

Maximum building heights

- 31.0 metres AOD
- 32.0 metres AOD
- 33.0 metres AOD
- 35.0 metres AOD
- 36.0 metres AOD
- 37.0 metres AOD
- 38.0 metres AOD
- 41.0 metres AOD
- See Parameter Plan 05 for maximum AOD height

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Notes:

Camera information:
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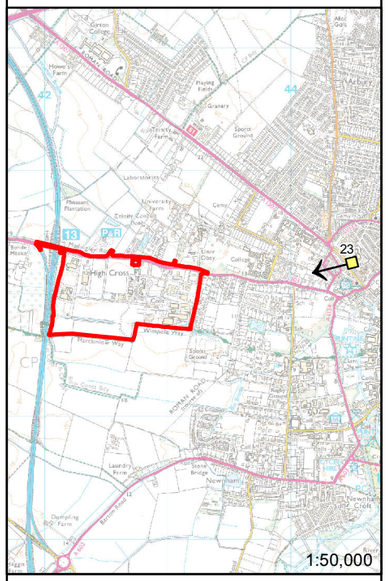
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2016-02-25, weather as per photographs, direction as per photolocation plan

Viewpoint height:
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Title
Landscape
Photomontage Views
Viewpoint 23 - Winter, Proposed
Sheet 32 of 32

Sheet Size	Original Scale	Designed / Drawn	Checked	Authorised
A3	N/A	SJD Date 14/06/17	JW Date 14/06/17	DP Date 14/06/17

Drawing Number: 5137998_CAM_LV_PM23WP
Rev: 01

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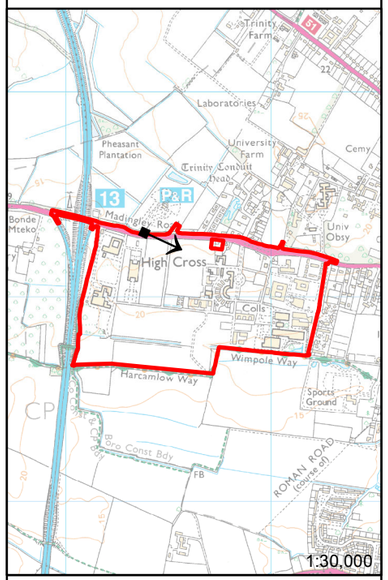
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Title
Landscape
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Madingley Road Viewpoint - 24 - Existing
Sheet 1 of 6

Sheet Size	Original Scale	Designed / Drawn	Checked	Authorised
A3	N/A	SJD Date 14/07/17	HM Date 14/07/17	DP Date 14/07/17

Drawing Number
5137998_CAM_LV_PMMR1E

Rev
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Maximum building heights

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- 33.0 metres AOD
- 35.0 metres AOD
- 36.0 metres AOD
- 37.0 metres AOD
- 38.0 metres AOD
- 41.0 metres AOD
- See Parameter Plan 05 for maximum AOD height

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Notes:

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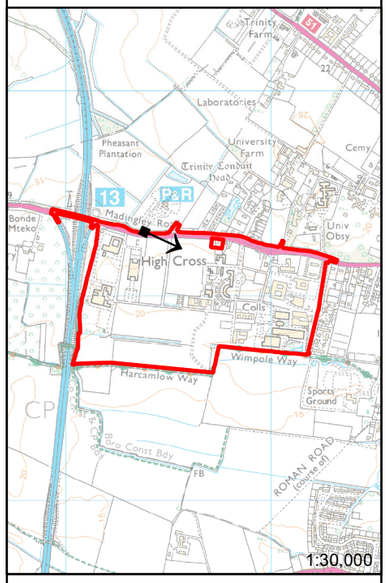
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Title
Landscape
Photomontage Views
Madingley Road Viewpoint - 24 - Proposed
Sheet 2 of 6

Sheet Size	Original Scale	Designed / Drawn	Checked	Authorised
A3	N/A	SJD Date 14/07/17	HM Date 14/07/17	DP Date 14/07/17

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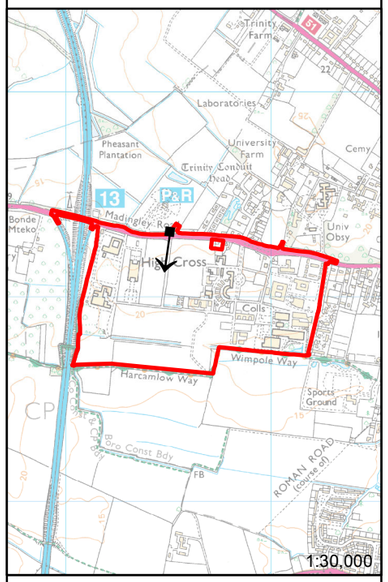
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Title
Landscape
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Madingley Road Viewpoint - 25 - Existing
Sheet 3 of 6

Sheet Size	Original Scale	Designed / Drawn	Checked	Authorised
A3	N/A	SJD Date 14/07/17	HM Date 14/07/17	DP Date 14/07/17

Drawing Number: 5137998_CAM_LV_PMMR2E
Rev: 01

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Maximum building heights

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- 32.0 metres AOD
- 33.0 metres AOD
- 35.0 metres AOD
- 36.0 metres AOD
- 37.0 metres AOD
- 38.0 metres AOD
- 41.0 metres AOD
- See Parameter Plan 05 for maximum AOD height

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Notes:

Camera information:
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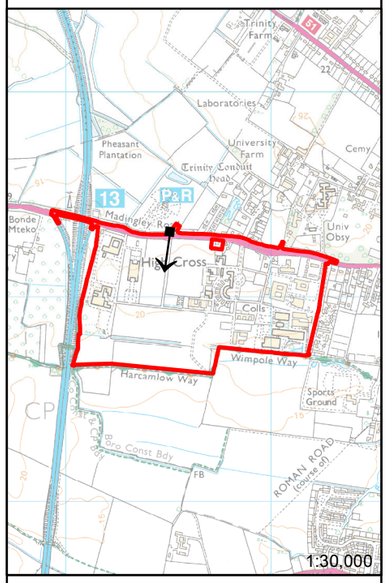
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Title
Landscape
Photomontage Views
Madingley Road Viewpoint - 25 - Proposed
Sheet 4 of 6

Sheet Size	Original Scale	Designed / Drawn	Checked	Authorised
A3	N/A	SJD Date 14/07/17	HM Date 14/07/17	DP Date 14/07/17

Drawing Number: 5137998_CAM_LV_PMMR2P
Rev: 01

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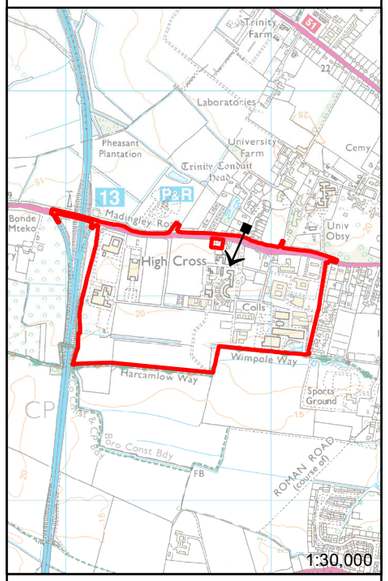
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Title
Landscape
Photomontage Views
Madingley Road Viewpoint - 26 - Existing
Sheet 5 of 6

Sheet Size	Original Scale	Designed / Drawn	Checked	Authorised
A3	N/A	SJD Date 14/07/17	HM Date 14/07/17	DP Date 14/07/17

Drawing Number
5137998_CAM_LV_PMMR3E

Rev
01

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Maximum building heights

- 31.0 metres AOD
- 32.0 metres AOD
- 33.0 metres AOD
- 35.0 metres AOD
- 36.0 metres AOD
- 37.0 metres AOD
- 38.0 metres AOD
- 41.0 metres AOD
- See Parameter Plan 05 for maximum AOD height

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Notes:

Camera information:
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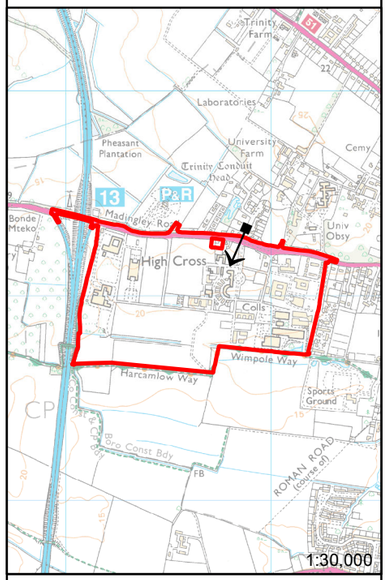
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Title
Landscape
Photomontage Views
Madingley Road Viewpoint - 26 - Proposed
Sheet 6 of 6

Sheet Size	Original Scale	Designed / Drawn	Checked	Authorised
A3	N/A	SJD Date 12/09/17	HM Date 12/09/17	DP Date 12/09/17

Drawing Number: 5137998_CAM_LV_PMMR3P
Rev: 02

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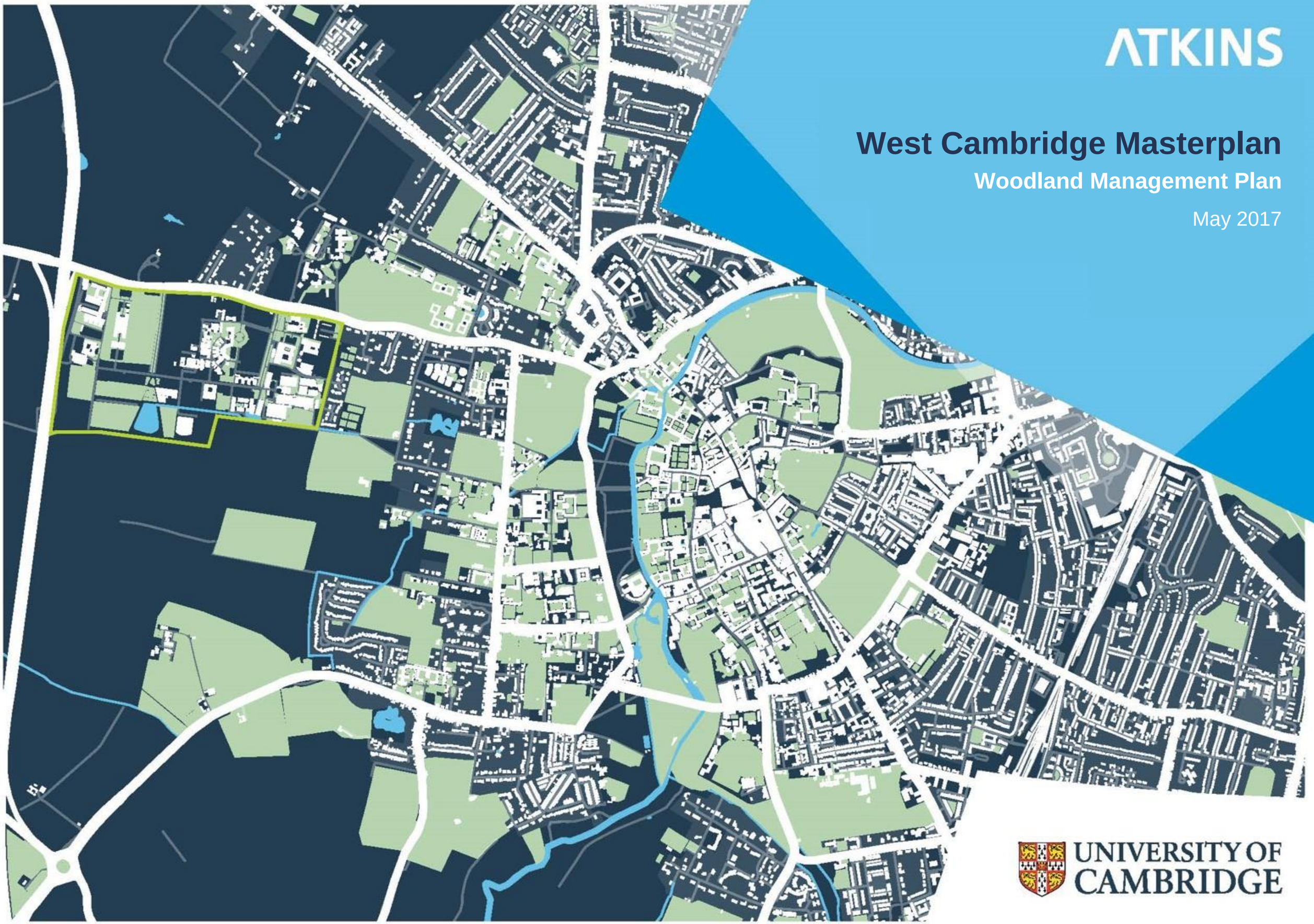
Appendix 8.4 Woodland Management Plan

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West Cambridge Masterplan

Woodland Management Plan

May 2017



UNIVERSITY OF CAMBRIDGE

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Document History

Job number: 5137998			Document ref: 5137998-WMP			
Revision	**Purpose description**	**Originated**	**Checked**	**Reviewed**	**Authorised**	**Date**
Rev 1.0	Draft	TD	AA	DP	PW	07/12/16
Rev 2.0	Draft	TD	AA	DP	PW	22/12/16
Rev 3.0	Draft	TD	AA	DP	PW	11/01/17
Rev 4.0	Draft	TD	AA	DP	PW	16/02/17
Rev 5.0	Draft	TD	AA	DP	PW	26/04/17
Rev 6.0	Draft	TD	AA	DP	PW	12/05/17
Rev 7.0	Final	TD	AA	DP	PW	16/05/17

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1. Introduction

1.1 Terms of reference

1.1.1 Atkins Limited (Atkins) has been commissioned by the University of Cambridge to produce a 'Woodland Management Strategy' for boundary tree groups at the West Cambridge site as part of the outline planning application (OPA) for the development of the West Cambridge site.

1.1.2 This 'Woodland Management Strategy' has been prepared to provide management principles and objectives for the tree and shrub groups which are to be retained on the boundaries of the West Cambridge site, and occasional groups which are more central that have been identified for inclusion by the council. This is to address concerns from Cambridge City Council over their lack of management. Similarly, if a management regime is not implemented then the condition of the groups will deteriorate, meaning they will no longer meet the requirements of their particular landscape function.

1.1.3 The requirements for this strategy were identified as an action during a Post Submission workshop with Cambridge City Council on 1st November 2016.

1.1.4 The council made reference to the production of an 'Existing Vegetation Management Strategy', to include; the identification of all existing vegetation; the condition of the vegetation; whether the vegetation is identified for removal at Outline stage; and protection of existing vegetation.

1.1.5 All of this information has already been produced as part of the Outline Planning Application and is contained within the produced Arboricultural Impact Assessment and accompanying Tree Protection Plans for the Outline Planning Application. Accordingly, this strategy focuses on the following information:

- Identify landscape function of woodland tree groups.
- Preparation of woodland management principles for the boundary woodland and tree groups recorded on the West Cambridge site, as these areas cover potential conflicts with the proposed building zones on site and they are important for screening functions to views in and out of the site;
- The management principles apply solely to the woodland tree groups that are growing directly on the boundaries of the site and incorporating a mixture of tree and shrub species. It omits individual trees or tree groups containing individually recorded trees because these have not been planted or growing as woodland screens.
- Capturing data in line with the UK Woodland Assurance Standard Third Edition (version 3.1) (http://ukwas.org.uk/wp-content/uploads/2012/05/UKWAS-Third-Edition-version-3.1-20122.pdf) which is a published certification standard defining appropriate and effective woodland management for the UK;
- The assessment of each woodland or group edge for canopy tree species, i.e. those that are capable of being long lived. The tagging of pertinent trees by the Arboriculturists for plotting by a land survey team that will follow on behind the arboriculturists to make sure these trees are plotted to influence the offsets required for the building zones .

1.1.6 All of this information forms part of this 'Woodland Management Strategy' report and is supplemented by plans covering their locations.

1.2 Tree groups

1.2.1 The following boundary woodland and tree groups are included within this strategy, the reference numbers correspond to the Atkins Arboricultural Impact Assessment and Tree Protection Plans for the West Cambridge site;

- Woodland references – W1, W2, W3A-B & W4A-C which run along part of the southern boundary and all of the western boundary;
- Tree groups – G019, G041, G090, G105, G116, G016A-E, G003, G002, G024A which run along the site's north, south and east boundaries.

1.3 Scope of works

1.3.1 This report presents information captured on 17th & 18th November 2016 by Atkins' Arboricultural Team Leader Tom Dale BSc (Hons), Cert Arb (L6 (ABC), M.Arbor.A, and Atkins' Landscape and Arboricultural Consultant Adam Atkins, BA (Hons) CMLI, TechCert (ArborA).

1.4 Purpose of plan

1.4.1 This report covers the long-term management of specific woodland or tree group within the West Cambridge site for the woodland/trees to continue to meet their landscape functions, including screening, and to provide the setting for longer lived tree species to thrive and develop into large mature specimens of cultural, arboricultural and landscape significance.

1.4.2 If these trees or woodlands are left unmanaged the condition of the vegetation will deteriorate over-time. This is through competition for sunlight and resources. The effects of which will inhibit the slower growing species and lead to slender trees and shrubs of limited crown extents, reducing screen functions and significantly increasing the risk of tree failures through wind-throw and a loss of vitality.

1.4.3 This management plan will also provide a central document for the University to adopt for the site and will form the basis on which future developers need to adhere to should they wish to build on a plot within the West Cambridge site. Placing the emphasis on producing sympathetic designs on which to retain existing trees/woodlands, rather than blanket removal.

2. Method

2.1 Survey method

2.1.1 The survey was a non-invasive ground level assessment looking specifically at the tree and shrub populations within the groups.

2.1.2 Tree groups were assessed by Atkins' Arboriculturists to identify the following information in line with the UK Woodland Assurance Standard Third Edition (version 3.1) (http://ukwas.org.uk/wp-content/uploads/2012/05/UKWAS-Third-Edition-version-3.1-20122.pdf) which is a published certification standard defining appropriate and effective woodland management for the UK;

- Define long-term management principles for the woodland or group;
- Assessment of the relevant aspects of the woodland or group resource – e.g. species, age, vitality, spacing, current management;
- Identify any special characteristics and sensitivities of the woodland or group and appropriate treatments;
- Set objectives;
- Rationale for management prescriptions;
- Outline the planned felling and regeneration over the next 20 years – including specific measures to enhance, where possible, the areas assessed. The 20 years is the maximum period of time the guidance recommends given the significant changes that can occur within that 20 year period, most notably the potential arrival and spread of Ash dieback disease which could result in the mortality of the majority of Ash trees on site.

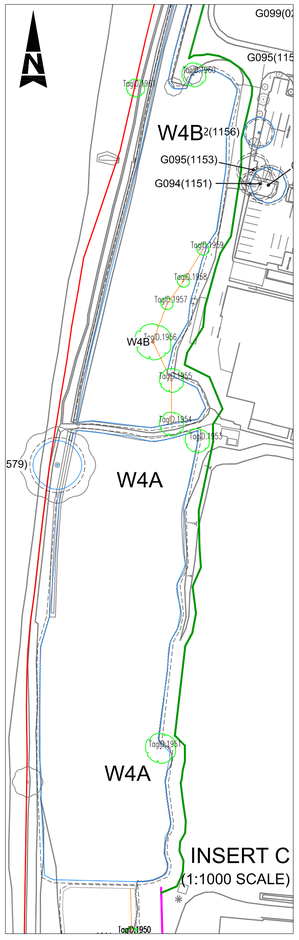
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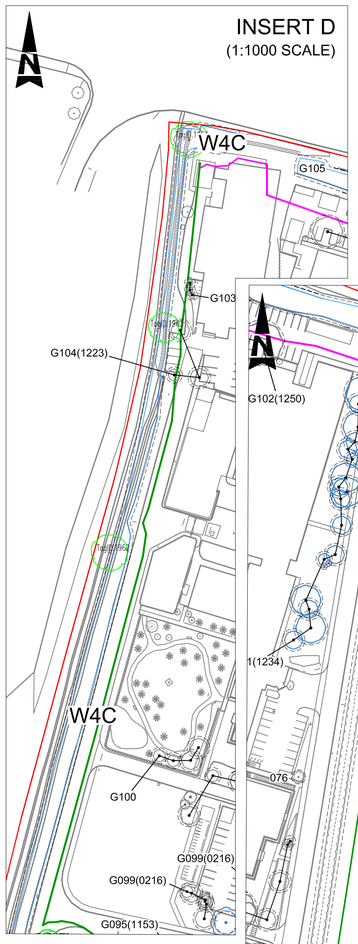
2.2.1 The survey is an assessment of the woodland or group as a whole, meaning individual trees were not inspected to inform on their retention values or safe useful life expectancies. Where dangerous or dead trees were identified, reasonable management prescriptions have been made as part of this strategy to cover the required works.

2.2.2 The survey did not involve the tagging of all the individual canopy trees along their boundaries with the building zones, as this would have resulted in a significant number of trees. Instead the survey picked up canopy tree species at intervals of approximately 5m – 10m. This is deemed reasonable in order to gain an average offset of the larger trees from the woodland edges.

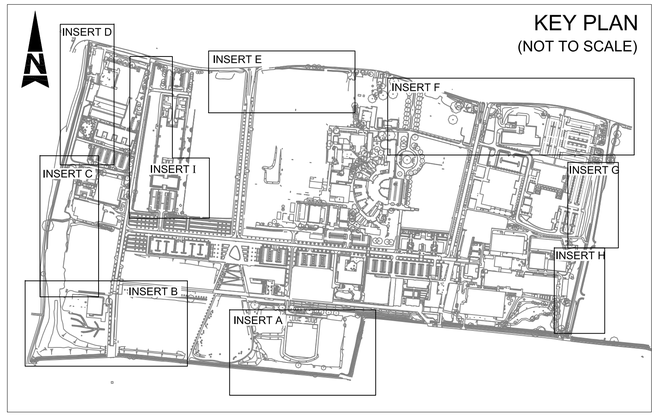
2.3 Survey locations

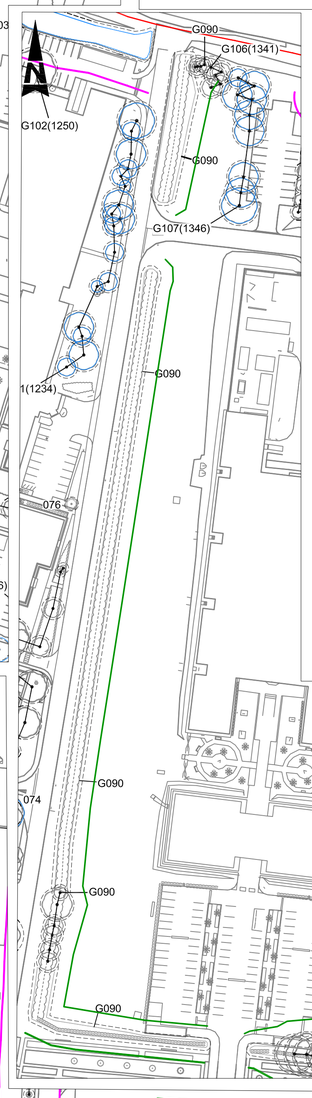
2.3.1 The location of the groups are illustrated on Figure 2.1. Appendix C shows Figure 2.1 with enlarged detail.

