%
Southbound	38,322	38,293	-29	-0.08%
Total	**75,901**	**75,842**	**-59**	**-0.08%**

Table 4.7 2017 /2018 AADT Traffic Flows on the A40 With and Without EWR Phase 1

Direction	AADT Traffic Flow without EWR Phase 1	AADT Traffic Flow with EWR Phase 1	Difference	% Impact
Northbound	11,990	12,036	+46	+0.39%
Southbound	11,203	11,248	+45	+0.39%
Total	**23,193**	**23,284**	**+91**	**+0.39%**

Table 4.6 shows that the traffic impacts of EWR Phase 1 rail passengers on the A34(T) equates to a small reduction in traffic flows of less than 1% due to are roughly comparable between the baseline (0.21% to 0.40%) and Year One (0.15% to 0.39%) across the year. The impacts on the A34(T) have however changed, with passengers from the west of Oxford, in towns such as Witney and Eynsham, now not using this stretch of the A34(T), or to a lesser degree, as they are using Oxford Parkway station instead of Oxford station.

Table 4.7 shows that the traffic impacts of EWR Phase 1 rail passengers accounts for a 0.39% increase of traffic flows on the A40, associated with the use of Oxford Parkway station by more people living to the west of Oxford.

Conclusion

The survey results indicate that EWR Phase 1, which includes the new station at Oxford Parkway, has resulted in an increase in overall rail passenger numbers and changes to passengers travel patterns.

The daily number of rail passengers routeing via the A34(T) has reduced following the introduction of the Scheme. This is primarily a result of rail passengers living to the west of Oxford, in towns such as Witney and Eynsham, re-routing to use the new Oxford Parkway Station rather than Oxford Station, as they had previously done.

The daily number of rail passengers routeing via the A40 has increased slightly as it has attracted more people living to the west of Oxford to use Oxford Parkway Station. The level of increase in traffic flows on the A40 as a result of the Scheme is however small, at less than 100 vehicles (two-way) per day. This level of traffic is not considered to be material given the overall traffic flows on the A40 on a typical day, representing less than 0.4% of the average daily flow.

The small increase in traffic on the relevant section of the A40 is much less than had been predicted from the earlier modelling, which had predicted an increase in traffic on the A40 of some 750 vehicles (two-way) as a consequence of EWR Phase 1.

The A40 has not seen any significant increase in overall traffic flows following the introduction of the Scheme with AADT flows (two-way) increasing by only 300 vehicles between 2014/15 and 2017/18. This further suggests that EWR Phase 1 has not had a material impact on traffic flows on the A40 and also helps to validate the results of the rail passenger surveys.

5 SUMMARY

5.1 INTRODUCTION

This section summarises the findings of the Year One surveys undertaken at the Oxford Meadows SAC and at Hook Meadow and The Trap Grounds SSSI over the period September 2017 to August 2018. It compares the Year One findings to the baseline conditions and draws conclusions on the extent to which criteria and thresholds for mitigation have been met, or exceeded.

5.2 SCOPE AND PURPOSE OF THE MONITORING

The Year One monitoring has been carried out in accordance with the approved Scheme of Further Assessment required under Conditions 31 and 32 included as part of the deemed permission to protect the Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI from harm by virtue of air pollution, in accordance with the precautionary approach advocated by NE.

The purpose of the monitoring is to demonstrate that the operation of EWR Phase 1, including the associated road traffic effects, has not caused harm to the qualifying interests or species for which the Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI were designated.

Emissions from road traffic using the A40 and the A34(T) impact on the 'lowland hay meadow' sensitive habitat on the adjoining parts of the Oxford Meadows SAC. In the case of trains using the Oxford to Bicester line and the mainline, the relevant designated sensitive habitat is the 'lowland hay meadow' on parts of the Hook Meadow and The Trap Grounds SSSI. Those parts of the Oxford Meadows SAC close to the EWR Phase 1 do not support sensitive habitat, for the purposes of Condition 31.

The aim of the monitoring is to identify any signs of change which could be attributable to EWR Phase 1 prior to any significant effect resulting.

5.3 CHANGES IN RAIL AND ROAD TRAFFIC

Road Traffic

Annual average daily traffic flows from rail passengers using the A34(T) reduces as a consequence of EWR Phase 1. For the A40 there is a marginal increase of less than 100 vehicles (two-way) per day which is not considered to be material, and is significantly less than that which was presented at the public inquiry.

The greatest impact of rail passengers on the A34(T) and A40 is from those passengers using Oxford Parkway station, even then they only account for 2.9% of all trips on the A34(T) and 4.8% of all trips on the A40. The impact on the A34(T) and A40 from those passengers using Oxford station is minimal accounting for less than 0.5% of all passenger movements. EWR Phase 1 passengers using Bicester Village station have no impacts on the A34(T) or A40.