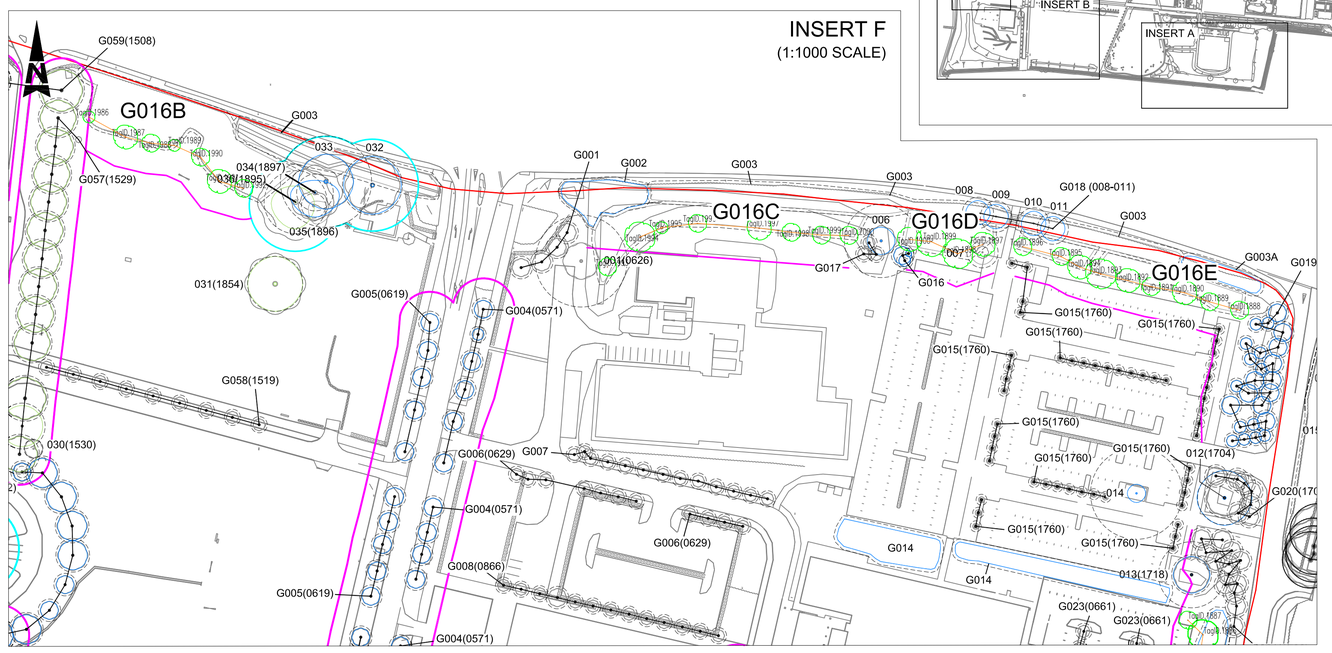


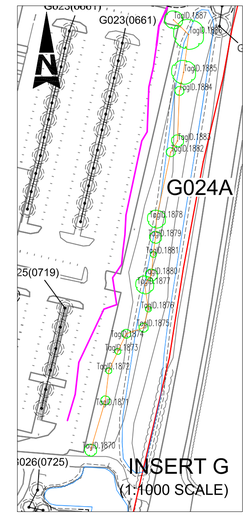


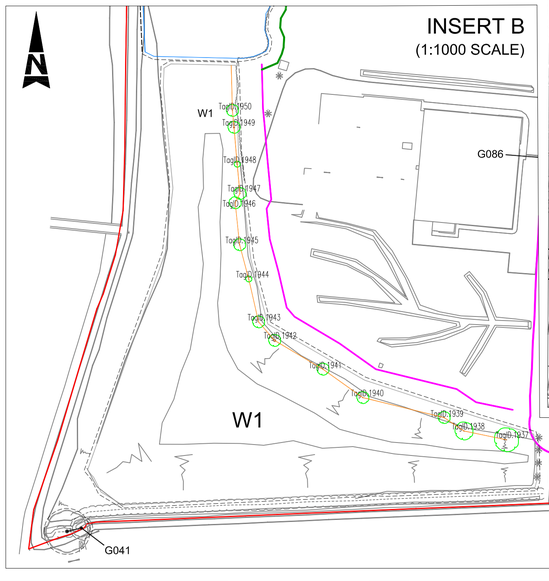


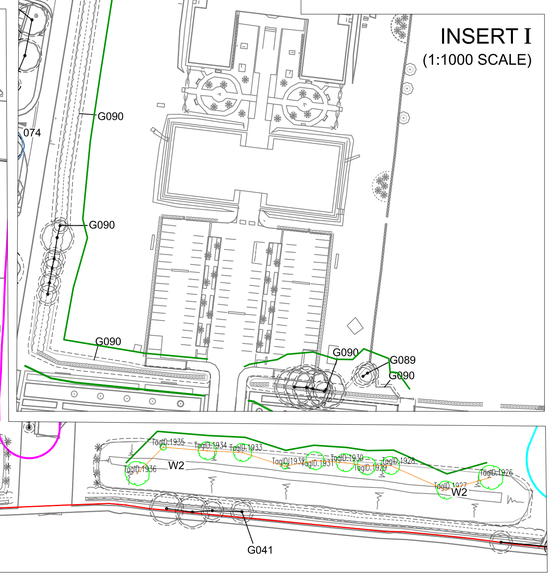




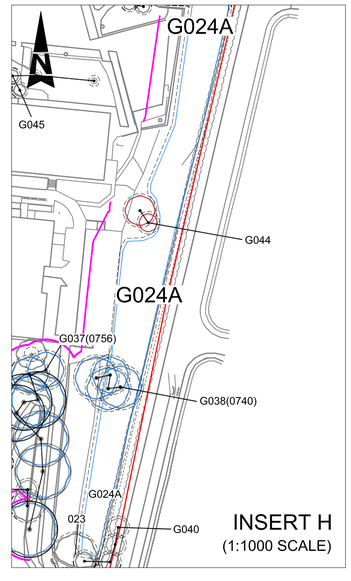












TREE PROTECTION KEY

- CATEGORY A TREE + TREE REF.
- CATEGORY B TREE + TREE REF.
- CATEGORY C TREE + TREE REF.
- CATEGORY U TREE + TREE REF.
- TREE GROUP REFERENCE (COLOUR RELATES TO BS CATEGORIES AS FOR INDIVIDUAL TREES AS SHOWN ABOVE)
- WOODLAND GROUP REFERENCE (COLOUR RELATES TO BS CATEGORIES AS FOR INDIVIDUAL TREES AS SHOWN ABOVE)
- ROOT PROTECTION AREA
- EXTENT OF OUTER EDGE TREE STEMS OF WOODLAND/ GROUPS
- 5M BUFFER FROM TREE STEM TO BUILDING EDGE
- 8M BUFFER FROM TREE STEM TO BUILDING EDGE
- 10M BUFFER FROM TREE STEM TO BUILDING EDGE
- 15M BUFFER FROM TREE STEM TO BUILDING EDGE

Stat	Purpose of Issue	Date	Auth
PLANNING		02/12/16	TD

Rev	Description	By	Date	Chk'd	Auth
E	INCLUSION G090	BC	12/05/17	TD	TD
D	UPDATE BUFFER ZONES	BC	26/04/17	TD	TD
C	UPDATE BUFFER ZONES	BC	16/02/17	TD	TD
B	OMIT 10M & 20M OFFSETS	BC	22/12/16	TD	TD
A	ADD 10M & 20M OFFSETS	BC	06/12/16	TD	TD
–	ORIGINAL	BC	02/12/16	TD	TD

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Client: UNIVERSITY OF CAMBRIDGE

Project: WEST CAMBRIDGE MASTERPLAN (EIA)

Title: WOODLAND MANAGEMENT PLAN
FIGURE 2.1

Sheet Size	Original Scale	Designed/Drawn	Checked	Authorised
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3. General management principles

3.1 General

3.1.1 These groups of trees are boundary features, as such their primary function is for screening to views in and out of the site. This means that there are general management principles which are applicable to all of the groups and these are listed below:

- Resilience – implement correct management to ensure that the groups still provide screening functions into the future;
- Biodiversity – implementing correct management for the benefit of biodiversity, identifying and exploiting opportunities to increase the level of biodiversity;
- Continuity of cover – implement correct management to ensure continuous cover;
- Legacy – implement correct management to enable the development of selected individual specimen trees within some of the larger groups;
- Legal compliance – implement correct management that complies with the legal requirements relevant to the management undertaken.

3.1.2 These are the principles to which management objectives shall be prescribed for each of the boundary groups.

3.2 Resilience

3.2.1 This management principle is related to the ability of the woodland or group to continue to function as an effective screen and shall be underpinned by the following aims:

- Create a diverse structure to include variations in age, tree form, layering and the distribution of deadwood.
- Create dense young growth created by coppicing and promoting a varied vertical structure within the group.
- Implement management practices to move away from a single species dominating the planting composition, to mitigate for potential pests and disease or climate change.
- Early identification of any pests and diseases, and the implementation of corrective measures as appropriate.

3.3 Biodiversity

3.3.1 This management principle is related to implementing correct management for the benefit of biodiversity and shall be underpinned by the following aims:

- Identify any special characteristics or sensitivities of the woodland/group through consultation with the project team's Ecologist and implement appropriate treatments.
- Check the relevant Habitat Action Plans (HAPs) or Species Action Plans (SAPs) in the UK Biodiversity Action Plan and Local Authority's Biodiversity Action Plans(BAPs).

3.4 Continuity of cover

3.4.1 This management principle is related to the ability of the woodland to continue to function as an effective screen and shall be underpinned by the following aims:

- Maintain a woodland canopy during the implementation of management by selective thinning, rather than any clear felling operations.
- Ensure regeneration failures are kept to a minimum through implementing management practices to limit browsing potential and through managing surrounding vegetation to reduce competition.

3.5 Legacy

3.5.1 This management principle is related to managing the woodland to enable selected individual specimen trees to develop and achieve their full growth potential and shall be underpinned by the following aims:

- Maintain adequate space around the selected trees free from competition.
- Ensure these trees have a minimum of 15m offset from the building zones.

3.6 Legal compliance

3.6.1 This management strategy will have to comply with the legal requirements relevant to the management undertaken including:

Forestry Act 1967 (as amended)

- Felling licences are covered within the Forestry Act 1967;
- The Forestry Act 1967 makes it an offence to fell licensable trees without having obtained a licence or other valid permission;
- Licensable trees are those that fall outside of the exemptions detailed below;
- Fines or a re-stocking notice can be served if an offence can be proved and convicted;
- Any fines or re-stocking notices will be served by the Forestry Commission, not the Local Planning Authority.

Relevant Exemptions

- In any calendar quarter you may fell 5 cubic metres of timber without a licence;
- A calendar quarter is defined as 1st Jan to 31st March, 1st April to 30th June, 1st July to 30th September and 1st October to 31st December;
- Felling trees which, when measured at a height of 1.3m from the ground have a diameter of 80mm or less;
- Felling trees with a diameter of 100mm or less for the purpose of thinning a tree group;

Plant Health Act 1967

3.6.2 All tree works are to be undertaken in line with current recommendations in accordance with *BS3998:2010 Tree work – Recommendations* and shall comply with the most recent advice and guidelines from the Arboriculture and Forestry Advisory Group (AFAG), the Forestry Industry Safety Accord (FISA), or the Health and Safety Executive (HSE) .

3.6.3 The tree works contractor will have to submit a risk assessment and method statement for review by the University of Cambridge prior to commencing works on site.

Conservation of Habitats and Species Regulations 2010 (as amended) – specifically in regards to Bats, Dormice, Wild Plants

3.6.4 Tree works are to be planned to ensure protection of people, property and wildlife. If the works are to be undertaken during the bird nesting season then advice is to be sought from an Ecologist prior to undertaking tree works.

Wildlife and Countryside Act 1981 (as amended).

3.6.5 Where a group contains protected, rare and endangered flora and fauna then the works may require specific notification or permission to be obtained from the applicable governing body to undertake any works. Table 3.1 summarises applicable types of offences and licensing procedures and guidance.

Table 3.1 Wildlife and Countryside Act 1981 offences, licensing procedures, and guidance

Species	Legislation (England & Wales)	Offences	Licensing procedures and guidance (England & Wales)
Bats European protected species	Conservation of Habitats and Species Regulations 2010 (as amended) Reg 41	Deliberately capture, injure or kill a bat; deliberate disturbance of bats; or damage or destroy a breeding site or resting place used by a bat. [The protection of bat roosts is considered to apply regardless of whether bats are present.]	A Natural England (NE) licence in respect of development is required in England or a licence from the Welsh Assembly Government in consultation with Natural Resources Wales (NRW) in Wales. European Protected Species: Mitigation Licensing- How to get a licence (NE 2010) Bat Mitigation Guidelines (English Nature 2004) Bat Workers Manual (JNCC 2004)
	Wildlife and Countryside Act 1981 (as amended) S.9	Intentionally or recklessly obstruct access to any structure or place used for shelter or protection or disturb a bat in such a place.	Licence from NE or NRW is required for surveys (scientific purposes) that would involve disturbance of bats or entering a known or suspected roost site.
Dormouse European protected species	Conservation of Habitats and Species Regulations 2010 (as amended) Reg 41	Deliberately capture, injure or kill a dormouse; deliberate disturbance of a dormouse; or damage or destroy a breeding site or resting place used by a dormouse.	A Natural England licence in respect of development is required in England or a licence from Natural Resources Wales (NRW) in Wales. European Protected Species: Mitigation Licensing- How to get a licence (NE 2010) Dormouse Conservation Handbook (English Nature 2006)
	Wildlife and Countryside Act 1981 (as amended) S.9	Intentionally or recklessly obstruct access to any structure or place used for shelter or protection or disturb a dormouse in such a place.	Licence issued for survey and conservation by Natural England or Natural Resources Wales.
Birds	Wildlife and Countryside Act 1981 (as amended) S.1	Intentionally kill, injure or take any wild bird; intentionally take, damage or destroy the nest of any wild bird while that nest is in use or being built; intentionally take or destroy the nest or eggs of any wild bird. [Special penalties are liable for these offences involving birds on Schedule 1 (e.g. most birds of prey, kingfisher, barn owl).] Intentionally or recklessly disturb a Schedule 1 species while it is building a nest or is in, on or near a nest containing eggs or young; intentionally or recklessly disturb dependent young of such a species.	No licences are available to disturb any birds in regard to development. Licences are available in certain circumstances to damage or destroy nests, but these only apply to the list of licensable activities in the Act and do not cover development. General licences are available in respect of 'pest species' but only for certain very specific purposes e.g. public health, public safety, air safety.
Plants European protected species	Conservation of Habitats and Species Regulations 2010 (as amended); Reg.45	Deliberately pick, collect, cut, uproot or destroy a wild plant of a European protected species (Schedule 5).	Licences can be issued for science, education and conservation and also in respect of a development if it is of overriding public interest. Since the 21st August 2007 it is no longer a defence to show that the picking, cutting, collecting, uprooting or destruction of a wild European Protected Species of plant was the incidental and unavoidable result of an otherwise lawful activity. European Protected Species: Mitigation Licensing- How to get a licence (NE 2010) Licences can also be issued for destructive survey methods for floating water plantain, where non-destructive methods are insufficient to determine presence (Guidance on sampling rare aquatic plants, NE 2009).
Plants Nationally protected species	Wildlife and Countryside Act 1981 S.13 (Schedule 8)	Intentionally pick, uproot or destroy any wild plant on Schedule 8	Licences can be issued by Natural England for specific purposes only, such as science and education or conservation purposes. There is no provision for licensing the above actions for development operations under the Wildlife & Countryside Act 1981 (as amended). Such actions can only proceed if they are covered by the appropriate defence in the Act, which permits otherwise illegal activities if they are the 'incidental result of a lawful operation and could not reasonably have been avoided'. Only a court can decide what is 'reasonable' in any set of circumstances. No licence is required for survey in England or Wales. Guidance on survey techniques is available from Natural England.
Plants All plants	Wildlife and Countryside Act 1981 S.13	To uproot any wild plant without authorisation.	No licence is required. The land owner's permission is required. (England and Wales)

4. Existing conditions

4.1 Existing plot details

4.1.1 Table 4.1 provides details on the existing woodland groups and specifically the opportunities for management:

Table 4.1 Existing woodland and tree groups and management opportunities

Group reference	Species	Age	Current layout and spacing	Current management & vitality	Public access	Invasive Species	Amount of regeneration	Current protection	Current observations, issues and opportunities
W1 1937 to 1950	Trees: Common Oak, Common Ash, Silver Birch, Aspen, Cherry, Field Maple Shrubs: Hawthorn, Hazel, Blackthorn	Young	Growing on earth mound, triangular shape. Average 2m spacings between rows and plants, planting rows from 7 to 12 in places. Staggered hedgerow on south boundary. No management recorded, stock now leggy and drawn. Groups of multi-stem hazel and other pockets of odd-numbered shrubs. Existing variation in vertical structure – between shrub and tree stock. No woodland edge habitat on boundary with building zone.	No recent management record. Good vitality, occasional dead trees resulting from over competition	No	Areas of bramble	Low – occasional self-sown Alder & Ash saplings. Wet, saturated areas opposite building zone on north edge of group being colonised by Alder.	Tree/shrub guards still attached to majority of stock	Relatively sparse on the crest of the earth mound at the south west corner, where planting becomes intermittent, with trees at 2.5-4m spacings Tree/shrub guards restricting growth in places. Ash dominating tree species. Aspen present which can outcompete more preferable or higher value species. No management undertaken on southern hedgerow. Close spacing between trees/shrubs restricting crown formations. Landscape function – Shelter belt and woodland group
W2 1926 to 1936	Trees: Common Oak, Common Ash, Aspen, Cherry, Field Maple Shrubs: Hawthorn, Hazel, Elder, Guelder Rose	Young	Growing on earth mound, rectangular shape Average 1.5-2m spacings between rows and plants. Approximately 8 rows. Staggered hedgerow on south boundary. No management recorded, stock now leggy and drawn. Groups of multi-stem hazel and other pockets of odd-numbered shrubs. Limited variation in vertical structure. No woodland edge habitat on boundary with building zone.	No recent management record. Good vitality	No	None	Low – occasional self-sown Elder	Tree/shrub guards still attached to majority of stock	Tree/shrub guards restricting growth in places. No management undertaken on southern hedgerow. Close spacing between trees/shrubs restricting crown formations. Relatively uniform height throughout. Aspen present which can outcompete more preferable species or higher value species. Landscape function – shelter belt

Group reference	Species	Age	Current layout and spacing	Current management & vitality	Public access	Invasive Species	Amount of regeneration	Current protection	Current observations, issues and opportunities
W3A 1901 to 1913	Trees: Common Oak, Common Ash, Field Maple, Scots Pine, Cherry, Apple Shrubs: Hawthorn, Elder	Young to semi-mature	Growing on level ground as a rectangular plot. Earth bund to west of group. Planted in diagonal rows, each row approximately 5m apart. The plants in the rows are growing at approximately 2m spacings. Scots Pine more prevalent in southern extents – largely failed to establish with dead stems present. Intermittent hedgerow planting on west extents, largely failed to establish, occasional shrubs remaining. There is a mature field boundary hedgerow outside of group to the east which has intermittent gaps, with the specimens having received no recent management with leggy and drawn stems on existing shrubs. No woodland edge habitat on boundary with building zone.	No recent management record. Good vitality, on broad leaf specimens, poor on coniferous trees with occasional dead stems of Scots Pine present from over competition.	There are signs of public access, with desire lines to the north of the group.	Dense pockets of bramble	Low – occasional self-sown Elder and Ash & Oak saplings	Open boundary to east. Occasional tree stake still attached.	Limited shrub species, and relatively uniform vertical structure. Standing dead trees. Scots Pine failing to thrive throughout the majority of the group. No management undertaken on eastern hedgerow. West woodland edge planting failed to establish. Close spacing between trees/shrubs restricting crown formations. Limited understorey vegetation. Landscape function – Shelter belt and woodland group
W3B 1914 to 1925	Trees: Common Oak, Common Ash, Aspen, Cherry, Field Maple, Alder Shrubs: Hawthorn, Hazel, Elder, Dogwood	Young	Growing on level ground as a rectangular plot. Average 1-1.5m spacings between plants. Planted hedgerow on southern boundary. No management recorded, stock now leggy and drawn. Groups of multi-stem hazel and other pockets of odd-numbered shrubs. Limited variation in vertical structure. No woodland edge habitat on boundary with building zone.	No recent management record. Good vitality	No	Pockets of bramble in places	Low – occasional self-sown Elder	Tree/shrub guards still attached to majority of stock	Tree/shrub guards restricting growth in places. No management undertaken on southern hedgerow. Close spacing between trees/shrubs restricting crown formations. Relatively uniform height throughout. Aspen present which can outcompete with more preferable species. Ash dominating tree species. Landscape function – Shelter belt
W4A 1951 & 1953	Trees: Elm Shrubs: Hawthorn, Elder	Young to over-mature	Growing as a rectangular plot. Average 5m spacings between plants. No planted stock, all natural regeneration. Limited variation in vertical structure. No woodland edge habitat on boundary with building zone.	No recent management record. Fair vitality, standing dead stems in places with some collapsed.	Public footpath runs parallel to western edge.	Pockets of bramble in places	Medium – majority of plants have naturally regenerated	Timber panelled fence between group and building zone.	Hawthorn dominant species. Collapsed and dead stems in places through neglect, windthrow and competition for light inducing drawn and unbalanced crowns. Occasional Elm sapling. Dutch Elm Disease prevalent, with standing dead stems. Limited understorey, dense canopy cover from Hawthorn crowns intertwining. Landscape function – Scrub woodland

Group reference	Species	Age	Current layout and spacing	Current management & vitality	Public access	Invasive Species	Amount of regeneration	Current protection	Current observations, issues and opportunities
W4B 1954 to 1960	Trees: Common Ash, Norway Maple, Sycamore, Crack Willow Shrubs: Hawthorn, Blackthorn, Elder	Young to mature	Rectangular plot. Earth mound on its north extents covered with largely self-sown scrub vegetation. Dominated by natural regeneration. A 3-5m band of sycamore on south east corner. The majority have self-sown. Average of 3m spacings between plants. Limited variation in vertical structure. No woodland edge habitat on boundary with building zone.	Current management of scrub vegetation to keep access road clear. Fair vitality, standing dead stems in places with some collapsed.	Public footpath runs parallel to western edge and internal access road to east.	Pockets of bramble and areas of Blackthorn scrub in places	Medium – majority of plants have naturally regenerated	No guards or protection in place	Hawthorn dominant species. Collapsed and dead stems in places through neglect, windthrow and competition for light inducing drawn and unbalanced crowns. Occasional Sycamore with a number of saplings having self-sown on south east corner of the group. Limited understorey, dense canopy cover from Hawthorn crowns intertwining. The earth mound is heavily infested by rabbits, meaning the potential to enhance this area with new planting will require pest control and adequate protection in order for the plants to establish. Landscape function – Scrub woodland
W4C 1962 to 1964	Trees: Horse Chestnutx1, Common Ashx1, Elm Shrubs: Hawthorn, Blackthorn, Elder	Young to mature	Lapsed hedgerow. Not continuous, occasional gaps. 6m walkway between group and the highway plot to west. Successional growth from blackthorn scrub. No defined uniform hedgerow.	Current management of scrub vegetation to keep access road clear. Fair vitality, standing dead stems in places with some collapsed.	Public footpath runs parallel to western edge and internal access road to east.	Pockets of bramble and areas of Blackthorn scrub in places	Low – pockets of Blackthorn successional growth	No guards or protection in place	Limited species diversity. Collapsed and dead stems in places through neglect, windthrow and competition for light inducing drawn and unbalanced crowns. Standard trees limited to 2no. Gaps in places from collapsed stems. Dry ditch to west of group. Dense ivy clad stems from centre. Occasional Elm sapling, with Dutch Elm Disease present within group. Landscape function – Hedgerow
G116	Trees: Common Ash, Common Oak, Field Maple, Lime, Cherry, Scots Pine Shrubs: Hazel, Elder	Young	Rectangular plot. Growing on level ground. Planted plot with approximately 6 rows and an average of 1.5-2m spacings between trees. Limited variation in vertical structure. Groups of multi-stem hazel within group. No woodland edge habitat on boundary with building zone.	No active management recorded. Fair to good vitality, standing dead stems in places with dead Scots Pine trees.	No public access, fencing surrounds area	None observed	Low – occasional elder sapling	Rabbit proof fencing surrounds plot.	Close spacing between trees/shrubs restricting crown formations. Relatively uniform height throughout. Ash dominant tree species. Limited understorey vegetation due to dense canopy cover. Areas to east of group suitable for new planting. Landscape function – Shelter belt
G016A	Trees: Common Ash, Common Oak, Field Maple, Lime, Cherry, Whitebeam Shrubs: Hazel, Elder, Hawthorn	Young to semi-mature	Growing as a largely rectangular plot, on level ground. Planted plot with no obvious rows. Random planting configuration and an average of 2m spacings between trees. Limited variation in vertical structure. Groups of multi-stem hazel within group. No woodland edge habitat on boundary with building zone.	No active management recorded. Fair to good vitality, standing dead stems in places with dead trees.	No public access, fencing surrounds area	None observed	Low – occasional elder sapling	Rabbit proof fencing surrounds plot.	Close spacing between trees/shrubs restricting crown formations. Relatively uniform height throughout. Ash dominant tree species. Limited understorey vegetation due to dense canopy cover. Lapsed hedgerow to north of group along highway. High number of dead elms. Landscape function – Shelter belt

Group reference	Species	Age	Current layout and spacing	Current management & vitality	Public access	Invasive Species	Amount of regeneration	Current protection	Current observations, issues and opportunities
G016B	Trees: Common Ash, Common Oak, Silver Birch, Lime, Cherry, Whitebeam Shrubs: Hazel, Elder, Hawthorn	Young to semi-mature	Growing as a largely rectangular plot, on level ground. Planted plot with approximately 7no. rows, with 1.5-2m spacings between rows and trees. Limited variation in vertical structure. Groups of multi-stem hazel within group. No woodland edge habitat on boundary with building zone.	No active management recorded. Fair to good vitality, standing dead stems in places with dead trees.	No public access, fencing surrounds area	None observed	Low – occasional elder sapling	Rabbit proof fencing surrounds plot. However, this has been breached in places with girdled stems recorded from mammal grazing. The affected trees have largely died as a result.	Close spacing between trees/shrubs restricting crown formations. Relatively uniform height throughout. Ash dominant tree species. Limited understorey vegetation due to dense canopy cover. Lapsed hedgerow to north of group along highway. High number of dead elms. Rabbit damage on trees, therefore, repairs required to existing rabbit proof fencing and pest control in order to protect any new planting or coppiced trees/shrubs Landscape function – Shelter belt
G016C	Trees: Common Ash, Common Oak, Silver Birch, Lime, Cherry, Beech, Elm Shrubs: Hazel, Elder, Hawthorn	Young to semi-mature	Growing as a broadly rectangular plot on an earth mound. Planted plot with no obvious rows. Random planting configuration with 1-2m spacings between trees. Limited variation in vertical structure. Groups of multi-stem hazel within group. No woodland edge habitat on boundary with building zone.	No active management recorded. Fair to good vitality.	No public access, fencing surrounds area	None observed	Low – occasional Oak sapling and Elm	Rabbit proof fencing surrounds plot.	Close spacing between trees/shrubs restricting crown formations. Relatively uniform height throughout. Limited understorey vegetation due to dense canopy cover. Lapsed hedgerow to north of group along highway. High number of dead elms. Narrow plot. Landscape function – Shelter belt
G016D	Trees: Common Ash, Common Oak, Cherry, Beech Shrubs: Hazel, Hawthorn	Young to semi-mature	Growing as a broadly rectangular plot on level ground. Planted plot with no obvious rows. Random planting configuration with 1-2m spacings between trees. Limited variation in vertical structure. Groups of multi-stem hazel within group. No woodland edge habitat on boundary with building zone.	No active management recorded. Fair to good vitality.	No public access, fencing surrounds area	None observed	Low – occasional Oak sapling	Rabbit proof fencing surrounds plot. Tree stakes and ties still attached.	Close spacing between trees/shrubs restricting crown formations. Relatively uniform height throughout. Limited understorey vegetation due to dense canopy cover. Lapsed hedgerow to north of group along highway. High number of dead elms. Narrow plot. Tree ties restricting growth in places. Landscape function – Shelter belt
G016E	Trees: Common Ash, Common Oak, Cherry, Beech, Lime Shrubs: Hazel, Hawthorn	Young to semi-mature	Growing as a broadly rectangular plot on level ground. Planted plot with no obvious rows. Random planting configuration with 1-2m spacings between trees. Limited variation in vertical structure. Groups of multi-stem hazel within group. No woodland edge habitat on boundary with building zone.	No active management recorded. Fair to good vitality.	No public access, fencing surrounds area	None observed	Low – occasional Oak sapling	Rabbit proof fencing surrounds plot. Tree stakes and ties still attached.	Close spacing between trees/shrubs restricting crown formations. Relatively uniform height throughout. Limited understorey vegetation due to dense canopy cover. Lapsed hedgerow to north of group along highway. High number of dead elms. Narrow plot. Tree ties restricting growth in places. Landscape function – Shelter belt

Group reference	Species	Age	Current layout and spacing	Current management & vitality	Public access	Invasive Species	Amount of regeneration	Current protection	Current observations, issues and opportunities
G002	Trees: Sycamore, Elm Shrubs: Elder	Young to mature	Informal group of primarily Elm. Dry ditch to north. Sloped banks to south. Average spacing 5m between trees.	Historic management of cut stems on Elm recorded and trimming back of vegetation from highway infrastructure to north. Fair to good vitality.	Public footpath runs parallel to north.	Dense ivy ground cover	Medium – largely self-sown Elm	No guards or protection in place	Potentially outside of site ownership. Limited species diversity. Dry ditch to north of group. Dense ivy clad stems in places. Majority of trees are Elm, with Dutch Elm Disease present within locality. Landscape function – Shelter belt
G003 & G003A	Trees: Common Ash, Elm Shrubs: Hawthorn, Blackthorn, Elder	Young to mature	Lapsed hedgerow running along the north boundary of the site. Not continuous, occasional gaps. Intermittent standard trees present. Successional growth from blackthorn scrub. Largely Elm and hawthorn.	Historic management of cut stems on Elm recorded and trimming back of vegetation from highway infrastructure to north. Fair vitality, standing dead stems in places with some collapsed.	Public footpath runs parallel to north.	Pockets of bramble and areas of Blackthorn scrub in places	Medium – largely self-sown Elm	No guards or protection in place	Potentially outside of site ownership. Limited species diversity. Collapsed and dead stems in places through neglect, windthrow and competition for light, inducing drawn and unbalanced crowns. Standard trees limited. Gaps in places from collapsed stems. Dry ditch to south of group in places. Dense ivy clad stems in places and covering ground. Majority of trees are Elm, with Dutch Elm Disease present within group. Landscape function – hedgerow and occasional standard trees
G024A	Trees: Common Oak, Common Ash, Aspen, Cherry, Field Maple, Scots Pine Shrubs: Hawthorn, Hazel, Elder, Guelder Rose, Privet, Dog Rose, Dogwood, Blackthorn	Young to semi-mature	Growing on earth mound, rectangular shape Average 1.5-2m spacings between rows and plants. No management recorded, stock now leggy and drawn. Groups of multi-stem hazel and other pockets of odd-numbered shrubs. Some variation in vertical structure. Areas of shrubs on boundaries.	No recent management record. Good vitality	No	Dense pockets of Blackthorn and Bramble	Medium – occasional self-sown Elder, blackthorn	Tree/shrub guards still attached to majority of stock	Tree/shrub guards restricting growth in places. Close spacing between trees/shrubs restricting crown formations. Aspen present which can outcompete with more preferable species. Landscape function – Shelter belt
G019	Trees: Common Oak, Beech, Lime, Horse Chestnut	Young to semi-mature	Growing within maintained grass area. Intermittent standard trees.	No recent management recorded. Primarily in good vitality	Unrestricted access	None recorded	None recorded	None recorded	Tree 1691 – horse chestnut in decline due to Bleeding canker – need felling. Close spacing between trees/shrubs restricting crown formations. Additional low level planting to reinforce screen. Landscape function – standard tree group

Group reference	Species	Age	Current layout and spacing	Current management & vitality	Public access	Invasive Species	Amount of regeneration	Current protection	Current observations, issues and opportunities
G041	Trees: Field Maple, Elm, Ash, Alder Shrubs: Hawthorn, Elder, Hazel, Blackthorn	Young to early-mature	Boundary hedgerow & occasional trees. Predominantly self-set elm. Southside cut back for cycle way clearance. Fair vitality, deadwood in crowns. Gaps in line.	Southside cut in places opposite footpath	Unrestricted access	Dense ivy and bramble	Medium – occasional self-sown Elder, blackthorn	Tree/shrub guards still attached to some planted stock on north side of footpath	Limited species diversity. Collapsed and dead stems in places through neglect, windthrow and competition for light inducing drawn and unbalanced crowns. Standard trees limited. Gaps in places from collapsed stems. Dense ivy clad stems in places. Landscape function – Hedgerow with standard trees
G090	Trees: Crab Apple Shrubs: Hawthorn, Elder	Semi-mature – mature	Old field boundary hedgerow. 5xindividual crab apple trees-crown lifted to 3m. Decay entry points, old branch wounds. Fair to good vitality.	Hedgerow topped at 2m. Western extents not topped. Gaps in places. Ivy clad stems.	Unrestricted access	Dense ivy in places	Low	None identified	Hedgerow to receive consistent management along its entire extents to prevent it from becoming leggy and drawn. Landscape function – hedgerow
G105	Trees: Silver Birch, Hawthorn Scots Pine, Lime, Whitebeam.	Young to semi-mature	Boundary tree planting. No understorey. Average spacing 3m.	No current management recorded	Unrestricted access	Ivy in places	Low	None identified	Excavation works to north for highway improvements. Boundary vegetation removed to north from highway works. Drawn stems given close spacing between trees. No shrub understorey. Landscape function – standard tree group

4.2 General management prescriptions

4.2.1 There are general management prescriptions that are applicable to all groups and these are as follows:

- Thinning of those that are failing to thrive to enable more space within the woodland groups for the remaining trees/shrubs to continue to develop – thinning to target removal of dangerous trees and the shorter-lived tree species or those that will respond to coppice management, i.e. the felling of trees/shrubs to above ground level to enable them to regenerate.
- Removal of tree stakes, guards and ties that are currently restricting growth;
- New planting to enhance species diversity and improve screen functions over the long term;
- Hedgerow management to return lapsed hedgerows back to continuous screens and to improve their density at lower levels by cutting their tops to promote lateral spread;
- Improve habitat value within each group.

4.3 General management objectives

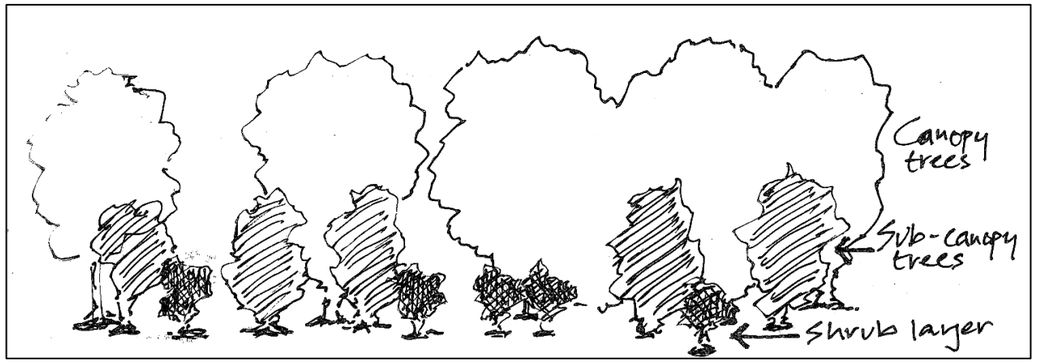
4.3.1 There are general management objectives in order to meet the prescriptions above that are applicable to all groups:

- Reduce the total percentage of single species dominance to below 50% of tree population, through targeted thinning and replacement of felled trees with alternative species.
- Dead and dying trees play an integral role in the functioning and productivity of woodland group ecosystems. As such the objective shall be for a minimum of six fallen and six standing pieces of deadwood per group, spread throughout the group. Any trees felled for the works can be processed and retained as a deadwood source, e.g. deadwood piles. Leave deadwood in canopies, especially with rot holes for nesting or roosting habitat, or fix sections of deadwood in canopies.
- The creation of woodland edge habitat shall be undertaken on the sides of the groups adjacent to the building zones where they do not already exist. Woodland edges can be planted to allow widths of natural regeneration to occur. A minimum of 5m in width is recommended with a minimum of 50% of the side of the woodland adjacent to the building zone used to create new woodland edge habitat, if a continuous line is not adopted. This will create a scalloped edge to the woodland on the development side. If they are planted then a layout of five staggered rows is typical. Evergreen trees or shrubs shall be included to woodland edge planting as they provide year-round shelter. Scalloping the woodland edges will maximise woodland edge habitat.
- Veteranisation of existing trees. A veteran tree is one with habitat features such as wounds or decay. A veteran may be a comparatively young tree with a small girth in contrast to an ancient tree, but with key characteristics, e.g. scars of age including decay or hollowing trunk, significant amounts of deadwood, etc. The veteranisation of existing trees is the practice of inducing decline in a tree using chainsaws or handsaws to promote veteran tree features such as deadwood, rot holes and hollowing stems. The objective shall be 3-6 veteran trees within suitable groups.
- Areas of dense bramble, ivy and Blackthorn scrub can outcompete the more beneficial flora or shrubs. Management shall be aimed at stopping their spread by scrub control or hand pulling. Applications of herbicide on cut stumps shall be undertaken where necessary to prevent regeneration. It must be noted that pockets of bramble are beneficial for wildlife, as such certain sections shall be retained as agreed through consultation with an ecologist.
- Blocks of new shrub planting shall be undertaken in suitable plots to enhance screen functions and where appropriate achieve a multi-layered age and height structure with no single age classification above 50%. Planting shall only be native trees and shrubs. Native trees of local provenance are genetically adapted to the local climate and environmental conditions. Planting non-local provenance trees could upset the fine balance between native trees and the wildlife they support, e.g. through flowering or seeding at different times.

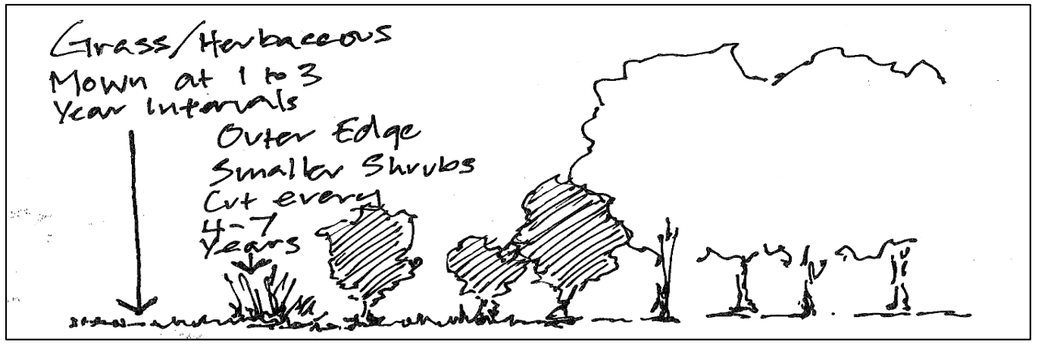
4.4 Woodland edge habitat and supplementary planting

4.4.1 The aim of any planted woodland edge habitat and new supplementary planting is to establish irregularly spaced and sized groups of shrubs and potentially small trees along or close to the edges of the existing groups to improve species diversity and enhance screening functions.

4.4.2 An idealised woodland edge would provide a gradual progression from shrubs through to canopy trees as illustrated in the sketch below. This tiered approach also serves to provide buffering to winds that can minimise potential windthrow occurrences for any previously sheltered trees that may be revealed during any prescribed thinning operations. The planting should take a more natural layout targeting scalloped edges with irregular numbers of different tree/shrubs species, evergreen species should also be used to improve the year round screen functions of the groups, e.g. Holly and Yew.



4.4.3 The size and extent of any new planting will need to be designed specifically for each plot. As mentioned a 5m width of woodland edge habitat is recommended with the subsequent future management of the planting possibly taking the form of that described on the sketch below where there is sufficient space:


Grass/Herbaceous
Mown at 1 to 3
Year Intervals
Outer Edge
Smaller Shrubs
Cut every
4-7
Years

5. Specific objectives

5.1 Specific objectives

5.1.1 The plot specific objectives are as follows:

Actions	
1.1	Confirmation of legal compliance for any works including felling licence and protected species requirements.
1.2	Remove tree stakes, ties and guards from trees/shrubs that no longer require them. Re-fix where they are still required for support.
1.3	Carry out thinning operations. Favouring the retention of Oak. Target felling of Cherry and Aspen the shorter lived species or those species that will coppice, e.g. Hazel, Field Maple and Ash, or those in poor condition. Implement veteranisation of certain trees to be thinned and create dead wood habitat as direct by an ecologist.
1.5	Implement management practices in line with County Wildlife Management plan, favouring retention of scrub communities within appropriate groups.
1.6	Implement scrub clearance of pockets of bramble, ivy and blackthorn & self-sown sycamore with appropriate groups.
1.8	Design and plant woodland edge adjacent to building zones. Planting design to be agreed.
1.11	Implement hedgerow management by topping between 1.5--5m and flailing sides and undertaking supplementary planting where appropriate
1.13	Implement aftercare maintenance for all newly planted stock for a minimum of 5 years to ensure successful establishment
2.1	Implement coppicing of previously felled trees and shrubs whose stumps were not treated with herbicide.

5.2 Monitoring

5.2.1 A system of monitoring is important to assess the efficiency, effectiveness and impact of any management objectives or actions implemented. The monitoring system shall be designed in line with the objectives identified within this management plan.

5.2.2 In assessing monitoring requirements it is advisable to follow the checklist below in order to promote effective results, if the answer is no for any of the questions then undertake a review of the procedures.

Table 5.1 Monitoring checklist

Question	Y/N
Has the monitoring been undertaken at the optimal times of year for the subject matter?	
Do the surveyors have the appropriate expertise to undertake the monitoring required for the data collection sheet?	
Has training been provided for less expert surveyors as appropriate for the subject matter?	
Have the monitoring limitations been recognised? This may include: sub-optimal survey periods, failure to survey whole site etc.?	
Has the monitoring been supported by appropriate and accurate aerial imagery, mapping information or photographs taken at set locations marked on the map information?	

6. Development offsets

6.1 General

6.1.1 One of the aims of this plan was to establish the proximity of canopy tree species within the boundary tree groups that are growing adjacent to proposed building zones within the site. The canopy species selected are those that have the capacity to be long-lived trees, barring the arrival of any pests and diseases that may influence their longevity. The species recorded are Common Oak, Common Ash, Lime and Alder.

6.1.2 When assessing suitable offsets it is the opinion of the Arboriculturist that the growth potential of the trees within the context of these boundary groups is not the same as those which are open grown standard trees. This is due to competition with neighbouring trees for sunlight, space and nutrients, which can stunt growth or indeed induce tall and drawn forms, rather than large open canopied trees which is why 10m is deemed adequate for canopy trees within the larger groups.

6.1.3 Whilst, the principal role of the woodland groups is to provide perimeter enclosure and screening, rather than as individual standard specimen trees in the landscape, occasional individual trees within some of the larger groups, specifically those along the southern edge, will be assessed for the creation and subsequent preservation of 'legacy' trees. These works will not be carried out within all groups as the creation of sufficient space to enable the trees to fully develop will diminish the screen functions of the narrower groups which is one of the main concerns of the Local Authority going forward.