Rail Traffic

There has been little change to the service levels and patterns between 2017 and 2020 and it is reasonable to assume there will be no further significant increase in services in the next few years.

5.4 CHANGES IN AIR QUALITY

The air quality survey has shown improvements in air quality at all monitoring locations, reflecting a wider improvement in the Oxford area. This is principally due to extensive measures implemented in Oxford City to reduce emissions. The NO_2 levels on the Oxford Meadows SAC in Year One were on average 4 µg m^{-3} lower than the levels measured during the baseline survey, which correspond to a 19% reduction on average. This is consistent with the overall 20% decrease in NO_2 concentrations in the Oxford area over the years preceding the survey in Year One. As in the baseline survey, a gradual decline in NO_2 levels was observed, the further away the survey location was from the pollution source.

On Hook Meadow and The Trap Grounds SSSI, the NO_2 levels were on average 1.8 µg m^{-3} lower than the levels measured during the baseline survey, which corresponds to an 18% reduction on average. There was some variation between the levels at the closest and furthest points from the source on Transects T6, T7 and T8 where levels are generally higher at 20 m from the source than at 10 m. This pattern was similar to the baseline survey.

Given the magnitude of the overall changes to the background levels compared with the small changes in road and rail traffic associated with EWR Phase 1 the extent to which EWR Phase 1 has, in itself, contributed to a change in NO_2/NO_x levels on the Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI is marginal.

The NO_x levels on the Oxford Meadows SAC are all below the 30 µg m^{-3} critical level, except for the point on Transect 4 within 50 m of the A34(T). On Hook Meadow and The Trap Grounds SSSI, all of the estimated NO_x levels are below the critical level.

The nutrient nitrogen deposition on the Oxford Meadows SAC is significantly below 70% of the critical load (which would be 14 kgN ha^{-1} yr^{-1}). The maximum deposition was calculated to occur on Transect T4, at 10 m from the A34(T), with a load representing 32% of the critical load. Nutrient nitrogen deposition is therefore not significant on Oxford Meadows SAC.

Similarly, on Hook Meadow and The Trap Grounds SSSI, the loads were significantly below 70% of the critical load. The maximum deposition was predicted to occur on Transect T8, with a load representing 17% of the critical load. Nutrient nitrogen deposition is therefore not significant on Hook Meadow and The Trap Grounds SSSI.

The calculated acid deposition loads for both Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI do not reach 0.1% of the MinCLminN critical load and are, therefore, insignificant.

5.5 CHANGES IN QUALIFYING INTERESTS AND SPECIES

Plant Tissue

The foliar nitrogen concentration of many plants has been found to be related to atmospheric inputs, and thus can be used as an indicator of nitrogen deposition. Samples were taken from three of the main qualifying interest plant species at each sample location unless fewer than three of these species occurred, in which case samples were collected from the more common plant species present.

The total nitrogen content ranged between 0.5% to 3.3% (wet weight), $\delta^{15}N$ values ranged from approximately -2 to +11, and total phosphorus levels (mg kg^{-1}) ranged from approximately 500 to 4,300. However, there were no consistent patterns across species and/or transects.

A comparison of the two data sets, shows that the total nitrogen content percentages (wet weight), were largely similar at both the Oxford Meadows SAC and at Hook Meadow and The Trap Grounds SSSI. There was no consistent pattern between the baseline and Year One findings for the total phosphorus, or the $\delta^{15}N$ values.

The results of the plant tissue analysis do not show any direct relationship between the operation of EWR Phase 1 and changes in the total nitrogen content of plant tissue of qualifying interest plant species for which the Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI were designated.

Lichens

As other factors can lead to changes in the site flora (eg. flooding and grazing levels) and hence influence the findings from the analyses of plant tissues, the approach has included analysis of lichens, to remove these factors from the assessment. Lichens provide information relating to nitrogen accumulation in plant tissue acting as an indicator of exposure to airborne nitrogen.

The findings of the lichen monitoring recorded little change in pH following exposure. The nitrogen isotope ($\delta^{15}N$) analysis shows that many of the samples became less negative after exposure (ie. a positive effect), suggesting an influence of emissions from road/rail traffic.

The findings show that there is a low correlation between NO_2 and the %N accumulation in the lichens. The most conspicuous difference is between the effect of road and rail transport on %N accumulation in both species of lichen, with the highest %N accumulations recorded in Transect T2 (likely to be due to the road traffic on the A40) and lowest along Transect T7 (that is close to the EWR Phase 1 line).

There was however, little or no correlation with the findings of the NO_2 diffusion tube survey in terms of distance from the source. The reasons for this are unclear, but suggest that there are contributions other than the road / rail transport to %N in both lichen species.