6.2 Tree tag table and offsets

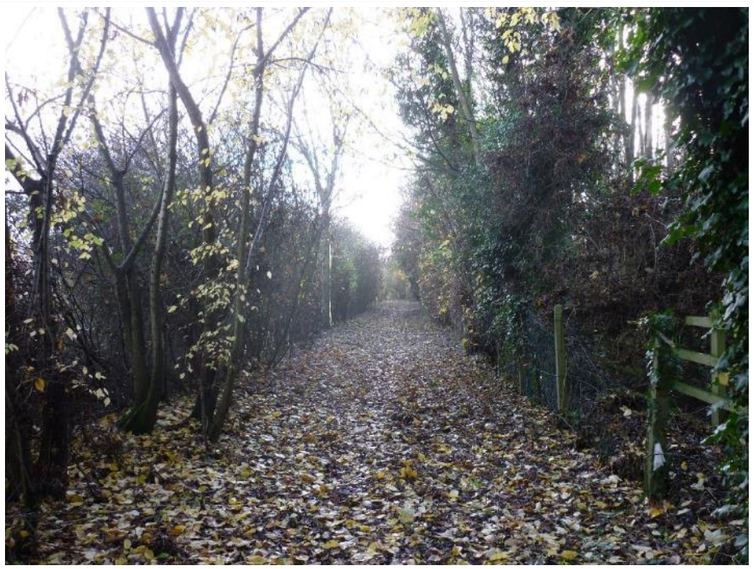
6.2.1 The table below captures all the tree tags and their associated species. It also recommends reasonable offsets from building zones from these canopy trees using the previously agreed offsets with the Local Authority as guidance and using professional opinion:

Plot	Species	Recommended offset
W1 1937-1950	1937-1939, 1942, 1943, 1945, 1946 & 1950 – Common Ash 1940 & 1941 – Common Oak 1944, 1947, 1948 & 1949 – Common Alder	10m
W2 1926-1936	1926-1929, 1931, 1932 & 1936 – Common Ash 1930 & 1935 – Common Alder 1934 – Common Oak	5m 15m for legacy trees – 3no. trees to be identified
W3A 1901-1913	1901-1903, 1905-1908, 1912 & 1913 – Common Ash 1904, 1909-1911 – Common Oak	10m 15m for legacy trees – 3no. trees to be identified
W3B 1914-1925	1914-1924 – Common Ash 1925 – Common Oak	5m 15m for legacy trees – 3no. trees to be identified
W4A 1951-1953	1951 & 1953 – Hawthorn 1952-missing tag	No canopy trees within this group. An offset of a minimum of 5m from the edge of the group should be allowed in order to enable sufficient space for future management and any new planting
W4B 1954-1960	1954, 1956-1960 – Sycamore 1955 – Common Ash	An offset of a minimum of 5m from the edge of the group should be allowed in order to enable sufficient space for future management and any new planting.
W4C 1961-1963	1961 – Blackthorn 1962 – Common Ash 1963 – Horse Chestnut	An offset of a minimum of 5m from the edge of the group should be allowed in order to enable sufficient space for future management and any new planting.
G116 1965-1968	1965 & 1967 – Common Ash 1966 & 1968 – Common Oak	10m
G016A 1969-1985	1969, 1970, 1982 & 1985 – Common Oak 1971-1975, 1977, 1979-1981 & 1983 – Common Ash 1976, 1978 & 1984 - Lime	10m
G016B 1986-1992	1986 – Common Oak 1988-1992 – Common Ash 1987 – Lime	10m
G016C 1993-2000	1993, 1995, 1998-200 – Common Oak 1994 & 1997 – Common Ash 1996 – Lime	10m
G016D 1897-1900	1897-1900 – Common Ash	10m
G016E 1888-1896	1896, 1894-1890 & 1888 – Common Ash 1895 & 1889 – Common Oak	10m
G024A 1887-1870	1887-1885, 1883, 1876-1874, 1871 & 1870 – Common Ash 1884, 1882, 1881, 1879, 1877, 1873 & 1872 – Common Oak 1880 & 1878 - Lime	10m
G105	Mixed	10m
G019	Mixed	10m
G041	Mixed	5m
G090	Mixed	5m

Appendix A: Site survey photographs

	Wood W3A looking north-east, diagonal row of oaks
	Young multi-stemmed hazel in Wood W3B (western section)

	Wood W2 – young growth with tubing/stakes still in place
	Wood W4A - interior

	Wood W4B – sycamore colonising wood edge
	Wood W4C, showing clustering elm on left side, with single ash specimen beyond and highway planting to west

	Woodland group G116 looking north-east, showing space available at east end for additional planting and space to south for woodland edge planting
	Woodland group G016A (western section), looking west

	Woodland group G016B (section to west of J.J. Thomson Avenue) looking north-west, showing space available for additional planting
	Woodland group G016C (section to west of J.J. Thomson Avenue) – interior view

	Woodland group G016D&E (eastern section) – front view looking north-west from car park
	Woodland group G024A – front view looking north-east from car park

	Woodland group G024A – interior

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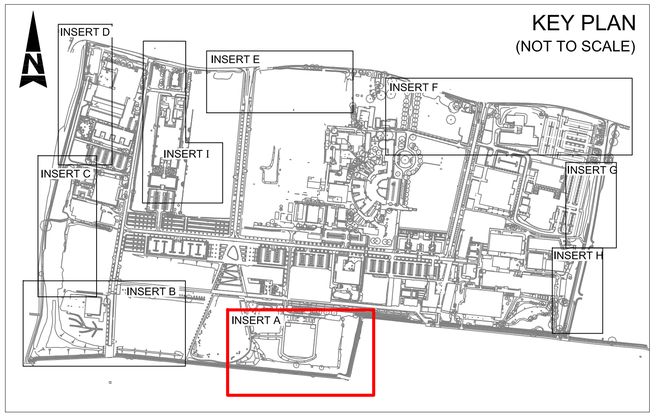
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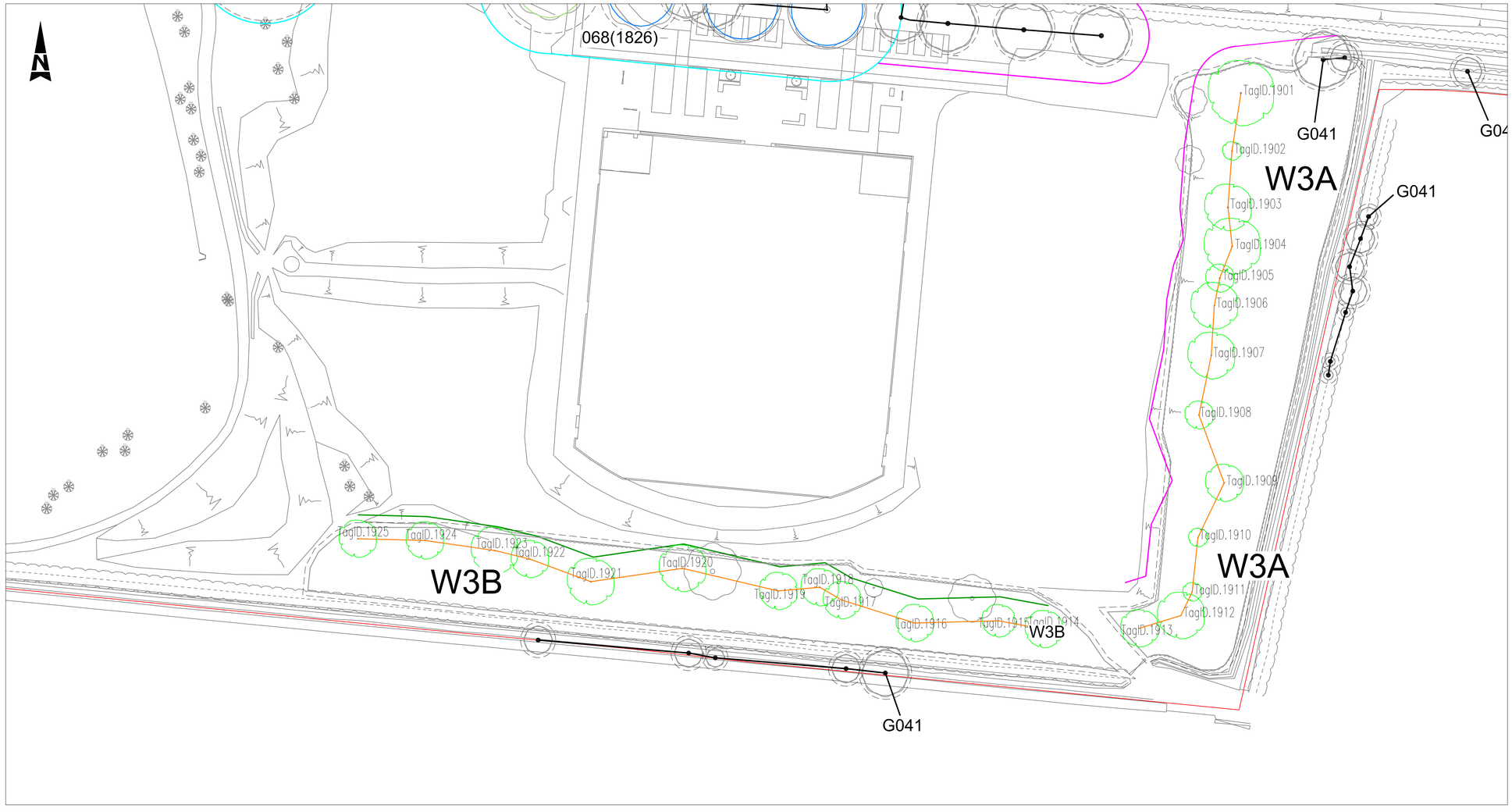
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Appendix C Detailed Figures

KEY PLAN
(NOT TO SCALE)



INSERT A
(1:500 SCALE)



TREE PROTECTION KEY

- 000 — CATEGORY A TREE + TREE REF.
- 000 — CATEGORY B TREE + TREE REF.
- 000 — CATEGORY C TREE + TREE REF.
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Stat	Purpose of Issue	Date	Auth
P	PLANNING	13/01/17	TD

Rev	Description	By	Date	Chk'd	Auth
C	UPDATE KEY PLAN	BC	12/05/17	TD	TD
B	UPDATE BUFFER ZONES	BC	26/04/17	TD	TD
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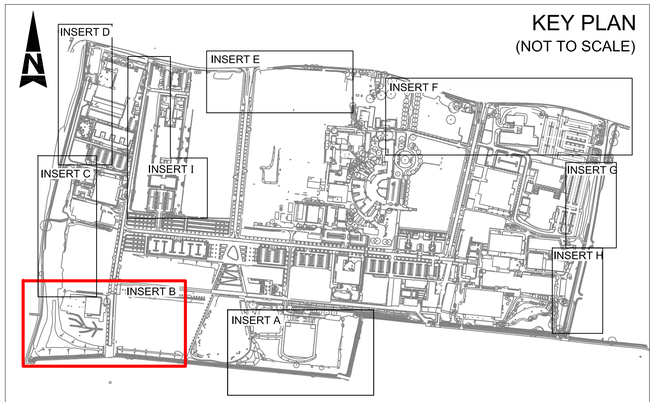
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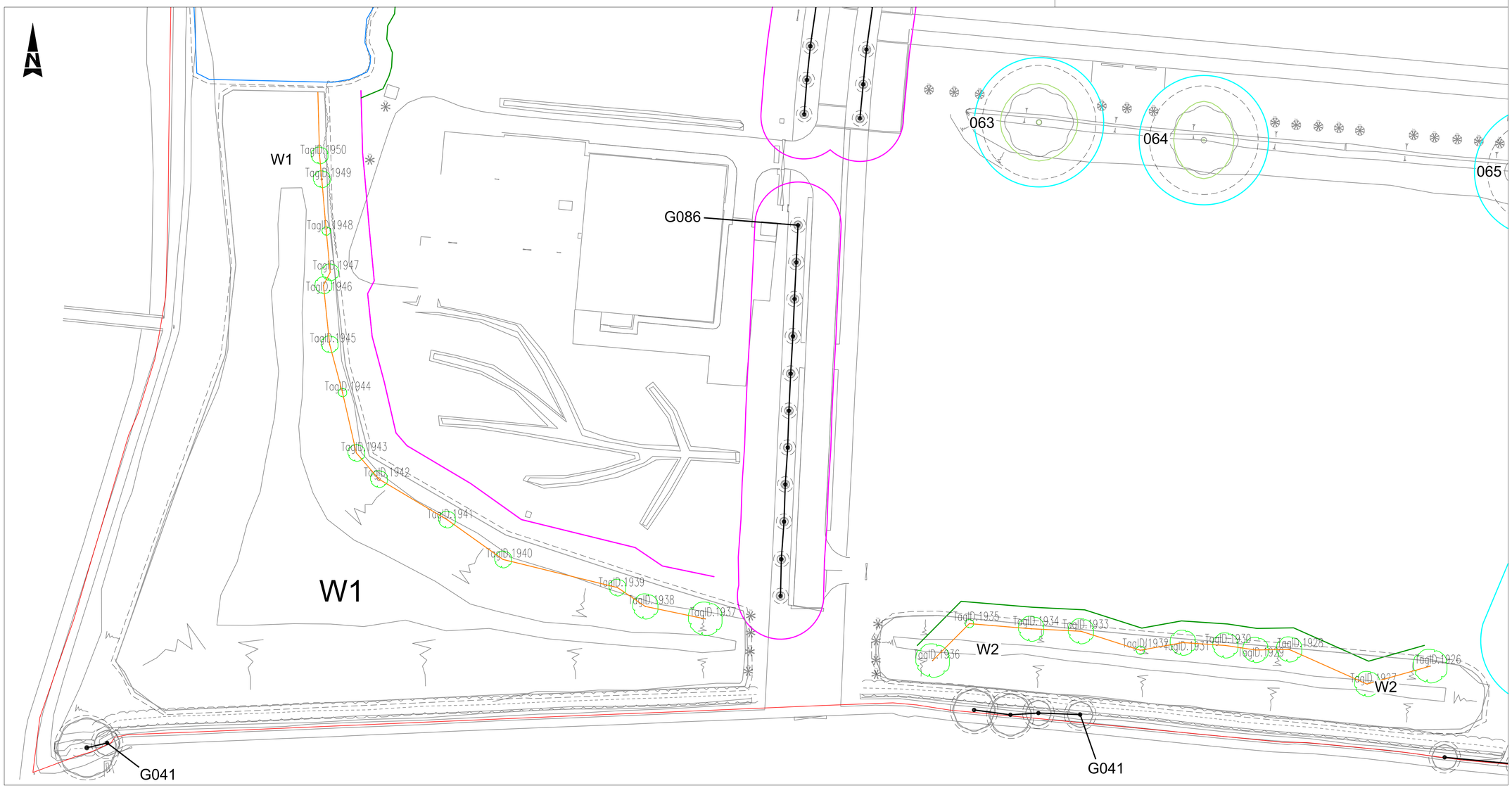
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KEY PLAN
(NOT TO SCALE)



INSERT B
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TREE PROTECTION KEY

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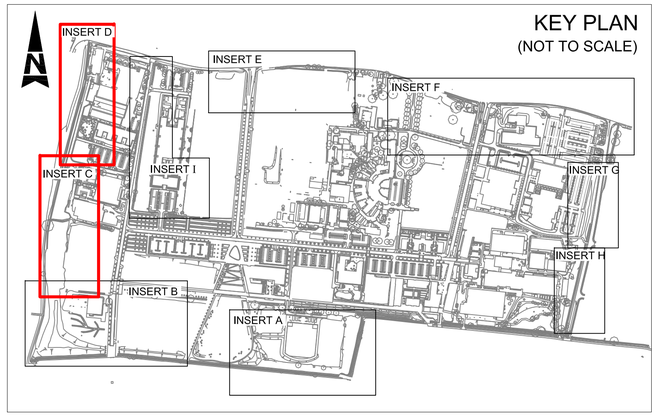
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Status	Drawing Number	Rev
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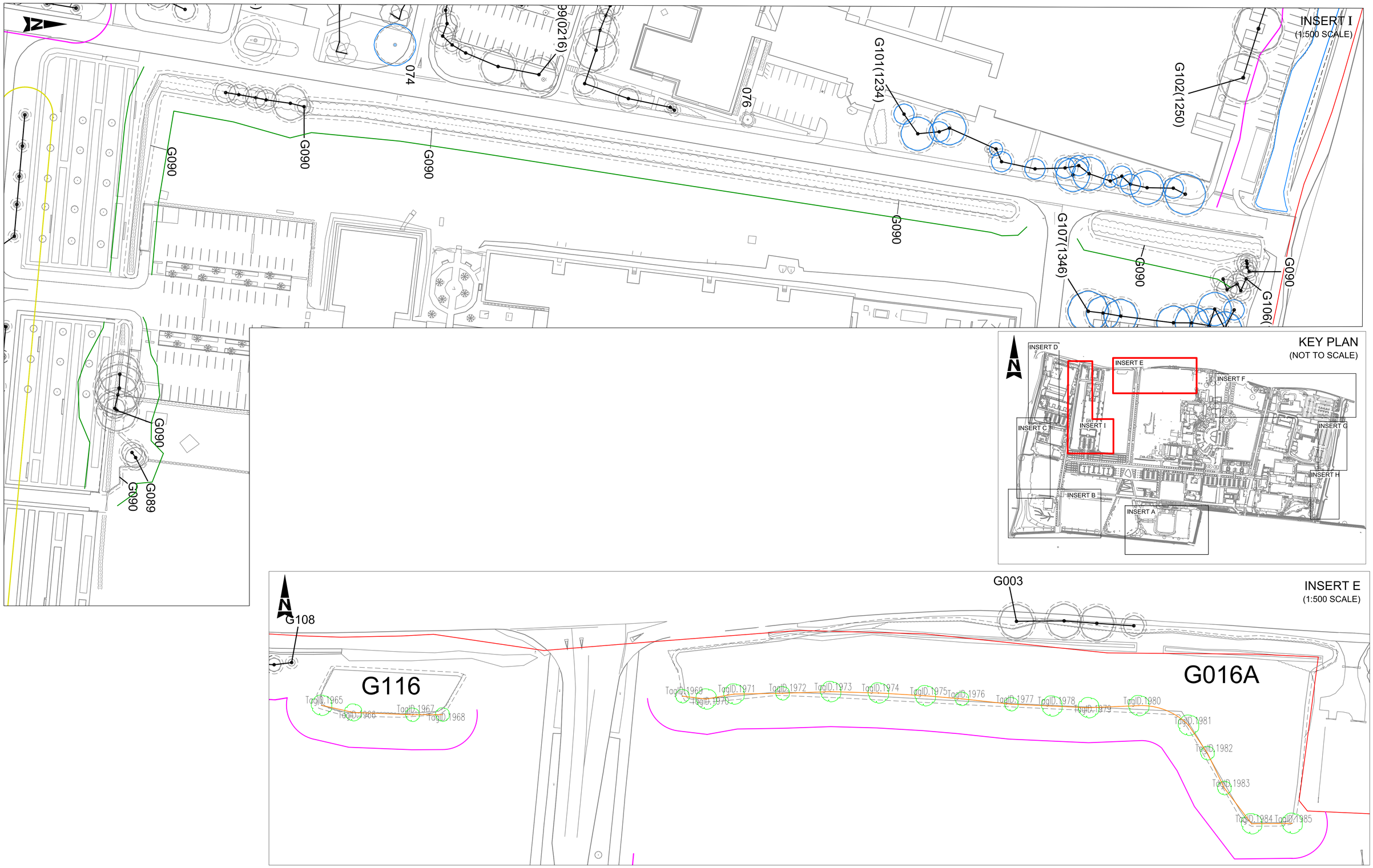
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KEY PLAN
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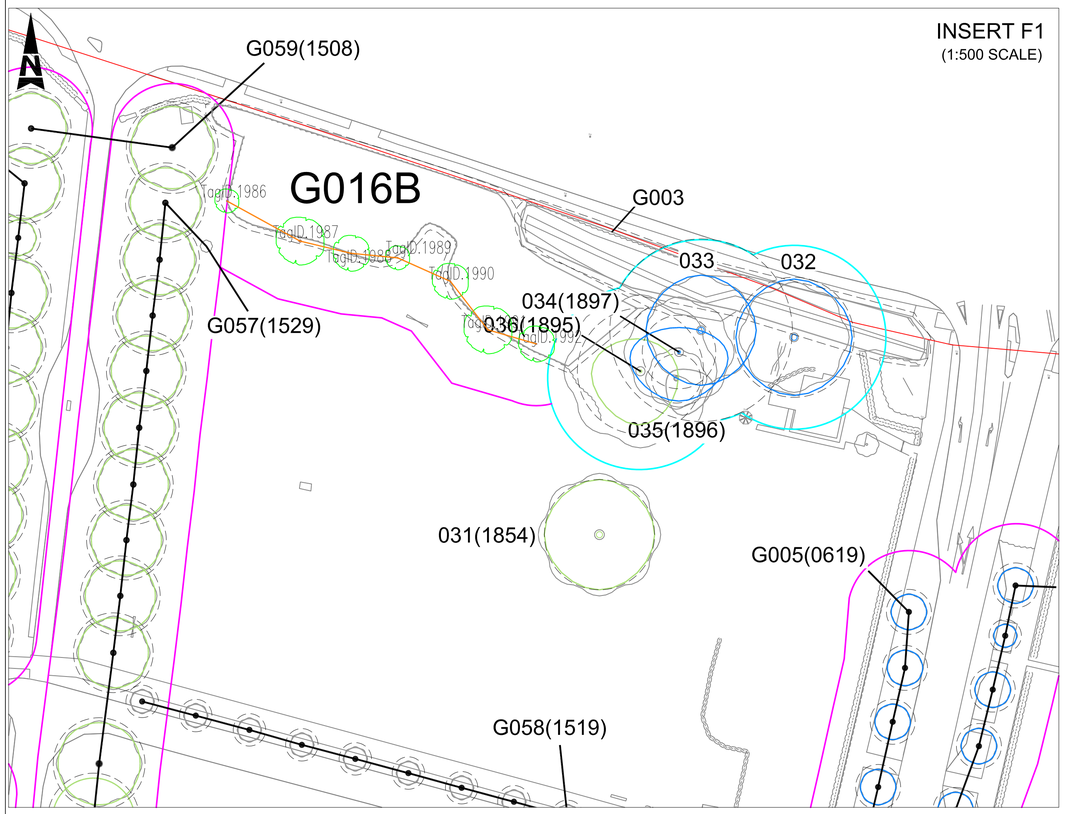
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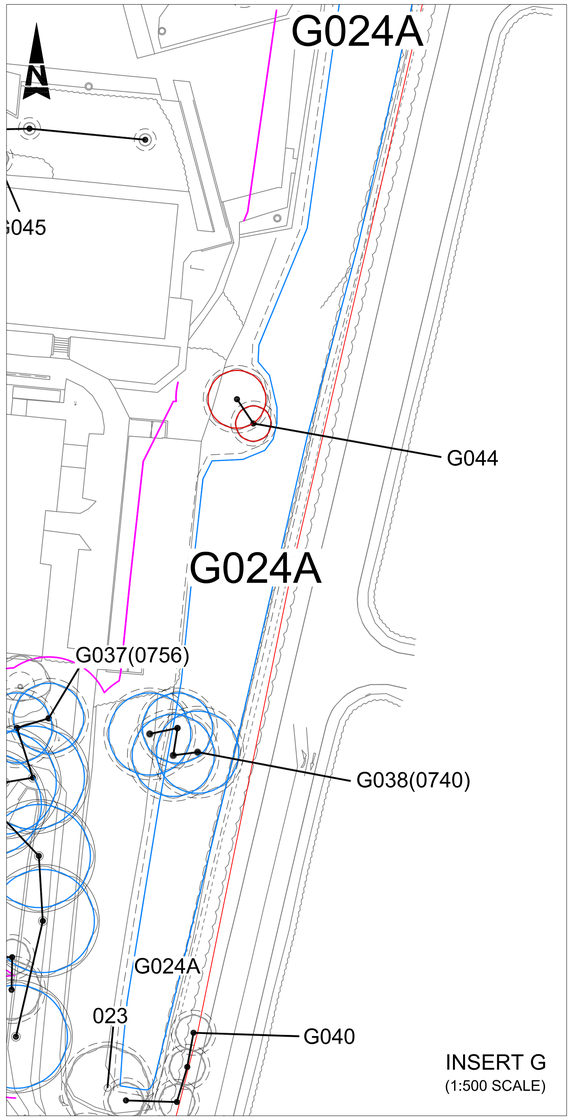
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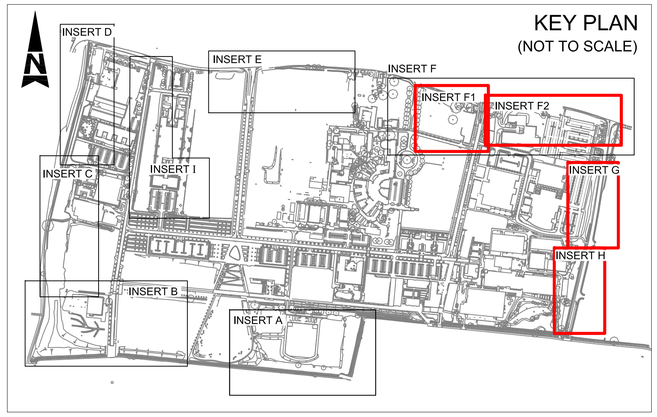
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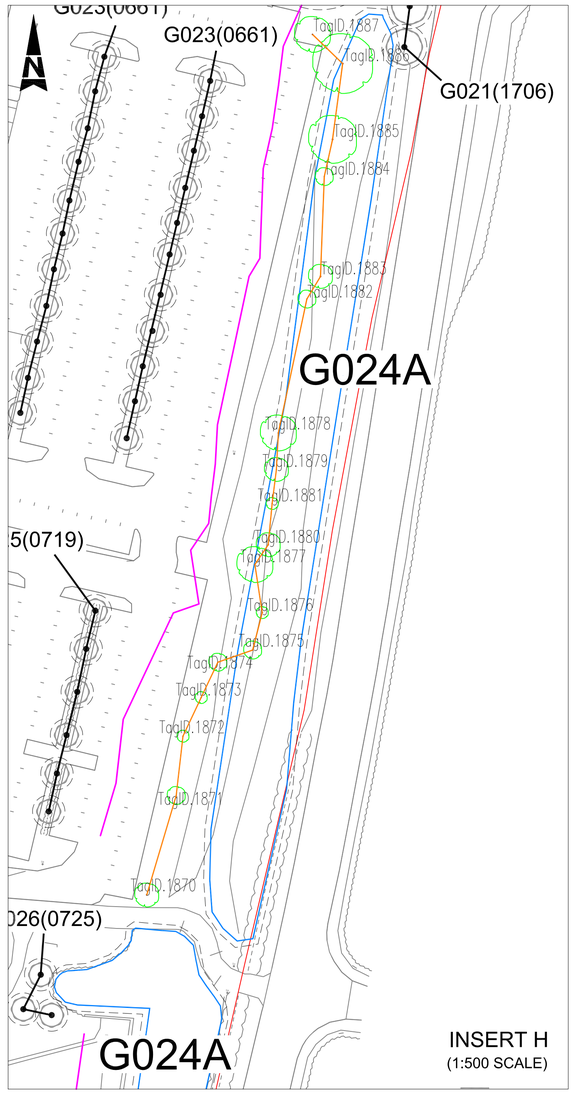
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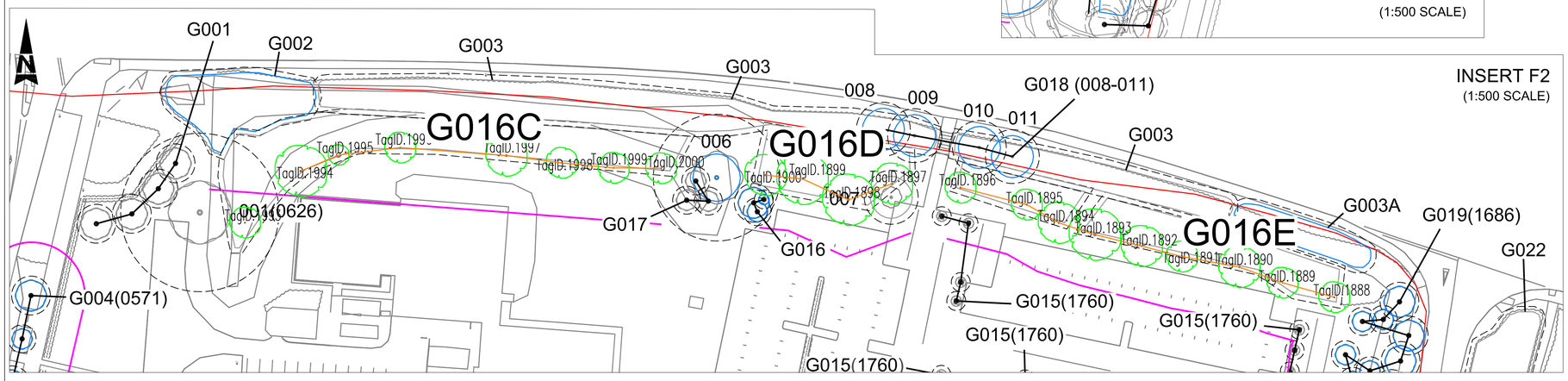
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FIGURE 2.1
ENLARGEMENT F, G & H

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Rev: C

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Appendix 9.1 Employment calculations

Maximum employment calculations

Construction phase employment

Construction cost of the Proposed Development has been estimated at £1.8 billion. Using an average construction turnover per employee of £225,000 (based on a sample of 30 major UK construction companies), the Proposed Development creates 8,000 construction person year jobs, an equivalent of 800 FTE construction jobs over the Development's 15 year construction period.

Assuming a moderate composite multiplier of 1.25 at the local level and 1.50 at the regional level (as recommended by the HCA Additionality Guide 2014), the construction of the Proposed Development could indirectly support a further 200 jobs locally and 400 jobs regionally.

Operational phase jobs on Site

The total number of jobs on Site after completion of the Proposed Development in 2031 was calculated using total proposed floorspace figures provided by AECOM, average employment densities from the Employment Densities Guide 2nd Edition (HCA) and guidance from AECOM and Creative Places (see Table A9.1.1). All jobs referred to in this report are Full Time Equivalent (FTE) jobs. The total number of FTE jobs on Site is calculated to be 13,994.

This must be considered alongside the estimated 4,350 FTE jobs at the adjacent North West Cambridge scheme upon completion in 2026 (source: NWC EIA, Table 5.14, page 5-17).

The total employment floorspace of the West Cambridge Site when the Proposed Development is complete (existing + proposed net additional floorspace) will be 500,280m^2, comprising: 210,386 m^2 commercial, 257,909 m^2 academic, 1,000 m^2 retail/food drink, 3,150 m^2 nursery, 10,160 m^2 assembly and leisure, 7,675 m^2 ancillary and 10,000 m^2 residential.

To calculate commercial, retail and academic employment, it was first assumed that the floorspace figures given were Gross External Area (GEA) and that this represents 120% of Net Internal Area (NIA) i.e. the area supporting employment. The NIA for commercial floorspace is therefore 175,322 m^2, for retail/food & drink 833 m^2 and for academic 214,924 m^2.

It was assumed that 99% of the commercial NIA (173,568 m^2) will be office, dry lab and workshop uses with respective employment densities of 17 m^2, 25 m^2 and 35 m^2 per FTE (based upon AECOM and Creative Places guidance). The floorspace was assumed to be split between the uses as follows: 80% office (138,855 m^2), 10% dry lab and 10% workshop (17,357 m^2 each). The three uses together support 9,358 jobs. It should be noted that this assumption represents the maximum expected office use class floorspace. It may be the case that a higher proportion of the commercial floorspace is dry lab/workshop use. If so, the level of employment will be lower.

It is assumed that 98% of the academic NIA (210,626m^2) will be used for academic purposes. Based on AECOM guidance regarding the University of Cambridge's employment densities for academic floorspace, an employment density of 50 m^2 per FTE was used for the academic floorspace NIA of 210,626m^2. Academic jobs on Site will therefore number 4,213.

For retail/food & drink employment, the remaining 1% of the commercial NIA (1,753m^2) and 2% of the academic NIA (4,298m^2) was assumed to be retail/food & drink shared facilities within academic and commercial space. In addition to the 833 m^2 specified retail/food & drink floorspace, this brings total retail/food & drink NIA to 6,885 m^2. (Note: the revised description of development for which planning permission is sought includes up to 4,000 m^2 (GEA) of 'stand alone' retail / food & drink (Use Classes A1-A5). The Original Planning Application description of development identified up to 1,000 m^2 (GEA) of floorspace in Use Classes A1-A5. This amendment has been made to allow a greater proportion of the retail/food & drink floorspace to be delivered through 'stand alone' facilities (such as the Shared Facilities Hub), rather than as accommodation within predominantly academic (Class D1) or commercial research (Class B1(b) facilities. This amendment does not change the assumption that in total around 6,885 m^2 NIA of retail/food & drink would be provided on site, either as stand alone facilities or as ancillary space. An Employment density of 18 m^2 per FTE would apply to both types of provision, which is based upon Employment Densities Guide 2nd Edition densities for high street (19), food superstores (17), and restaurants & cafes (18). This supports 383 jobs. This total number of retail/food & drink jobs does not change as a result of the amendment to the description of development in the revised description of development. The amendment does not change the assumption about the total amount of retail/food & drink floorspace to be provided on site – 6,885 m^2 (NIA) during the operational phase, it merely enables a greater proportion of this space to be provided as stand alone accommodation (Class A1-A5) than was the case in the Original Planning Application.

Following discussion with AECOM, provisional figures of 20 nursery and 20 assembly and leisure jobs have been used rather than calculating based upon floorspace. Ancillary floorspace is expected to be used for an energy centre with negligible employment creation, thus assumed to be zero. These figures are to be refined at a later stage. The existing residential floorspace (10,000 m^2 GEA, 8,333 m^2 NIA) on site is not expected to generate employment opportunities.

Operational phase net additional employment benefits

The net additional job creation of the Proposed Development is estimated to be 6,600 FTE jobs at the local level and 8,100 FTE jobs at the regional level.

The total number of jobs to be created on site by the Proposed Development excluding deadweight was calculated at 6,367 office-based, 541 dry lab, 387 workshop, 308 retail, and 2,526 academic, using the proposed (rather than existing) floorspace figures and above assumptions regarding floorspace uses and employment density. The 20 assembly and leisure jobs are eliminated as deadweight, whilst the 20 nursery jobs were excluded from calculations because their numbers are too low to have any significant leakage, displacement or economic multiplier effects.

The net employment benefits at the local and regional levels were calculated by incorporating leakage, displacement, and economic multiplier effects. The HCA ready-reckoners (HCA Additionality Guide 2014) were used to quantify these effects, with assessment of Cambridge's economic characteristics and baseline informing the selection of each ready-reckoner, as follows.

Leakage

Leakage is estimated as the number or proportion of outputs that will benefit those outside the Proposed Development's target area.

For office, dry lab and workshop jobs, the high quality of jobs is usually likely to lead to higher levels of leakage as it provides incentive for people from outside the local area to commute to access employment opportunities. Evidence suggests that this is indeed the case in the Cambridge area. However, given the high level of qualification of residents of Cambridge and South Cambridgeshire - far exceeding the regional average - and resultant significant pool of suitable potential employees, it is assumed that a significant number of jobs created will be taken up by those residing within the two local authorities, mitigating some of the leakage effects. This employment leakage is therefore expected to be moderate (25% by the HCA ready-reckoners).

The leakage for office, dry lab and workshop jobs on the regional level is likely to be low (10% by the HCA ready-reckoners), since commuting from beyond the region is not expected to be very prevalent.

For retail, leakages are expected to be low on the local level (10%) and negligible (0%) on the regional level. This is because of the low value nature of these jobs which make long commutes highly unlikely.

For academic jobs, leakages on the local and regional levels are expected to be very low (10% and 5% respectively), because the vast majority will be taken up by those based locally at the University of Cambridge.

Displacement

Displacement would arise if businesses located in the Proposed Development were to employ people currently employed by firms elsewhere in the area. It follows that these jobs would not be additional jobs but rather displaced from elsewhere in the area.

For office jobs the displacement effect is assumed to be low (25% on the local level and 30% on the regional level) because a large proportion of businesses located on the Proposed Development are to be start-ups and new firms rather than firms previously based elsewhere in the local or regional area. Whilst local businesses experience a significant level of competition within the cluster which would ordinarily result in displacement, the particularly large and growing pool of skilled labour associated with the University is likely to go a considerable way towards eliminating this effect.

For retail, the expected local, convenience nature of the businesses established make it unlikely that significant numbers of other jobs will be displaced. The displacement is therefore assumed to be low – 25% at both the local and regional levels.

For academic jobs, the majority of floorspace is to be used to rehouse pre-existing academic departments. A high level of displacement is assumed – 65% for the local and regional levels.

Economic multiplier

Economic multiplier effects refer to knock-on effects within the local economy by which the economic impact of a development is multiplied. In accordance with the HCA Additionality Guide 2014, composite multipliers are assumed to be 1.29 at a local level and 1.44 at a regional level for office development. The same assumption was used for academic jobs, because of the supply chain linkages required for scientific research.

For retail jobs, the HCA recommends lower multipliers, of 1.21 at the local level and 1.38 at the regional level.

Following these assumptions, the leakages and displacement were deducted from the total number of jobs supported by the proposed floorspace, and this figure was put through the multiplier. The total employment figures have been rounded to the nearest 100 FTEs. The process and results are shown in Table A9.1.2 – Table A9.1.4.

Table A9.1.1 Operational phase jobs on Site

	Commercial - Office	Commercial - Dry lab	Commercial - Workshop	Retail/food & drink	Academic	Nursery	Assembly and leisure	Ancillary	Residential
Proposed floorspace (m2)	210,386	210,386	210,386	1,000	257,909	N/A	N/A	N/A	10,000
NIA conversion (m2)	175,321	175,321	175,321	833	214,924	N/A	N/A	N/A	8,333
NIA adjusted for use (m2)	138,8551	17,3572	17,3572	6,885	210,6264	N/A	N/A	N/A	c.8,333
Employment density (m2 per FTE)	17	25	35	18	50	N/A	N/A	N/A	N/A
Total jobs (FTE)	**8,168**	**694**	**496**	**383**	**4,213**	**20**	**20**	**0**	**0**

1 – 80% of the 99% of total commercial NIA, with remaining 1% designated as ancillary retail/food & drink
2 – 10% of the 99% of total commercial NIA, with remaining 1% designated as ancillary retail/food & drink
3 – Includes 1% of commercial NIA and 2% academic NIA as shared facilities ancillary to main use
4 – 98% of total academic NIA, with remaining 2% designated as ancillary retail/food & drink

Table A9.1.2 Net additional office, dry lab and workshop jobs

Office, dry lab and workshop FTE jobs	Local	Regional
Gross direct jobs	7,294	7,294
Leakage level	25%	10%
Leakage quantity	1,824	729
Jobs after leakage	5,471	6,565
Displacement level	25%	30%
Displacement quantity	1,368	1,969
Jobs after displacement	4,103	4,595
Economic multiplier	1.29	1.44
Net additional jobs	5,293	6,617
Net additional jobs (rounded)	5,300	6,600

Table A9.1.3 Net additional retail jobs

Retail FTE jobs	Local	Regional
Gross direct jobs	308	308
Leakage level	10%	0%
Leakage quantity	31	0
Jobs after leakage	278	308
Displacement level	25%	25%
Displacement quantity	69	77
Jobs after displacement	208	231
Economic multiplier	1.21	1.38
Net additional jobs	252	319
Net additional jobs (rounded)	300	300

Table A9.1.4 Net additional academic jobs

Academic FTE jobs	Local	Regional
Gross direct jobs	2,526	2,526
Leakage level	10%	5%
Leakage quantity	253	126
Jobs after leakage	2,274	2,400
Displacement level	65%	65%
Displacement quantity	1,478	1,560
Jobs after displacement	796	840
Economic multiplier	1.29	1.44
Net additional jobs	1,027	1,210
Net additional jobs (rounded)	1,000	1,200

Minimum employment calculations

Operational phase jobs on Site

The minimum total number of jobs on Site after completion of the Proposed Development in 2031 was calculated using total proposed floorspace figures which replace all proposed commercial floorspace with academic floorspace (retaining existing commercial floorspace), average employment densities from the Employment Densities Guide 2nd Edition (HCA) and guidance from AECOM and Creative Places (see Table A9.1.5). The minimum total number of FTE jobs on Site is calculated to be 9,453. All jobs referred to in this appendix are Full Time Equivalent (FTE) jobs.

Table A9.1.5 Minimum operational phase jobs on Site

	Commercial - Office	Commercial - Dry lab	Commercial - Workshop	Retail/food & drink	Academic	Nursery	Assembly and leisure	Ancillary	Residential
Proposed floorspace adjusted for use (m2)	36,7491	4,5942	4,5942	9,9023	413,457 4	N/A	N/A	N/A	10,000
NIA conversion (m2)	30,624	3,828	3,8282	8,2523	344,548	N/A	N/A	N/A	c.8,333
Employment density (m2 per FTE)	17	25	35	18	50	N/A	N/A	N/A	N/A
Total jobs (FTE)	1,800	200	100	500	6,900	20	20	0	0

1 – 80% of the 99% of total commercial floorspace, with remaining 1% designated as ancillary retail/food & drink

2 – 10% of the 99% of total commercial floorspace, with remaining 1% designated as ancillary retail/food & drink

3 – Includes 1,000sq.m proposed retail floorspace plus 1% of commercial floorspace and 2% academic floorspace as shared facilities ancillary to main use

4 – 98% of total academic NIA, with remaining 2% designated as ancillary retail/food & drink

This must be considered alongside the estimated 4,350 FTE jobs at the adjacent North West Cambridge scheme upon completion in 2026 (source: NWC EIA, Table 5.14, page 5-17).

The total employment floorspace of the West Cambridge Site when the Proposed Development is complete (existing + proposed net additional floorspace) will comprise: 46,400 m^2 commercial, 421,895 m^2 academic, 1,000 m^2 retail/food drink, 3,150 m^2 nursery, 10,160 m^2 assembly and leisure, 7,675 m^2 ancillary and 10,000 m^2 residential.

It was assumed that 99% of the existing commercial floorspace (45,936 m^2) is split between uses as follows: 80% office (36,749 m^2), 10% dry lab and 10% workshop (4,594 m^2 each). It is assumed that 98% of the total proposed academic floorspace (413,457 m^2) will be used for academic purposes.

The remaining 1% of the commercial floorspace and 2% of the academic floorspace was assumed to be retail/food & drink shared facilities within academic and commercial space. In addition to the 1,000 m^2 specified retail/food & drink floorspace, this brings total retail/food & drink floorspace to 9,902 m^2.

To calculate commercial, retail and academic employment, it was assumed that the floorspace figures given were Gross External Area (GEA) and that this represents 120% of Net Internal Area (NIA) i.e. the area supporting employment. The NIA for commercial floorspace is therefore 38,280 m^2: 30,624 m^2 office and 3,828 m^2 each for dry lab and workshop. The office, dry lab and workshop uses - with respective employment densities of 17 m^2, 25 m^2 and 35 m^2 per FTE (based upon AECOM and Creative Places guidance) - together support 2,064 jobs.

Based on AECOM guidance regarding the University of Cambridge's employment densities for academic floorspace, an employment density of 50 m^2 per FTE was used for the academic NIA of 344,548 m^2. Academic jobs on Site will therefore number 6,891.

For retail employment, an employment density of 18 m^2 per FTE was used, based upon Employment Densities Guide 2nd Edition densities for high street (19), food superstores (17), and restaurants & cafes (18). The total of 8,252 m^2 NIA supports 458 jobs.

Following discussion with AECOM, provisional figures of 20 nursery and 20 assembly and leisure jobs have been used rather than calculating based upon floorspace. Ancillary floorspace is expected to be used for an energy centre with negligible employment creation, thus assumed to be zero. These figures are to be refined at a later stage. The existing residential floorspace (10,000 m^2 GEA, 8,333 m^2 NIA) on site is not expected to generate employment opportunities.

Operational phase net additional employment benefits

The net additional job creation of the Proposed Development is estimated to be 2,400 FTE jobs at the local level and 2,900 FTE jobs at the regional level.

The total number of jobs to be created on site by the Proposed Development excluding deadweight was calculated at 384 retail and 5,205 academic, using the proposed (rather than existing) floorspace figures and above assumptions regarding floorspace uses and employment density. The 20 assembly and leisure jobs are eliminated as deadweight, whilst the 20 nursery jobs were excluded from calculations because their numbers are too low to have any significant leakage, displacement or economic multiplier effects.

The net employment benefits at the local and regional levels were calculated by incorporating leakage, displacement, and economic multiplier effects. The HCA ready-reckoners (HCA Additionality Guide 2014) were used to quantify these effects, with assessment of Cambridge's economic characteristics and baseline informing the selection of each ready-reckoner, as follows.

Leakage

Leakage is estimated as the number or proportion of outputs that will benefit those outside the Proposed Development's target area.

For retail, leakages are expected to be low on the local level (10%) and negligible (0%) on the regional level. This is because of the low value nature of these jobs which make long commutes highly unlikely.

For academic jobs, leakages on the local and regional levels are expected to be very low (10% and 5% respectively), because the vast majority will be taken up by those based locally at the University of Cambridge.

Displacement

Displacement would arise if businesses located in the Proposed Development were to employ people currently employed by firms elsewhere in the area. It follows that these jobs would not be additional jobs but rather displaced from elsewhere in the area.

For retail, the expected local, convenience nature of the businesses established make it unlikely that significant numbers of other jobs will be displaced. The displacement is therefore assumed to be low – 25% at both the local and regional levels.

For academic jobs, the majority of floorspace is to be used to rehouse pre-existing academic departments. A high level of displacement is assumed – 65% for the local and regional levels.

Economic multiplier

Economic multiplier effects refer to knock-on effects within the local economy by which the economic impact of a development is multiplied. In accordance with the HCA Additionality Guide 2014, composite multipliers are assumed to be 1.29 at a local level and 1.44 at a regional level for academic jobs, because of the supply chain linkages required for scientific research.

For retail jobs, the HCA recommends lower multipliers, of 1.21 at the local level and 1.38 at the regional level.

Following these assumptions, the leakages and displacement were deducted from the total number of jobs supported by the proposed floorspace, and this figure was put through the multiplier. The total employment figures have been rounded to the nearest 100 FTEs. The process and results are shown in Table A9.1.6 – Table A9.1.7.

Table A9.1.6 Net additional retail jobs

Retail FTE jobs	Local	Regional
Gross direct jobs	384	384
Leakage level	10%	0%
Leakage quantity	38	0
Jobs after leakage	346	384
Displacement level	25%	25%
Displacement quantity	86	96
Jobs after displacement	259	288
Economic multiplier	1.21	1.38
Net additional jobs	314	398
Net additional jobs (rounded)	300	400

Table A9.1.7 Net additional academic jobs

Academic FTE jobs	Local	Regional
Gross direct jobs	5,205	5,205
Leakage level	10%	5%
Leakage quantity	520	260
Jobs after leakage	4,684	4,944
Displacement level	65%	65%
Displacement quantity	3,045	3,214
Jobs after displacement	1,639	1,731
Economic multiplier	1.29	1.44
Net additional jobs	2,115	2,492
Net additional jobs (rounded)	2,100	2,500

Appendix 10.1 Construction traffic assessment

11 Construction Traffic

11.1 Introduction

11.1.1 This section identifies the potential peak movements associated with the construction of the Development, and assesses the effects of these movements on the surrounding highway network.

11.2 Assessment of the peak Construction movements

11.2.1 The assessment of the peak construction movements is contained in Appendix 11.1.

11.2.2 The assumed Initial Phase peak Daily Construction traffic flows are summarised in Table 11.1:

Table 11.1 – Peak Daily Construction Movements

Activity	Max Light Vehicle Movts / day			Max Heavy Vehicle Movts / day			Max Total Vehicle Movts / day		
	In	Out	Tot	In	Out	Tot	In	Out	Tot
Earthworks	10	10	20	82	82	164	92	92	184
On-Site Drainage	4	4	8	4	4	8	8	8	16
Carriageway construction	6	6	12	60	60	120	66	66	132
Building construction	10	10	20	0	0	0	10	10	20
Total	**30**	**30**	**60**	**146**	**146**	**292**	**176**	**176**	**352**

11.2.3 These flows are used to assess the impact of the Development on the surrounding highway network.

11.3 Assessment of the peak Construction impact

11.3.1 Of the Construction flows summarised above, only a limited number of car and HGV movements would typically occur during the peak hours: the working hours of most operatives would not coincide with the network peak, and construction processes would be programmed to avoid reliance on deliveries of concrete and bituminous materials during the more congested periods. As there would be only a limited number of Construction movements in the peak hours, no peak hour assessment has been made.