In comparison with the baseline, the findings were broadly similar. There was little change in pH after exposure in either survey year, total nitrogen increased over both years, and the $\delta^{15}N$ ratios generally became less negative. The greater reductions in $\delta^{15}N$ in Year One after exposure at the Oxford Meadows SAC compared with the baseline, suggest that the lichens absorbed less nitrogen from airborne sources in Year One compared with the baseline survey.

Soil

The soil pH was as expected for neutral grasslands with pH levels ranging between 6 and 8 at both Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI.

The pH findings in Year One were similar to the baseline. The total nitrogen within the soil for Year One exceeded the levels recorded in the baseline. The patterns appeared similar to those recorded in the baseline surveys (ie. in Oxford Meadows SAC, transect T2 recorded the highest levels and transect T4 the lowest) and it was more variable across the SSSI transects. Neither the baseline nor Year One data displayed a clear relationship between distance from source along the transects and levels of total nitrogen in the soil.

As with the baseline survey findings, the Year One findings were generally within expected ranges. Some in Year One were higher / lower than expected and there was some variation in values between the baseline and Year One data sets. This may have been due to substantial differences in the rainfall in the survey periods in 2014 and 2018, especially in the months of June and July.

Both Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI are in the floodplain and are susceptible to flooding which, alongside variations in grazing regimes, can influence the levels of nitrogen in the soil. Given that there is no clear relationship between distance from source along the transects and levels of total nitrogen in the soil, it is likely that these other factors are having a greater influence on soil conditions than road or rail traffic.

5.6 CRITERIA AND THRESHOLDS FOR MITIGATION

The Scheme of Further Assessment defined a set of thresholds for air quality that would trigger the need for further investigation and potentially mitigation. The exceedance of these triggers alone does not necessarily mean that the effect on the habitat and species of interest will be significant. Instead, it provides an indication of where further investigation of the potential impacts of emissions from EWR Phase 1 may be required in order to determine whether there is the potential for significant harm to arise.

Generally, the proposed approach, as described in **Section 3.2**, is that, if, once EWR Phase 1 is operational, the changes in NO_x and deposited nitrogen <1 % of the Critical Level/Load, or >1 %, but <70% as a total concentration, and there is little change to the baseline findings of the lichen analyses, then the changes can be deemed to be insignificant, and no mitigation is likely to be needed.

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The Year One survey results show that the critical level of 30 $\mu g/m^3$ NOx is only marginally exceeded at some of the sample sites along Transect T4 in the Oxford Meadows SAC closest to the A34(T). The levels at these sample locations already exceeded the critical level as part of the baseline and it is clear that recorded levels in Year One were lower than those recorded during the baseline survey, a trend which is evident across all the sample locations.

The threshold value of 70% of the critical load is 14 kg N ha^{-1} yr^{-1}, and the nutrient nitrogen deposition on the Oxford Meadows SAC is well below this value. The maximum deposition predicted to occur on Transect T4 is at 10 m from the A34(T), with a load representing 32% of the critical load, and hence is insignificant on the Oxford Meadows SAC.

On Hook Meadow and The Trap Grounds SSSI, the levels are also well below 70% of the critical load. The maximum deposition predicted to occur on Transect T8, represents 17% of the critical load. Nutrient nitrogen deposition is therefore insignificant on Hook Meadow and The Trap Grounds SSSI.

The lichen analysis clearly demonstrated that the greater reductions in $\delta^{15}N$ in Year One after exposure at the Oxford Meadows SAC compared with the baseline, suggest that the lichens absorbed less nitrogen from airborne sources in Year One compared with the baseline survey.

Based on the Year One survey results, there is no evidence of any potential effects and no mitigation is required.

5.7 OVERALL CONCLUSION

The purpose of the monitoring programme is to demonstrate that the operation of EWR Phase 1 has not created air quality changes that could cause harm to the qualifying interests or species for which the Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI were designated.

The Year One monitoring results are extremely positive showing that there have been decreases in NOx levels at the transect sample locations since the baseline survey, reflecting a wider improvement in air quality in the Oxford area.

The NO_2 levels on the Oxford Meadows SAC in Year One were on average 4 $\mu g\ m^{-3}$ lower than the levels measured during the baseline survey, which correspond to a 19% reduction on average. On Hook Meadow and The Trap Grounds SSSI, the NO_2 levels were on average 1.8 $\mu g\ m^{-3}$ lower than the levels measured during the baseline survey, which corresponds to an 18% reduction on average. Similar rates of decrease are expected to occur in the future, given the focus on both national and local initiatives to reduce emissions, generally, and in the Oxford area, in particular.

The rail passenger and road traffic surveys have demonstrated that EWR Phase 1 can only have had the most marginal influence on the ambient air quality at either of these designated sites.

It is evident from the Year One monitoring results, that the operation of EWR Phase 1 has not created air quality changes that could cause harm to the qualifying interests or species for which the Oxford Meadows SAC and Hook Meadow and The Trap Grounds SSSI were designated.