11.3.2 The following assumptions are made with respect to the assignment of these construction trips:

i) no heavy vehicle will be permitted to access the Development from the east through the City of Cambridge – all movements will be from the M11 or A1303;

ii) the operatives are assumed to be resident locally, and would arrive from the following destinations:

- Madingley Road (East) - 30%
- A14 (North West) - 25% (reassigning via Madingley Road)
- M11 (South) - 10%
- A14 (East) - 25% (reassigning via Madingley Road)
- A1303 / A428 - 10%

iii) reflecting the potential supplier locations, it is assumed that material deliveries will arrive from the following destinations:

- Madingley Road (East) - 0%
- A14 (North West) - 35% (reassigning via M11 Junction 12)
- M11 (South) - 25%
- A14 (East) - 25% (reassigning via M11 Junction 12)
- A1303 / A428 - 15%

11.3.3 On the basis of this worst case assessment of the construction activity trip generation, a worst case assessment of the likely impact on daily flow is shown in Table 11.2 with respect to the 2016 Base Year flows. The flows in this table assume that all access will be from M11 Junction 13 and Madingley Road:

Table 11.2: Construction traffic impacts – Pre Opening

Link No	Link	Base 2016 Daily Flow (24hr, 7 day 1-way flows)		Estimated Daily Construction Traffic (1 way)		Increase		
		All Vehs	Heavy Vehs	Light Vehs	Heavy Vehs	All Vehs	All Vehs	Heavy Vehs
1.0	M11 - J12 - J13 - Nbd	43,702	6,787	3	124	127	0.3%	1.8%
1.0	M11 - J12 - J13 - Sbd	43,702	6,787	3	124	127	0.3%	1.8%
1.1	M11 J13 -J14 - Nbd	32,329	5,021	0	88	88	0.3%	1.7%
1.1	M11 J13 -J14 - Sbd	31,812	4,940	0	88	88	0.3%	1.8%
1.3	M11 J13 off-slip - Nbd	10,033	1,558	3	124	127	1.3%	8.0%
1.3	M11 J13 on-slip - Sbd	7,232	1,123	3	124	127	1.8%	11.0%
2.0	A14 West of J30 (Bar Hill) - Ebd	36,872	6,757	8	51	59	0.2%	0.8%
2.0	A14 West of J30 (Bar Hill) - Wbd	38,330	7,024	8	51	59	0.2%	0.7%
2.1	A14 North East of M11 J14 - Ebd	36,763	6,737	8	51	59	0.2%	0.8%
2.1	A14 North East M11 J14 – Wbd	36,645	6,715	8	51	59	0.2%	0.8%

Link No	Link	Base 2016 Daily Flow (24hr, 7 day 1-way flows)		Estimated Daily Construction Traffic (1 way)		Increase		
		All Vehs	Heavy Vehs	Light Vehs	Heavy Vehs	All Vehs	All Vehs	Heavy Vehs
2.2	A14 West of J32 Interchange - Ebd	38,462	7,048	8	37	44	0.1%	0.5%
2.2	A14 West of J32 Interchange - Wbd	38,462	7,048	8	37	44	0.1%	0.5%
3.0	A1303 East of Madingley Mulch Rbt Ebd	6,608	362	3	22	25	0.4%	6.1%
3.0	A1303 East of Madingley Mulch Rbt Wbd	11,423	625	3	22	25	0.2%	3.5%
3.1	Madingley Rd - East of Cambridge Rd Crossroads Wbd	11,369	622	3	22	25	0.2%	3.5%
3.1	Madingley Rd - East of Cambridge Rd Crossroads Ebd	8,142	446	3	22	25	0.3%	4.9%
3.2	Madingley Rd on Over Bridge M11 Ebd	10,853	594	6	146	152	1.4%	24.6%
3.2	Madingley Rd on Over Bridge M11 Wbd	6,146	337	3	22	25	0.4%	6.5%
3.3	Madingley Rd between M11 Sbd On Slip - Proposed Madingley Rd West Access Ebd	9,976	339	6	146	152	1.5%	43.1%
3.3	Madingley Rd between M11 Sbd On Slip - Proposed Madingley Rd West Access Wbd	9,335	317	6	146	152	1.6%	46.0%
3.4	Madingley Rd - West of P&R Access Wbd	9,335	317	6	146	152	1.6%	46.0%
3.4	Madingley Rd - West of P&R Access Ebd	9,976	339	6	146	152	1.5%	43.1%
3.5	Madingley Rd - East of P&R Access Wbd	8,451	287	6	146	152	1.8%	50.8%
3.5	Madingley Rd - East of P&R Access Ebd	9,384	319	6	146	152	1.6%	45.8%
3.6	Madingley Rd - East of Proposed High Cross Access Ebd	8,256	281	6	146	152	1.8%	52.0%
3.6	Madingley Rd - East of Proposed High Cross Access Wbd	7,317	249	6	146	152	2.1%	58.7%
3.7	Madingley Rd - East of JJ Thomson Ave Ebd	8,988	305	24	0	24	0.3%	0.0%
3.7	Madingley Rd - East of JJ Thomson Ave Wbd	8,098	275	24	0	24	0.3%	0.0%
3.8	Madingley Rd - East of Clerk Maxwell Rd Ebd	8,774	298	24	0	24	0.3%	0.0%
3.8	Madingley Rd - East of Clerk Maxwell Rd Wbd	8,031	273	24	0	24	0.3%	0.0%

(Links with minimal impact have not been reported)

11.3.4 In terms of impact due to the construction of the Development, the largest increase in existing flows would be the increase of heavy vehicles on Madingley Road between the M11 and the Site Access, where there would be a circa 50% increase in existing heavy vehicles. Nevertheless, this would remain well within the overall capacity of the road – and subsumed within the negligible 2% all vehicle increase.

11.3.5 On all other routes, the increase in general traffic resulting from the construction activity is considered to be negligible.

Appendix 10.2 Existing fear, severance, and intimidation

Appendix 10.2 Existing severance, fear and intimidation

Table A10.2.1 Existing severance, fear and intimidation

Link Ref	Link Description	Severance based on 24 hour Flows	Fear and Intimidation			
			a) Average hourly Flows Over 18 hour day	b) Total 18hr HV Flows	c) Traffic Speed (mph)	d) Weighted Assessmentof a) – c)
1.0	M11 - J12 - J13 - Nbd	41,825	2,328	6,578	70	High
1.0	M11 - J12 - J13 - Sbd	37,287	2,075	5,864	70	High
1.1	M11 J13 -J14 - Nbd	31,262	1,740	4,917	70	High
1.1	M11 J13 -J14 - Sbd	30,763	1,712	4,838	70	High
1.2	M11 between A14 Ebd on-slip / Huntingdon Rd on slip - Nbd	21,921	1,220	3,448	70	High
1.2	M11 between A14 Ebd on-slip / Huntingdon Rd on slip - Sbd	22,365	1,245	3,517	70	High
1.3	M11 J13 off-slip - Nbd	10,547	587	1,659	70	Medium
1.3	M11 J13 on-slip - Sbd	6,871	382	1,081	70	Medium
2.0	A14 West of J30 (Bar Hill) - Ebd	35,645	2,152	7,258	70	High
2.0	A14 West of J30 (Bar Hill) - Wbd	37,053	2,237	7,545	70	High
2.1	A14 North West of M11 J14 - Ebd	35,897	2,167	7,310	70	High
2.1	A14 North West M11 J14 - Wbd	35,779	2,160	7,286	70	High
2.2	A14 West of J32 Interchange - Ebd	31,842	1,922	6,484	70	High
2.2	A14 West of J32 Interchange - Wbd	29,753	1,796	6,058	70	High
2.3	A428 -West of M11 J14 - Ebd	11,691	706	2,381	70	High
2.3	A428 - West of M11 J14 - Wbd	10,011	604	2,038	70	High
3.0	A1303 East of Madingley Mulch Rbt Ebd	6,327	364	376	50	Medium
3.0	A1303 East of Madingley Mulch Rbt Wbd	11,248	648	668	50	Medium
3.1	Madingley Rd - East of Cambridge Rd Crossroads Wbd	11,034	635	655	40	Medium
3.1	Madingley Rd - East of Cambridge Rd Crossroads Ebd	6,207	357	369	40	Medium
3.2	Madingley Rd on Over Bridge M11 Ebd	13,177	759	783	40	Medium
3.2	Madingley Rd on Over Bridge M11 Wbd	5,725	330	340	40	Medium
3.3	Madingley Rd between M11 Sbd On Slip - Proposed Madingley Rd West Access Ebd	9,622	556	367	40	Medium
3.3	Madingley Rd between M11 Sbd On Slip - Proposed Madingley Rd West Access Wbd	9,415	544	360	40	Medium
3.4	Madingley Rd - West of P&R Access Wbd	9,415	544	360	40	Medium
3.4	Madingley Rd - West of P&R Access Ebd	9,622	556	367	40	Medium
3.5	Madingley Rd - East of P&R Access Wbd	9,333	540	356	40	Medium
3.5	Madingley Rd - East of P&R Access Ebd	9,127	528	349	40	Medium
3.6	Madingley Rd - East of Proposed High Cross Access Ebd	7,905	457	302	40	Medium
3.6	Madingley Rd - East of Proposed High Cross Access Wbd	8,196	474	313	40	Medium

Link Ref	Link Description	Severance based on 24 hour Flows	Fear and Intimidation			
			a) Average hourly Flows Over 18 hour day	b) Total 18hr HV Flows	c) Traffic Speed (mph)	d) Weighted Assessmentof a) – c)
3.7	Madingley Rd - East of JJ Thomson Ave Ebd	8,998	520	344	30	Medium
3.7	Madingley Rd - East of JJ Thomson Ave Wbd	9,061	524	346	30	Medium
3.8	Madingley Rd - East of Clerk Maxwell Rd Ebd	8,770	507	335	30	Medium
3.8	Madingley Rd - East of Clerk Maxwell Rd Wbd	9,098	526	347	30	Medium
3.9	Madingley Rd - East of Storey's Way Ebd	7,531	435	288	30	Low
3.9	Madingley Rd - East of Storey's Way Wbd	7,390	427	282	30	Low
3.10	Madingley Rd - East of Grange Road Ebd	7,531	435	288	30	Low
3.10	Madingley Rd - East of Grange Road Wbd	7,390	427	282	30	Low
3.11	Madingley Rd - West of Queen's Rd / Northampton St Rbt Ebd	8,311	481	317	30	Low
3.11	Madingley Rd - West of Queen's Rd / Northampton St Rbt Wbd	7,799	451	298	30	Low
3.12	Northampton St - West of Pound Hill Ebd	6,713	388	256	30	Low
3.12	Northampton St - West of Pound Hill Wbd	6,817	394	260	30	Low
4.0	Huntingdon Rd - West of Proposed NWC HRW Access NWbd	6,104	353	233	60	Low
4.0	Huntingdon Rd - West of Proposed NWC HRW Access SEbd	4,402	255	168	60	Low
4.1	Huntingdon Rd - South East of Grange Drive opposite Girton College NWbd	6,104	353	233	30	Low
4.1	Huntingdon Rd - South East of Grange Drive opposite Girton College SEbd	4,402	255	168	30	Low
4.2	Huntingdon Rd - East of NWC HRE Access NWbd	8,018	464	306	30	Low
4.2	Huntingdon Rd - East of NWC HRE Access SEbd	6,744	390	258	30	Low
4.3	Huntingdon Rd - East of NIAB Access NWbd	8,652	500	330	30	Low
4.3	Huntingdon Rd - East of NIAB Access SEbd	8,793	508	336	30	Low
4.4	Huntingdon Rd - East of Storey's Way NWbd	8,134	470	311	30	Low
4.4	Huntingdon Rd - East of Storey's Way SEbd	8,067	467	308	30	Low
5.0	Barton Rd - West of Grantchester Rd Ebd	9,616	556	367	30	Low
5.0	Barton Rd - West of Grantchester Rd Wbd	7,599	439	290	30	Low
5.1	Barton Rd - East of Grantchester Rd Ebd	6,354	367	243	30	Low
5.1	Barton Rd - East of Grantchester Rd Wbd	7,268	420	278	30	Low
6.0	Queen's Rd - North of West Rd Nbd	6,726	389	257	30	Low
6.0	Queen's Rd - North of West Rd Sbd	8,012	463	306	30	Low
7.0	Histon Road - South of A14 Nbd	15,439	893	590	40	Medium
7.0	Histon Road - South of A14 Sbd	18,317	1,059	700	40	Medium
8.0	Grange Rd - South of Madingley Rd Nbd	1,933	113	99	30	Negligible
8.0	Grange Rd - South of Madingley Rd Sbd	2,304	135	118	30	Negligible
9.0	Storey's Way - between Madingley Rd and Huntingdon Rd Ebd	1,671	98	86	20	Negligible

Link Ref	Link Description	Severance based on 24 hour Flows	Fear and Intimidation			
			a) Average hourly Flows Over 18 hour day	b) Total 18hr HV Flows	c) Traffic Speed (mph)	d) Weighted Assessmentof a) – c)
9.0	Storey's Way - between Madingley Rd and Huntingdon Rd Wbd	1,503	88	77	20	Negligible
10.0	Girton Rd - North of Huntingdon Rd Nbd	2,299	135	118	30	Negligible
10.0	Girton Rd - North of Huntingdon Rd Sbd	2,655	155	136	30	Negligible
11.0	Proposed NIAB Access - between Huntingdon Rd and Histon Rd Nbd	Minimal	0	0	20	n/a
11.0	Proposed NIAB Access - between Huntingdon Rd and Histon Rd Sbd	Minimal	0	0	20	n/a
11.1	Proposed Madingley Rd West Access to NWC Nbd	Not Open	Not Open	Not Open	20	n/a
11.1	Proposed Madingley Rd West Access to NWC Sbd	Not Open	Not Open	Not Open	20	n/a
11.2	Proposed Huntingdon Rd West Access to NWC Nbd	Not Open	Not Open	Not Open	20	n/a
11.2	Proposed Huntingdon Rd West Access to NWC Sbd	Not Open	Not Open	Not Open	20	n/a
11.3	Proposed Huntingdon Rd East Access to NWC Sbd	Not Open	Not Open	Not Open	20	n/a
11.3	Proposed Huntingdon Rd East Access to NWC Nbd	Not Open	Not Open	Not Open	20	n/a
12.0	Western Access to Madingley Rd Nbd	Not Open	Not Open	Not Open	20	n/a
12.0	Western Access to Madingley Rd Sbd	Not Open	Not Open	Not Open	20	n/a
12.1	High Cross Access to Madingley Rd Nbd	1,072	77	92	25	Negligible
12.1	High Cross Access to Madingley Rd Sbd	1,123	81	97	25	Negligible
12.2	JJ Thomson Ave Access to Madingley Rd Nbd	1,274	92	110	25	Negligible
12.2	JJ Thomson Ave Access to Madingley Rd Sbd	1,119	81	96	25	Negligible
12.3	Clerk Maxwell Rd Nbd	349	25	30	30	Negligible
12.3	Clerk Maxwell Rd Sbd	305	22	26	30	Negligible

Level	**Impact**
High	> 90% change
Medium	60% - 90% change
Low	30% - 60% change
< 30% change	Negligible

Appendix 10.3 Traffic flows

31500 West Cambridge

Flows for Environmental Statement - Transport Air Quality and Noise Assessments

2016 Base Flows

		2016 Base Flows					
		2016 Base Flows				>3.5 tonne % and Associated Number of Vehicles	
No.	Link / Notes Refer to Reference Link Plan	Total one-way Vehicles AM Peak	Total one-way Vehicles PM Peak	Observed / estimated Combined one-way 18hr Base 5d flows	Observed / estimated Combined one-way 24hr Base 7d flows	Observed / estimated 18 hr 5d >3.5t flow	Observed / estimated 24 hr 7d >3.5t flow
1.0	M11 - J12 - J13 - Nbd	3,392	3,503	43,775	43,702	6,873	6,787
1.0	M11 - J12 - J13 - Sbd	3,503	3,392	43,775	43,702	6,873	6,787
1.1	M11 J13 -J14 - Nbd	2,199	2,902	32,384	32,329	5,085	5,021
1.1	M11 J13 -J14 - Sbd	2,651	2,368	31,865	31,812	5,003	4,940
1.2	M11 between A14 Ebd on-slip / Huntingdon Rd on slip - Nbd	1,464	2,144	22,904	22,865	3,596	3,551
1.2	M11 between A14 Ebd on-slip / Huntingdon Rd on slip - Sbd	2,144	1,534	23,346	23,307	3,666	3,620
1.3	M11 J13 off-slip - Nbd	950	633	10,050	10,033	1,578	1,558
1.3	M11 J13 on-slip - Sbd	353	788	7,244	7,232	1,137	1,123
2.0	A14 West of J30 (Bar Hill) - Ebd	3,685	3,342	40,071	36,872	7,508	6,757
2.0	A14 West of J30 (Bar Hill) - Wbd	3,081	4,224	41,655	38,330	7,805	7,024
2.1	A14 North West of M11 J14 - Ebd	3,697	3,309	39,953	36,763	7,486	6,737
2.1	A14 North West M11 J14 - Wbd	2,994	3,989	39,824	36,645	7,462	6,715
2.2	A14 West of J32 Interchange - Ebd	3,711	3,619	41,798	38,462	7,832	7,048
2.2	A14 West of J32 Interchange - Wbd	3,619	3,711	41,798	38,462	7,832	7,048
2.3	A428 -West of M11 J14 - Ebd	1,567	721	13,046	12,004	2,444	2,200
2.3	A428 - West of M11 J14 - Wbd	756	1,203	11,173	10,281	2,093	1,884
3.0	A1303 East of Madingley Mulch R'bout Ebd	474	513	6,849	6,608	392	362
3.0	A1303 East of Madingley Mulch R'bout Wbd	516	1,190	11,839	11,423	678	625
3.1	Madingley Rd - East of Cambridge Rd Crossroads Wbd	499	1,199	11,783	11,369	675	622
3.1	Madingley Rd - East of Cambridge Rd Crossroads Ebd	722	494	8,439	8,142	484	446
3.2	Madingley Rd on Over Bridge M11 Ebd	1,205	416	11,249	10,853	645	594
3.2	Madingley Rd on Over Bridge M11 Wbd	180	738	6,371	6,146	365	337
3.3	Madingley Rd between M11 Sbd On Slip - Proposed Madingley Rd West Access Ebd	1,212	424	10,384	9,976	381	339
3.3	Madingley Rd between M11 Sbd On Slip - Proposed Madingley Rd West Access Wbd	321	1,210	9,717	9,335	357	317
3.4	Madingley Rd - West of P&R Access Wbd	321	1,210	9,717	9,335	357	317
3.4	Madingley Rd - West of P&R Access Ebd	1,212	424	10,384	9,976	381	339
3.5	Madingley Rd - East of P&R Access Wbd	368	1,018	8,797	8,451	323	287
3.5	Madingley Rd - East of P&R Access Ebd	1,071	468	9,768	9,384	358	319
3.6	Madingley Rd - East of Proposed High Cross Access Ebd	885	469	8,594	8,256	315	281
3.6	Madingley Rd - East of Proposed High Cross Access Wbd	414	786	7,616	7,317	279	249
3.7	Madingley Rd - East of JJ Thomson Ave Ebd	837	637	9,355	8,988	343	305
3.7	Madingley Rd - East of JJ Thomson Ave Wbd	591	737	8,429	8,098	309	275
3.8	Madingley Rd - East of Clerk Maxwell Rd Ebd	755	684	9,133	8,774	335	298
3.8	Madingley Rd - East of Clerk Maxwell Rd Wbd	643	674	8,359	8,031	307	273
3.9	Madingley Rd - East of Storey's Way Ebd	685	566	7,939	7,627	291	259
3.9	Madingley Rd - East of Storey's Way Wbd	628	599	7,792	7,485	286	254
3.10	Madingley Rd - East of Grange Road Ebd	685	566	7,939	7,627	291	259
3.10	Madingley Rd - East of Grange Road Wbd	628	599	7,792	7,485	286	254
3.11	Madingley Rd - West of Queen's Rd / Northampton St R'bout Ebd	807	573	8,761	8,417	321	286
3.11	Madingley Rd - West of Queen's Rd / Northampton St R'bout Wbd	588	708	8,223	7,900	302	269
3.12	Northampton St - West of Pound Hill Ebd	463	652	7,079	6,801	260	231
3.12	Northampton St - West of Pound Hill Wbd	558	575	7,188	6,905	264	235
4.0	Huntingdon Rd - West of Proposed NWC HRW Access NWbd	326	689	6,438	6,185	236	210
4.0	Huntingdon Rd - West of Proposed NWC HRW Access SEbd	400	332	4,641	4,459	170	152
4.1	Huntingdon Rd - South East of Grange Drive opposite Girton College NWbd	326	689	6,438	6,185	236	210
4.1	Huntingdon Rd - South East of Grange Drive opposite Girton College SEbd	400	332	4,641	4,459	170	152
4.2	Huntingdon Rd - East of NWC HRW Access NWbd	389	944	8,458	8,125	310	276
4.2	Huntingdon Rd - East of NWC HRW Access SEbd	668	452	7,109	6,829	261	232
4.3	Huntingdon Rd - East of NIAB Access NWbd	443	995	9,126	8,768	335	298
4.3	Huntingdon Rd - East of NIAB Access SEbd	942	518	9,268	8,903	340	303
4.4	Huntingdon Rd - East of Storey's Way NWbd	462	889	8,579	8,242	315	280
4.4	Huntingdon Rd - East of Storey's Way SEbd	792	548	8,504	8,170	312	278
5.0	Barton Rd - West of Grantchester Rd Ebd	1,115	489	10,178	9,778	373	332
5.0	Barton Rd - West of Grantchester Rd Wbd	303	968	8,066	7,749	296	263

5.1	Barton Rd - East of Grantchester Rd Ebd	618	437	6,698	6,434	246	219
5.1	Barton Rd - East of Grantchester Rd Wbd	282	926	7,668	7,366	281	250
6.0	Queen's Rd - North of West Rd Nbd	463	654	7,092	6,814	260	232
6.0	Queen's Rd - North of West Rd Sbd	781	550	8,446	8,114	310	276
7.0	Histon Road - South of A14 Nbd	946	1,619	16,283	15,643	597	532
7.0	Histon Road - South of A14 Sbd	1,825	1,217	19,308	18,549	708	630
7.1	Histon Rd - South of Akeman St Nbd			0	0	0	0
7.1	Histon Rd - South of Akeman St Sbd			0	0	0	0
8.0	Grange Rd - South of Madingley Rd Nbd	195	201	2,063	1,958	100	87
8.0	Grange Rd - South of Madingley Rd Sbd	321	151	2,458	2,333	119	103
9.0	Storey's Way - between Madingley Rd and Huntingdon Rd Ebd	260	82	1,782	1,692	87	75
9.0	Storey's Way - between Madingley Rd and Huntingdon Rd Wbd	91	217	1,605	1,523	78	67
10.0	Girton Rd - North of Huntingdon Rd Nbd	137	335	2,454	2,330	119	103
10.0	Girton Rd - North of Huntingdon Rd Sbd	342	202	2,832	2,689	138	119
11.0	Proposed NIAB Access - between Huntingdon Rd and Histon Rd Nbd	0	0	0	0	0	0
11.0	Proposed NIAB Access - between Huntingdon Rd and Histon Rd Sbd	0	0	0	0	0	0
11.1	Proposed Madingley Rd West Access to NWC Nbd	0	0	0	0	0	0
11.1	Proposed Madingley Rd West Access to NWC Sbd	0	0	0	0	0	0
11.2	Proposed Huntingdon Rd West Access to NWC Nbd	0	0	0	0	0	0
11.2	Proposed Huntingdon Rd West Access to NWC Sbd	0	0	0	0	0	0
11.3	Proposed Huntingdon Rd East Access to NWC Sbd	0	0	0	0	0	0
11.3	Proposed Huntingdon Rd East Access to NWC Nbd	0	0	0	0	0	0
12.0	Western Access to Madingley Rd Nbd	0	0	0	0	0	0
12.0	Western Access to Madingley Rd Sbd	0	0	0	0	0	0
12.1	High Cross Access to Madingley Rd Nbd	36	257	1,377	1,061	91	66
12.1	High Cross Access to Madingley Rd Sbd	275	46	1,508	1,162	100	73
12.2	JJ Thomson Ave Access to Madingley Rd Nbd	90	227	1,490	1,148	99	72
12.2	JJ Thomson Ave Access to Madingley Rd Sbd	238	77	1,480	1,141	98	71
12.3	Clerk Maxwell Rd Nbd - south of Car Park Access	10	32	197	152	13	10
12.3	Clerk Maxwell Rd Sbd - south of Car Park Access	38	9	221	170	15	11
12.4	Clerk Maxwell Rd Sbd - north of Car Park Access	119	9	601	464	40	29
12.4	Clerk Maxwell Rd Nbd - north of Car Park Access	4	103	503	387	33	24

31500 West Cambridge

Flows for Environmental Statement - Transport Air Quality and Noise Assessments

2021ES DM Flows

		2021ES DM Flows					
		2021ES DM Flows				>3.5 tonne % and Associated Number of Vehicles	
No.	Link / Notes Refer to Reference Link Plan	Total one-way Vehicles AM Peak	Total one-way Vehicles PM Peak	Observed / estimated Combined one-way 18hr Base 5d flows	Observed / estimated Combined one-way 24hr Base 7d flows	Observed / estimated 18 hr 5d >3.5t flow	Observed / estimated 24 hr 7d >3.5t flow
1.0	M11 - J12 - J13 - Nbd	3,583	3,743	46,509	46,431	7,302	7,211
1.0	M11 - J12 - J13 - Sbd	3,703	3,688	46,924	46,846	7,368	7,275
1.1	M11 J13 -J14 - Nbd	2,341	2,985	33,816	33,759	5,309	5,243
1.1	M11 J13 -J14 - Sbd	2,736	2,520	33,370	33,314	5,239	5,174
1.2	M11 between A14 Ebd on-slip / Huntingdon Rd on slip - Nbd	1,575	2,213	24,053	24,013	3,777	3,729
1.2	M11 between A14 Ebd on-slip / Huntingdon Rd on slip - Sbd	2,213	1,645	24,488	24,447	3,845	3,797
1.3	M11 J13 off-slip - Nbd	999	790	11,359	11,340	1,783	1,761
1.3	M11 J13 on-slip - Sbd	467	933	8,883	8,868	1,395	1,377
2.0	A14 West of J30 (Bar Hill) - Ebd	3,686	3,433	40,597	37,356	7,607	6,846
2.0	A14 West of J30 (Bar Hill) - Wbd	3,150	4,277	42,351	38,970	7,935	7,142
2.1	A14 North West of M11 J14 - Ebd	3,684	3,459	40,734	37,483	7,632	6,869
2.1	A14 North West M11 J14 - Wbd	3,148	3,984	40,670	37,424	7,620	6,858
2.2	A14 West of J32 Interchange - Ebd	3,818	3,795	43,416	39,951	8,135	7,321
2.2	A14 West of J32 Interchange - Wbd	3,799	3,817	43,432	39,965	8,138	7,324
2.3	A428 -West of M11 J14 - Ebd	1,604	756	13,458	12,383	2,522	2,269
2.3	A428 - West of M11 J14 - Wbd	791	1,234	11,547	10,625	2,163	1,947
3.0	A1303 East of Madingley Mulch R'bout Ebd	529	580	7,695	7,425	441	406
3.0	A1303 East of Madingley Mulch R'bout Wbd	569	1,262	12,705	12,258	728	671
3.1	Madingley Rd - East of Cambridge Rd Crossroads Wbd	537	1,162	11,789	11,374	675	623
3.1	Madingley Rd - East of Cambridge Rd Crossroads Ebd	692	561	8,694	8,388	498	459
3.2	Madingley Rd on Over Bridge M11 Ebd	1,203	613	12,599	12,156	722	666
3.2	Madingley Rd on Over Bridge M11 Wbd	197	672	6,033	5,820	346	319
3.3	Madingley Rd between M11 Sbd On Slip - Proposed Madingley Rd West Access Ebd	1,180	595	11,266	10,823	413	368
3.3	Madingley Rd between M11 Sbd On Slip - Proposed Madingley Rd West Access Wbd	423	1,264	10,707	10,286	393	350
3.4	Madingley Rd - West of P&R Access Wbd	423	1,264	10,707	10,286	393	350
3.4	Madingley Rd - West of P&R Access Ebd	1,180	595	11,266	10,823	413	368
3.5	Madingley Rd - East of P&R Access Wbd	470	1,072	9,787	9,402	359	320
3.5	Madingley Rd - East of P&R Access Ebd	1,039	639	10,650	10,232	391	348
3.6	Madingley Rd - East of Proposed High Cross Access Ebd	991	485	9,363	8,995	344	306
3.6	Madingley Rd - East of Proposed High Cross Access Wbd	403	944	8,548	8,212	314	279
3.7	Madingley Rd - East of JJ Thomson Ave Ebd	929	702	10,352	9,945	380	338
3.7	Madingley Rd - East of JJ Thomson Ave Wbd	552	874	9,052	8,696	332	296
3.8	Madingley Rd - East of Clerk Maxwell Rd Ebd	848	752	10,158	9,759	373	332
3.8	Madingley Rd - East of Clerk Maxwell Rd Wbd	607	813	9,011	8,657	331	294
3.9	Madingley Rd - East of Storey's Way Ebd	772	641	8,970	8,617	329	293
3.9	Madingley Rd - East of Storey's Way Wbd	632	743	8,725	8,382	320	285
3.10	Madingley Rd - East of Grange Road Ebd	765	641	8,925	8,575	327	291
3.10	Madingley Rd - East of Grange Road Wbd	634	736	8,695	8,353	319	284
3.11	Madingley Rd - West of Queen's Rd / Northampton St R'bout Ebd	899	678	10,007	9,614	367	327
3.11	Madingley Rd - West of Queen's Rd / Northampton St R'bout Wbd	660	848	9,568	9,192	351	312
3.12	Northampton St - West of Pound Hill Ebd	503	761	8,024	7,708	294	262
3.12	Northampton St - West of Pound Hill Wbd	668	647	8,344	8,017	306	272
4.0	Huntingdon Rd - West of Proposed NWC HRW Access NWbd	457	853	8,315	7,988	305	271
4.0	Huntingdon Rd - West of Proposed NWC HRW Access SEbd	489	476	6,126	5,886	225	200
4.1	Huntingdon Rd - South East of Grange Drive opposite Girton College NWbd	411	719	7,172	6,890	263	234
4.1	Huntingdon Rd - South East of Grange Drive opposite Girton College SEbd	395	401	5,054	4,855	185	165
4.2	Huntingdon Rd - East of NWC HRW Access NWbd	568	1,173	11,053	10,619	406	361
4.2	Huntingdon Rd - East of NWC HRW Access SEbd	900	687	10,070	9,675	369	329
4.3	Huntingdon Rd - East of NIAB Access NWbd	588	1,252	11,680	11,221	429	381
4.3	Huntingdon Rd - East of NIAB Access SEbd	1,221	721	12,326	11,841	452	402
4.4	Huntingdon Rd - East of Storey's Way NWbd	591	1,142	10,999	10,567	404	359
4.4	Huntingdon Rd - East of Storey's Way SEbd	1,096	745	11,682	11,223	429	381
5.0	Barton Rd - West of Grantchester Rd Ebd	1,128	506	10,373	9,965	381	339
5.0	Barton Rd - West of Grantchester Rd Wbd	314	977	8,193	7,871	301	268

5.1	Barton Rd - East of Grantchester Rd Ebd	632	454	6,893	6,622	253	225
5.1	Barton Rd - East of Grantchester Rd Wbd	293	935	7,794	7,488	286	254
6.0	Queen's Rd - North of West Rd Nbd	489	701	7,553	7,256	277	247
6.0	Queen's Rd - North of West Rd Sbd	828	572	8,881	8,532	326	290
7.0	Histon Road - South of A14 Nbd	1,086	1,687	17,600	16,908	646	575
7.0	Histon Road - South of A14 Sbd	1,807	1,379	20,217	19,423	742	660
8.0	Grange Rd - South of Madingley Rd Nbd	197	212	2,130	2,022	103	89
8.0	Grange Rd - South of Madingley Rd Sbd	331	156	2,537	2,408	123	107
9.0	Storey's Way - between Madingley Rd and Huntingdon Rd Ebd	209	70	1,453	1,380	71	61
9.0	Storey's Way - between Madingley Rd and Huntingdon Rd Wbd	86	201	1,496	1,420	73	63
10.0	Girton Rd - North of Huntingdon Rd Nbd	152	363	2,678	2,542	130	113
10.0	Girton Rd - North of Huntingdon Rd Sbd	364	224	3,058	2,903	149	128
11.0	Proposed NIAB Access - between Huntingdon Rd and Histon Rd Nbd	8	86	445	343	30	21
11.0	Proposed NIAB Access - between Huntingdon Rd and Histon Rd Sbd	91	27	552	425	37	27
11.1	Proposed Madingley Rd West Access to NWC Nbd	96	405	2,354	1,814	156	114
11.1	Proposed Madingley Rd West Access to NWC Sbd	299	208	2,382	1,836	158	115
11.2	Proposed Huntingdon Rd West Access to NWC Nbd	46	133	841	648	56	41
11.2	Proposed Huntingdon Rd West Access to NWC Sbd	94	75	794	612	53	38
11.3	Proposed Huntingdon Rd East Access to NWC Sbd	151	250	1,884	1,452	125	91
11.3	Proposed Huntingdon Rd East Access to NWC Nbd	286	222	2,387	1,840	158	115
12.0	Western Access to Madingley Rd Nbd	0	0	0	0	0	0
12.0	Western Access to Madingley Rd Sbd	0	0	0	0	0	0
12.1	High Cross Access to Madingley Rd Nbd	18	201	1,031	794	68	50
12.1	High Cross Access to Madingley Rd Sbd	212	52	1,240	956	82	60
12.2	JJ Thomson Ave Access to Madingley Rd Nbd	79	291	1,740	1,341	115	84
12.2	JJ Thomson Ave Access to Madingley Rd Sbd	213	70	1,329	1,024	88	64
12.3	Clerk Maxwell Rd Nbd - south of Car Park Access			199	154	13	10
12.3	Clerk Maxwell Rd Sbd - south of Car Park Access			194	158	13	10
12.4	Clerk Maxwell Rd Sbd - north of Car Park Access			498	397	33	25
12.4	Clerk Maxwell Rd Nbd - north of Car Park Access			508	405	34	25
				Found in 170531 Asst of 24hr Movts on CMR			

31500 West Cambridge

Flows for Environmental Statement - Transport Air Quality and Noise Assessments

2021 DS Flows

		2021 DS Flows					
		2021 DS Flows				>3.5 tonne % and Associated Number of Vehicles	
No.	Link / Notes Refer to Reference Link Plan	Total one-way Vehicles AM Peak	Total one-way Vehicles PM Peak	Observed / estimated Combined one-way 18hr Base 5d flows	Observed / estimated Combined one-way 24hr Base 7d flows	Observed / estimated 18 hr 5d >3.5t flow	Observed / estimated 24 hr 7d >3.5t flow
1.0	M11 - J12 - J13 - Nbd	3,665	3,729	46,943	46,864	7,370	7,278
1.0	M11 - J12 - J13 - Sbd	3,679	3,736	47,072	46,993	7,391	7,298
1.1	M11 J13 -J14 - Nbd	2,317	2,974	33,589	33,533	5,274	5,208
1.1	M11 J13 -J14 - Sbd	2,719	2,503	33,154	33,099	5,206	5,140
1.2	M11 between A14 Ebd on-slip / Huntingdon Rd on slip - Nbd	1,556	2,203	23,865	23,825	3,747	3,700
1.2	M11 between A14 Ebd on-slip / Huntingdon Rd on slip - Sbd	2,198	1,630	24,306	24,266	3,816	3,768
1.3	M11 J13 off-slip - Nbd	1,105	787	12,012	11,992	1,886	1,862
1.3	M11 J13 on-slip - Sbd	461	996	9,252	9,236	1,453	1,434
2.0	A14 West of J30 (Bar Hill) - Ebd	3,828	3,439	41,441	38,133	7,765	6,988
2.0	A14 West of J30 (Bar Hill) - Wbd	3,157	4,379	42,972	39,541	8,052	7,246
2.1	A14 North West of M11 J14 - Ebd	3,973	3,649	43,466	39,996	8,144	7,330
2.1	A14 North West M11 J14 - Wbd	3,312	4,263	43,196	39,748	8,094	7,284
2.2	A14 West of J32 Interchange - Ebd	3,808	3,767	43,194	39,746	8,093	7,284
2.2	A14 West of J32 Interchange - Wbd	3,762	3,815	43,204	39,755	8,095	7,285
2.3	A428 -West of M11 J14 - Ebd	1,599	752	13,408	12,338	2,512	2,261
2.3	A428 - West of M11 J14 - Wbd	785	1,233	11,502	10,584	2,155	1,940
3.0	A1303 East of Madingley Mulch R'bout Ebd	562	580	7,930	7,651	454	419
3.0	A1303 East of Madingley Mulch R'bout Wbd	566	1,286	12,851	12,399	736	679
3.1	Madingley Rd - East of Cambridge Rd Crossroads Wbd	535	1,187	11,945	11,525	684	631
3.1	Madingley Rd - East of Cambridge Rd Crossroads Ebd	730	561	8,958	8,643	513	473
3.2	Madingley Rd on Over Bridge M11 Ebd	1,349	612	13,614	13,136	780	719
3.2	Madingley Rd on Over Bridge M11 Wbd	197	701	6,234	6,014	357	329
3.3	Madingley Rd between M11 Sbd On Slip - Proposed Madingley Rd West Access Ebd	1,334	595	12,242	11,761	449	400
3.3	Madingley Rd between M11 Sbd On Slip - Proposed Madingley Rd West Access Wbd	424	1,356	11,294	10,850	414	369
3.4	Madingley Rd - West of P&R Access Wbd	478	1,384	11,818	11,354	434	386
3.4	Madingley Rd - West of P&R Access Ebd	1,374	608	12,580	12,085	462	411
3.5	Madingley Rd - East of P&R Access Wbd	498	1,198	10,765	10,341	395	351
3.5	Madingley Rd - East of P&R Access Ebd	1,241	664	12,091	11,616	444	395
3.6	Madingley Rd - East of Proposed High Cross Access Ebd	1,176	685	11,812	11,348	433	386
3.6	Madingley Rd - East of Proposed High Cross Access Wbd	578	1,053	10,352	9,945	380	338
3.7	Madingley Rd - East of JJ Thomson Ave Ebd	996	797	11,380	10,933	418	372
3.7	Madingley Rd - East of JJ Thomson Ave Wbd	688	898	10,066	9,671	369	329
3.8	Madingley Rd - East of Clerk Maxwell Rd Ebd	882	934	11,521	11,068	423	376
3.8	Madingley Rd - East of Clerk Maxwell Rd Wbd	868	833	10,794	10,370	396	352
3.9	Madingley Rd - East of Storey's Way Ebd	815	830	10,443	10,032	383	341
3.9	Madingley Rd - East of Storey's Way Wbd	904	769	10,615	10,198	389	347
3.10	Madingley Rd - East of Grange Road Ebd	806	824	10,342	9,936	379	338
3.10	Madingley Rd - East of Grange Road Wbd	899	758	10,517	10,104	386	343
3.11	Madingley Rd - West of Queen's Rd / Northampton St R'bout Ebd	909	698	10,197	9,796	374	333
3.11	Madingley Rd - West of Queen's Rd / Northampton St R'bout Wbd	697	849	9,812	9,427	360	320
3.12	Northampton St - West of Pound Hill Ebd	513	768	8,134	7,814	298	266
3.12	Northampton St - West of Pound Hill Wbd	659	650	8,305	7,978	305	271
4.0	Huntingdon Rd - West of Proposed NWC HRW Access NWbd	461	985	9,181	8,820	337	300
4.0	Huntingdon Rd - West of Proposed NWC HRW Access SEbd	671	481	7,307	7,020	268	239
4.1	Huntingdon Rd - South East of Grange Drive opposite Girton College NWbd	393	721	7,074	6,796	260	231
4.1	Huntingdon Rd - South East of Grange Drive opposite Girton College SEbd	394	396	5,014	4,817	184	164
4.2	Huntingdon Rd - East of NWC HRW Access NWbd	557	1,174	10,991	10,559	403	359
4.2	Huntingdon Rd - East of NWC HRW Access SEbd	807	695	9,531	9,157	350	311
4.3	Huntingdon Rd - East of NIAB Access NWbd	571	1,247	11,540	11,086	423	377
4.3	Huntingdon Rd - East of NIAB Access SEbd	1,120	722	11,688	11,229	429	382
4.4	Huntingdon Rd - East of Storey's Way NWbd	565	1,131	10,765	10,342	395	351
4.4	Huntingdon Rd - East of Storey's Way SEbd	999	732	10,981	10,549	403	359
5.0	Barton Rd - West of Grantchester Rd Ebd	1,128	505	10,361	9,953	380	338
5.0	Barton Rd - West of Grantchester Rd Wbd	312	977	8,185	7,863	300	267

5.1	Barton Rd - East of Grantchester Rd Ebd	631	453	6,880	6,610	252	225
5.1	Barton Rd - East of Grantchester Rd Wbd	292	935	7,786	7,480	286	254
6.0	Queen's Rd - North of West Rd Nbd	522	771	8,207	7,884	301	268
6.0	Queen's Rd - North of West Rd Sbd	883	609	9,470	9,098	347	309
7.0	Histon Road - South of A14 Nbd	1,085	1,837	18,541	17,813	680	605
7.0	Histon Road - South of A14 Sbd	2,019	1,381	21,577	20,729	792	705
8.0	Grange Rd - South of Madingley Rd Nbd	203	215	2,178	2,068	106	92
8.0	Grange Rd - South of Madingley Rd Sbd	333	161	2,575	2,445	125	108
9.0	Storey's Way - between Madingley Rd and Huntingdon Rd Ebd	209	70	1,452	1,378	71	61
9.0	Storey's Way - between Madingley Rd and Huntingdon Rd Wbd	86	201	1,496	1,421	73	63
10.0	Girton Rd - North of Huntingdon Rd Nbd	150	365	2,686	2,550	130	113
10.0	Girton Rd - North of Huntingdon Rd Sbd	368	224	3,082	2,926	150	129
11.0	Proposed NIAB Access - between Huntingdon Rd and Histon Rd Nbd	12	93	493	380	33	24
11.0	Proposed NIAB Access - between Huntingdon Rd and Histon Rd Sbd	92	32	580	447	39	28
11.1	Proposed Madingley Rd West Access to NWC Nbd	139	576	3,360	2,589	223	162
11.1	Proposed Madingley Rd West Access to NWC Sbd	514	230	3,495	2,693	232	168
11.2	Proposed Huntingdon Rd West Access to NWC Nbd	68	264	1,560	1,202	104	75
11.2	Proposed Huntingdon Rd West Access to NWC Sbd	276	85	1,698	1,308	113	82
11.3	Proposed Huntingdon Rd East Access to NWC Sbd	149	247	1,864	1,436	124	90
11.3	Proposed Huntingdon Rd East Access to NWC Nbd	181	237	1,961	1,511	130	95
12.0	Western Access to Madingley Rd Nbd	0	0	0	0	0	0
12.0	Western Access to Madingley Rd Sbd	0	0	0	0	0	0
12.1	High Cross Access to Madingley Rd Nbd	109	620	3,426	2,640	227	165
12.1	High Cross Access to Madingley Rd Sbd	656	113	3,614	2,785	240	174
12.2	JJ Thomson Ave Access to Madingley Rd Nbd	77	233	1,457	1,123	97	70
12.2	JJ Thomson Ave Access to Madingley Rd Sbd	288	50	1,588	1,224	105	77
12.3	Clerk Maxwell Rd Nbd - south of Car Park Access			65	52	4	3
12.3	Clerk Maxwell Rd Sbd - south of Car Park Access			62	50	4	3
12.4	Clerk Maxwell Rd Sbd - north of Car Park Access			1,002	799	67	50
12.4	Clerk Maxwell Rd Nbd - north of Car Park Access			1,021	814	68	54

Found in 170531 Asst of 24hr Movts on CMR

Flows found in 170601 - Junction Turning Movements

31500 West Cambridge

Flows for Environmental Statement - Transport Air Quality and Noise Assessments

2031 ES DM Flows

		2031 ES DM Flows					
		2031 ES DM Flows				>3.5 tonne % and Associated Number of Vehicles	
No.	Link / Notes Refer to Reference Link Plan	Total one-way Vehicles AM Peak	Total one-way Vehicles PM Peak	Observed / estimated Combined one-way 18hr Base 5d flows	Observed / estimated Combined one-way 24hr Base 7d flows	Observed / estimated 18 hr 5d >3.5t flow	Observed / estimated 24 hr 7d >3.5t flow
1.0	M11 - J12 - J13 - Nbd	3,639	3,948	48,166	48,086	7,563	7,468
1.0	M11 - J12 - J13 - Sbd	3,930	3,797	49,057	48,975	7,702	7,606
1.1	M11 J13 -J14 - Nbd	2,368	3,114	34,806	34,748	5,465	5,396
1.1	M11 J13 -J14 - Sbd	2,880	2,573	34,620	34,562	5,436	5,368
1.2	M11 between A14 Ebd on-slip / Huntingdon Rd on slip - Nbd	1,603	2,328	24,961	24,919	3,919	3,870
1.2	M11 between A14 Ebd on-slip / Huntingdon Rd on slip - Sbd	2,333	1,694	25,561	25,519	4,013	3,963
1.3	M11 J13 off-slip - Nbd	1,028	864	12,013	11,993	1,886	1,862
1.3	M11 J13 on-slip - Sbd	550	989	9,765	9,749	1,533	1,514
2.0	A14 West of J30 (Bar Hill) - Ebd	3,762	3,473	41,258	37,965	7,731	6,957
2.0	A14 West of J30 (Bar Hill) - Wbd	3,185	4,358	43,012	39,579	8,059	7,253
2.1	A14 North West of M11 J14 - Ebd	3,785	3,606	42,149	38,784	7,897	7,107
2.1	A14 North West M11 J14 - Wbd	3,287	4,079	42,004	38,651	7,870	7,083
2.2	A14 West of J32 Interchange - Ebd	3,919	3,942	44,831	41,252	8,400	7,560
2.2	A14 West of J32 Interchange - Wbd	3,938	3,912	44,767	41,193	8,388	7,549
2.3	A428 -West of M11 J14 - Ebd	1,643	826	14,079	12,955	2,638	2,374
2.3	A428 - West of M11 J14 - Wbd	863	1,267	12,145	11,176	2,276	2,048
3.0	A1303 East of Madingley Mulch R'bout Ebd	597	637	8,563	8,262	491	452
3.0	A1303 East of Madingley Mulch R'bout Wbd	619	1,330	13,523	13,048	775	714
3.1	Madingley Rd - East of Cambridge Rd Crossroads Wbd	587	1,230	12,607	12,164	722	666
3.1	Madingley Rd - East of Cambridge Rd Crossroads Ebd	760	619	9,568	9,231	548	505
3.2	Madingley Rd on Over Bridge M11 Ebd	1,286	716	13,889	13,401	796	734
3.2	Madingley Rd on Over Bridge M11 Wbd	233	711	6,553	6,323	375	346
3.3	Madingley Rd between M11 Sbd On Slip - Proposed Madingley Rd West Access Ebd	1,226	679	12,091	11,616	444	395
3.3	Madingley Rd between M11 Sbd On Slip - Proposed Madingley Rd West Access Wbd	505	1,339	11,704	11,244	429	382
3.4	Madingley Rd - West of P&R Access Wbd	505	1,339	11,704	11,244	429	382
3.4	Madingley Rd - West of P&R Access Ebd	1,226	679	12,091	11,616	444	395
3.5	Madingley Rd - East of P&R Access Wbd	552	1,147	10,783	10,359	396	352
3.5	Madingley Rd - East of P&R Access Ebd	1,085	723	11,475	11,024	421	375
3.6	Madingley Rd - East of Proposed High Cross Access Ebd	1,068	514	10,036	9,642	368	328
3.6	Madingley Rd - East of Proposed High Cross Access Wbd	426	1,049	9,360	8,992	343	306
3.7	Madingley Rd - East of JJ Thomson Ave Ebd	977	762	11,038	10,604	405	360
3.7	Madingley Rd - East of JJ Thomson Ave Wbd	594	928	9,661	9,282	354	315
3.8	Madingley Rd - East of Clerk Maxwell Rd Ebd	896	812	10,843	10,417	398	354
3.8	Madingley Rd - East of Clerk Maxwell Rd Wbd	649	867	9,621	9,243	353	314
3.9	Madingley Rd - East of Storey's Way Ebd	819	698	9,630	9,251	353	314
3.9	Madingley Rd - East of Storey's Way Wbd	674	796	9,328	8,962	342	305
3.10	Madingley Rd - East of Grange Road Ebd	809	699	9,573	9,197	351	313
3.10	Madingley Rd - East of Grange Road Wbd	679	785	9,292	8,926	341	303
3.11	Madingley Rd - West of Queen's Rd / Northampton St R'bout Ebd	940	709	10,464	10,053	384	342
3.11	Madingley Rd - West of Queen's Rd / Northampton St R'bout Wbd	685	891	10,000	9,607	367	327
3.12	Northampton St - West of Pound Hill Ebd	512	826	8,493	8,160	312	277
3.12	Northampton St - West of Pound Hill Wbd	730	665	8,852	8,504	325	289
4.0	Huntingdon Rd - West of Proposed NWC HRW Access NWbd	513	923	9,114	8,756	334	298
4.0	Huntingdon Rd - West of Proposed NWC HRW Access SEbd	546	545	6,926	6,654	254	226
4.1	Huntingdon Rd - South East of Grange Drive opposite Girton College NWbd	465	769	7,832	7,525	287	256
4.1	Huntingdon Rd - South East of Grange Drive opposite Girton College SEbd	440	467	5,758	5,532	211	188
4.2	Huntingdon Rd - East of NWC HRW Access NWbd	620	1,276	12,037	11,564	442	393
4.2	Huntingdon Rd - East of NWC HRW Access SEbd	1,006	766	11,244	10,803	413	367
4.3	Huntingdon Rd - East of NIAB Access NWbd	601	1,388	12,626	12,130	463	412
4.3	Huntingdon Rd - East of NIAB Access SEbd	1,378	768	13,621	13,085	500	445
4.4	Huntingdon Rd - East of Storey's Way NWbd	605	1,273	11,919	11,451	437	389
4.4	Huntingdon Rd - East of Storey's Way SEbd	1,249	790	12,939	12,431	475	422
5.0	Barton Rd - West of Grantchester Rd Ebd	1,139	512	10,481	10,069	385	342
5.0	Barton Rd - West of Grantchester Rd Wbd	318	988	8,288	7,962	304	271

5.1	Barton Rd - East of Grantchester Rd Ebd	643	460	7,001	6,725	257	229
5.1	Barton Rd - East of Grantchester Rd Wbd	297	946	7,889	7,579	289	258
6.0	Queen's Rd - North of West Rd Nbd	506	741	7,915	7,604	290	258
6.0	Queen's Rd - North of West Rd Sbd	871	590	9,269	8,904	340	303
7.0	Histon Road - South of A14 Nbd	1,166	1,753	18,526	17,798	680	605
7.0	Histon Road - South of A14 Sbd	1,859	1,457	21,042	20,215	772	687
8.0	Grange Rd - South of Madingley Rd Nbd	198	220	2,177	2,067	106	91
8.0	Grange Rd - South of Madingley Rd Sbd	339	158	2,589	2,457	126	109
9.0	Storey's Way - between Madingley Rd and Huntingdon Rd Ebd	211	70	1,464	1,389	71	61
9.0	Storey's Way - between Madingley Rd and Huntingdon Rd Wbd	87	203	1,512	1,435	73	64
10.0	Girton Rd - North of Huntingdon Rd Nbd	155	369	2,725	2,587	132	114
10.0	Girton Rd - North of Huntingdon Rd Sbd	370	227	3,105	2,948	151	130
11.0	Proposed NIAB Access - between Huntingdon Rd and Histon Rd Nbd	20	181	947	730	63	46
11.0	Proposed NIAB Access - between Huntingdon Rd and Histon Rd Sbd	191	57	1,163	896	77	56
11.1	Proposed Madingley Rd West Access to NWC Nbd	104	515	2,909	2,242	193	140
11.1	Proposed Madingley Rd West Access to NWC Sbd	398	234	2,970	2,289	197	143
11.2	Proposed Huntingdon Rd West Access to NWC Nbd	49	154	954	735	63	46
11.2	Proposed Huntingdon Rd West Access to NWC Sbd	107	79	874	674	58	42
11.3	Proposed Huntingdon Rd East Access to NWC Sbd	177	335	2,406	1,854	160	116
11.3	Proposed Huntingdon Rd East Access to NWC Nbd	374	271	3,031	2,336	201	146
12.0	Western Access to Madingley Rd Nbd	0	0	0	0	0	0
12.0	Western Access to Madingley Rd Sbd	0	0	0	0	0	0
12.1	High Cross Access to Madingley Rd Nbd	18	201	1,031	794	68	50
12.1	High Cross Access to Madingley Rd Sbd	212	52	1,240	956	82	60
12.2	JJ Thomson Ave Access to Madingley Rd Nbd	79	291	1,740	1,341	115	84
12.2	JJ Thomson Ave Access to Madingley Rd Sbd	213	70	1,329	1,024	88	64
12.3	Clerk Maxwell Rd Nbd - south of Car Park Access			199	158	13	10
12.3	Clerk Maxwell Rd Sbd - south of Car Park Access			194	154	13	10
12.4	Clerk Maxwell Rd Sbd - north of Car Park Access			498	397	33	25
12.4	Clerk Maxwell Rd Nbd - north of Car Park Access			508	405	34	25
				Found in 170531 Asst of 24hr Movts on CMR			

31500 West Cambridge

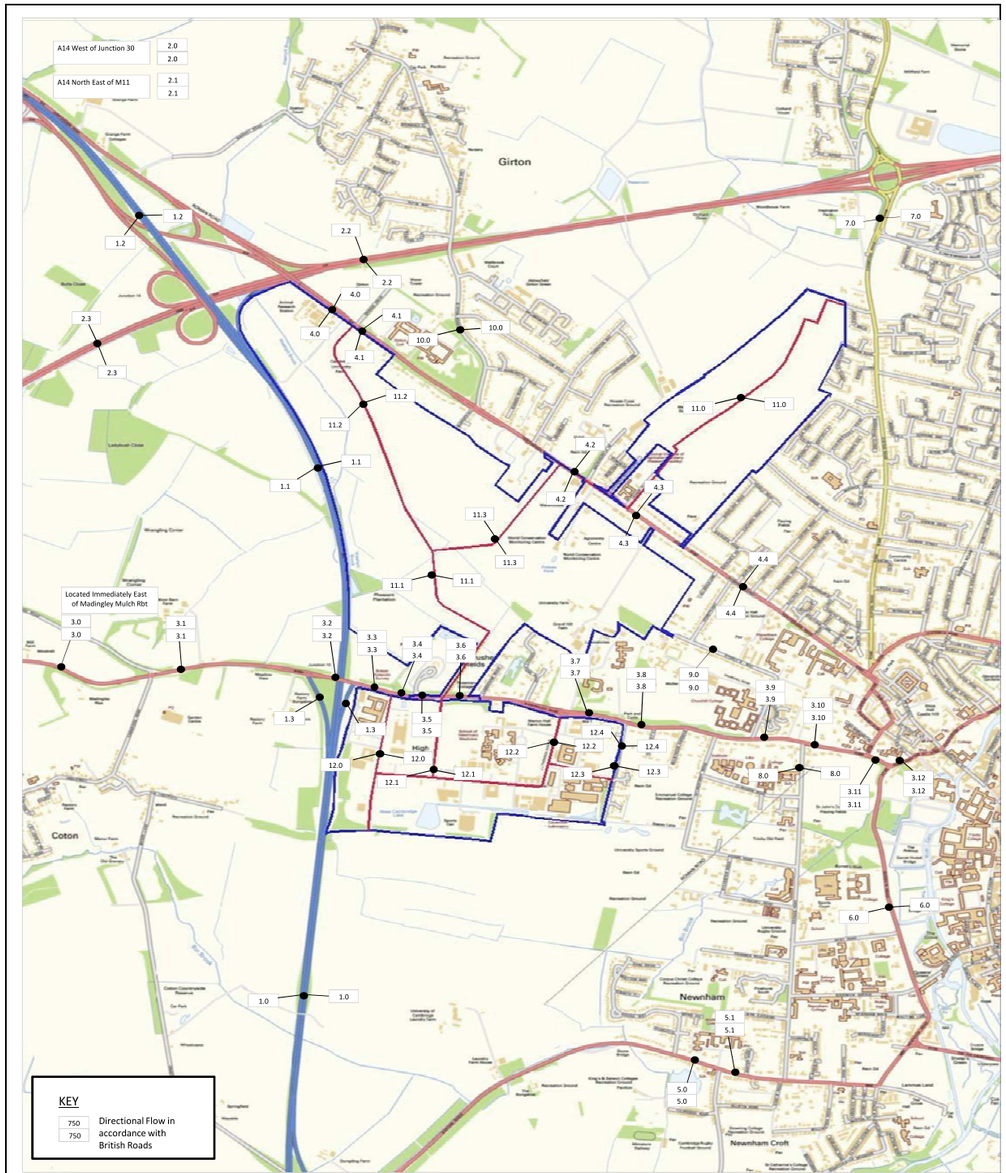
Flows for Environmental Statement - Transport Air Quality and Noise Assessments

2031 DS Flows

		2031 DS Flows					
		2031 DS Flows				>3.5 tonne % and Associated Number of Vehicles	
No.	Link / Notes Refer to Reference Link Plan	Total one-way Vehicles AM Peak	Total one-way Vehicles PM Peak	Observed / estimated Combined one-way 18hr Base 5d flows	Observed / estimated Combined one-way 24hr Base 7d flows	Observed / estimated 18 hr 5d >3.5t flow	Observed / estimated 24 hr 7d >3.5t flow
1.0	M11 - J12 - J13 - Nbd	3,891	3,926	49,630	49,547	7,792	7,695
1.0	M11 - J12 - J13 - Sbd	3,885	4,001	50,066	49,982	7,861	7,762
1.1	M11 J13 -J14 - Nbd	2,343	3,093	34,511	34,453	5,419	5,351
1.1	M11 J13 -J14 - Sbd	2,841	2,557	34,272	34,214	5,381	5,313
1.2	M11 between A14 Ebd on-slip / Huntingdon Rd on slip - Nbd	1,583	2,309	24,709	24,668	3,880	3,831
1.2	M11 between A14 Ebd on-slip / Huntingdon Rd on slip - Sbd	2,302	1,681	25,284	25,242	3,970	3,920
1.3	M11 J13 off-slip - Nbd	1,305	865	13,778	13,755	2,163	2,136
1.3	M11 J13 on-slip - Sbd	545	1,208	11,129	11,110	1,747	1,725
2.0	A14 West of J30 (Bar Hill) - Ebd	4,095	3,491	43,256	39,803	8,105	7,294
2.0	A14 West of J30 (Bar Hill) - Wbd	3,206	4,613	44,583	41,025	8,354	7,518
2.1	A14 North West of M11 J14 - Ebd	4,453	3,847	47,330	43,552	8,868	7,981
2.1	A14 North West M11 J14 - Wbd	3,453	4,717	46,588	42,869	8,729	7,856
2.2	A14 West of J32 Interchange - Ebd	3,907	3,901	44,525	40,971	8,343	7,508
2.2	A14 West of J32 Interchange - Wbd	3,880	3,915	44,448	40,900	8,328	7,495
2.3	A428 -West of M11 J14 - Ebd	1,636	811	13,954	12,840	2,615	2,353
2.3	A428 - West of M11 J14 - Wbd	843	1,266	12,028	11,068	2,254	2,028
3.0	A1303 East of Madingley Mulch R'bout Ebd	695	638	9,253	8,928	530	489
3.0	A1303 East of Madingley Mulch R'bout Wbd	615	1,409	14,046	13,552	805	742
3.1	Madingley Rd - East of Cambridge Rd Crossroads Wbd	584	1,317	13,195	12,731	756	697
3.1	Madingley Rd - East of Cambridge Rd Crossroads Ebd	871	619	10,340	9,976	592	546
3.2	Madingley Rd on Over Bridge M11 Ebd	1,679	723	16,669	16,082	955	880
3.2	Madingley Rd on Over Bridge M11 Wbd	235	806	7,225	6,971	414	382
3.3	Madingley Rd between M11 Sbd On Slip - Proposed Madingley Rd West Access Ebd	1,633	689	14,738	14,158	541	481
3.3	Madingley Rd between M11 Sbd On Slip - Proposed Madingley Rd West Access Wbd	515	1,656	13,780	13,238	506	450
3.4	Madingley Rd - West of P&R Access Wbd	503	1,101	10,181	9,781	374	332
3.4	Madingley Rd - West of P&R Access Ebd	1,113	611	10,942	10,512	401	357
3.5	Madingley Rd - East of P&R Access Wbd	523	915	9,127	8,768	335	298
3.5	Madingley Rd - East of P&R Access Ebd	980	667	10,454	10,043	384	341
3.6	Madingley Rd - East of Proposed High Cross Access Ebd	1,178	788	12,478	11,988	458	407
3.6	Madingley Rd - East of Proposed High Cross Access Wbd	582	1,220	11,437	10,988	420	373
3.7	Madingley Rd - East of JJ Thomson Ave Ebd	1,030	1,096	13,494	12,963	495	441
3.7	Madingley Rd - East of JJ Thomson Ave Wbd	968	1,022	12,631	12,134	463	412
3.8	Madingley Rd - East of Clerk Maxwell Rd Ebd	978	1,233	14,031	13,479	515	458
3.8	Madingley Rd - East of Clerk Maxwell Rd Wbd	1,215	929	13,610	13,075	499	444
3.9	Madingley Rd - East of Storey's Way Ebd	911	1,128	12,937	12,428	475	422
3.9	Madingley Rd - East of Storey's Way Wbd	1,249	865	13,415	12,888	492	438
3.10	Madingley Rd - East of Grange Road Ebd	898	1,117	12,790	12,288	469	418
3.10	Madingley Rd - East of Grange Road Wbd	1,241	849	13,269	12,748	487	433
3.11	Madingley Rd - West of Queen's Rd / Northampton St R'bout Ebd	956	881	11,662	11,203	428	381
3.11	Madingley Rd - West of Queen's Rd / Northampton St R'bout Wbd	899	896	11,393	10,946	418	372
3.12	Northampton St - West of Pound Hill Ebd	539	943	9,407	9,038	345	307
3.12	Northampton St - West of Pound Hill Wbd	800	678	9,383	9,014	344	306
4.0	Huntingdon Rd - West of Proposed NWC HRW Access NWbd	535	1,267	11,437	10,987	420	373
4.0	Huntingdon Rd - West of Proposed NWC HRW Access SEbd	984	565	9,833	9,447	361	321
4.1	Huntingdon Rd - South East of Grange Drive opposite Girton College NWbd	436	777	7,701	7,398	283	251
4.1	Huntingdon Rd - South East of Grange Drive opposite Girton College SEbd	443	454	5,696	5,472	209	186
4.2	Huntingdon Rd - East of NWC HRW Access NWbd	662	1,271	12,269	11,787	450	401
4.2	Huntingdon Rd - East of NWC HRW Access SEbd	893	814	10,836	10,410	398	354
4.3	Huntingdon Rd - East of NIAB Access NWbd	615	1,358	12,524	12,031	459	409
4.3	Huntingdon Rd - East of NIAB Access SEbd	1,231	788	12,811	12,308	470	418
4.4	Huntingdon Rd - East of Storey's Way NWbd	591	1,237	11,604	11,148	426	379
4.4	Huntingdon Rd - East of Storey's Way SEbd	1,105	782	11,973	11,502	439	391
5.0	Barton Rd - West of Grantchester Rd Ebd	1,140	519	10,533	10,119	386	344
5.0	Barton Rd - West of Grantchester Rd Wbd	316	989	8,286	7,960	304	271

5.1	Barton Rd - East of Grantchester Rd Ebd	644	468	7,053	6,776	259	230
5.1	Barton Rd - East of Grantchester Rd Wbd	296	947	7,887	7,577	289	258
6.0	Queen's Rd - North of West Rd Nbd	630	856	9,429	9,059	346	308
6.0	Queen's Rd - North of West Rd Sbd	952	683	10,381	9,973	381	339
7.0	Histon Road - South of A14 Nbd	1,179	1,958	19,911	19,128	730	650
7.0	Histon Road - South of A14 Sbd	2,138	1,475	22,927	22,026	841	749
8.0	Grange Rd - South of Madingley Rd Nbd	210	224	2,259	2,144	110	95
8.0	Grange Rd - South of Madingley Rd Sbd	341	169	2,654	2,520	129	112
9.0	Storey's Way - between Madingley Rd and Huntingdon Rd Ebd	211	70	1,461	1,387	71	61
9.0	Storey's Way - between Madingley Rd and Huntingdon Rd Wbd	87	203	1,506	1,430	73	63
10.0	Girton Rd - North of Huntingdon Rd Nbd	156	383	2,804	2,662	136	118
10.0	Girton Rd - North of Huntingdon Rd Sbd	389	229	3,218	3,055	156	135
11.0	Proposed NIAB Access - between Huntingdon Rd and Histon Rd Nbd	30	196	1,065	821	71	51
11.0	Proposed NIAB Access - between Huntingdon Rd and Histon Rd Sbd	196	67	1,236	953	82	60
11.1	Proposed Madingley Rd West Access to NWC Nbd	203	959	5,460	4,208	362	263
11.1	Proposed Madingley Rd West Access to NWC Sbd	942	304	5,853	4,510	388	282
11.2	Proposed Huntingdon Rd West Access to NWC Nbd	99	490	2,768	2,133	184	133
11.2	Proposed Huntingdon Rd West Access to NWC Sbd	541	111	3,065	2,362	203	148
11.3	Proposed Huntingdon Rd East Access to NWC Sbd	249	318	2,663	2,052	177	128
11.3	Proposed Huntingdon Rd East Access to NWC Nbd	240	340	2,724	2,099	181	131
12.0	Western Access to Madingley Rd Nbd	69	600	3,144	2,423	209	152
12.0	Western Access to Madingley Rd Sbd	582	94	3,177	2,448	211	153
12.1	High Cross Access to Madingley Rd Nbd	145	574	3,379	2,604	224	163
12.1	High Cross Access to Madingley Rd Sbd	758	124	4,145	3,194	275	200
12.2	JJ Thomson Ave Access to Madingley Rd Nbd	136	478	2,885	2,223	191	139
12.2	JJ Thomson Ave Access to Madingley Rd Sbd	560	96	3,083	2,375	205	149
12.3	Clerk Maxwell Rd Nbd - south of Car Park Access			65	52	4	3
12.3	Clerk Maxwell Rd Sbd - south of Car Park Access			62	50	4	3
12.4	Clerk Maxwell Rd Sbd - north of Car Park Access			1,036	826	69	52
12.4	Clerk Maxwell Rd Nbd - north of Car Park Access			1,056	841	70	53
				Found in 170531 Asst of 24hr Movts on CMR			

Flows found in 170601 - Junction Turning Movements



Link Reference Diagram

Appendix 10.4 TEMPRO growth factors for the Cambridge area

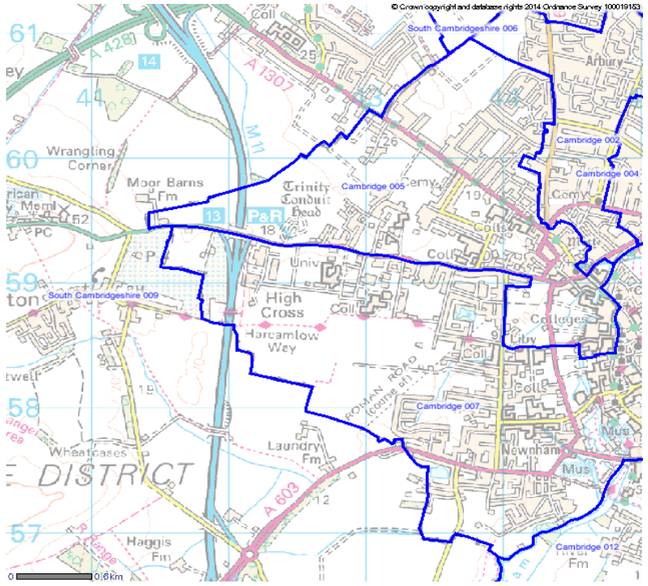
Job Number and Title

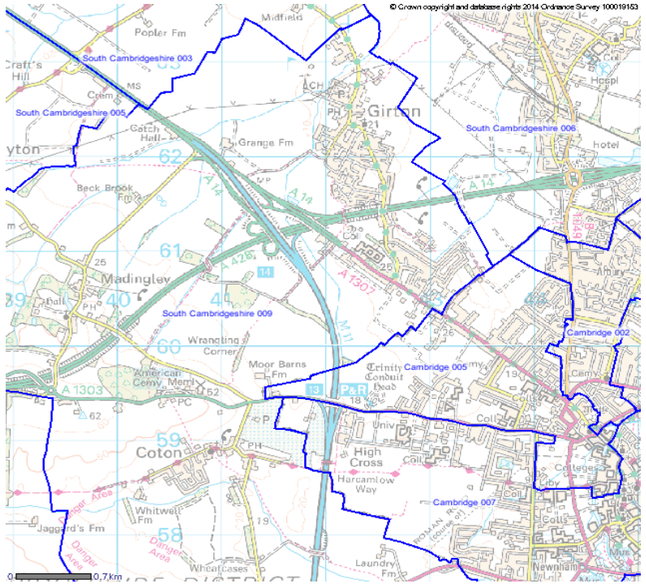
Prepared By: M Balding

TEMPRO Growth factors

Dataset Selected:

TEMPro Version 7.0.0 Growth Factors											
	Road Classification	Applied to (including)	2015-2016 Cambridge 005 (E02003723)		2015-2016 Cambridge 007 (E02003725)		2015-2016 Cambridge 009 (E02003727)		2014-2016 Cambridge 009 (E02003727)		2013-2016 Cambridge 007 (E02003725)	
			AM Peak (0700 - 0959)	PM Peak (1600 - 1859)	AM Peak (0700 - 0959)	PM Peak (1600 - 1859)	AM Peak (0700 - 0959)	PM Peak (1600 - 1859)	AM Peak (0700 - 0959)	PM Peak (1600 - 1859)	AM Peak (0700 - 0959)	PM Peak (1600 - 1859)
1	Urban Trunk	A428	1.0129	1.015	1.0151	1.0176			1.0425	1.0436		
2	Urban Principal Road	Madingley Road, Huntingdon Road, Barton Road, Northampton Road	1.0118	1.014	1.014	1.0166					1.041	1.0487
3	Urban Minor Road	Grange Road, Site Access	1.012	1.0141	1.0141	1.0167						
4	Rural Motorway	M11	1.0142	1.0164	1.0164	1.019			1.0454	1.0464		
5	Rural Trunk	A14	1.0151	1.0173	1.0173	1.0199	1.0239	1.0244	1.0465	1.0475		
6	Rural Principal	A1303 East of Madingley Mulch R'bout	1.0126	1.0147	1.0148	1.0173						
7	Rural Minor		1.0119	1.014	1.0141	1.0166						





Appendix 11.1 Human health receptors

Receptor	Location	Model Height (m)
Off-Site Receptors		
R1	1 Rhodegund Cottages, A14 Huntingdon Rd	1.5
R2	Hacker's Fruit Farm	1.5
R3	1 Huntingdon Road A14	1.5
R4	3-4 Elm Grange, A14 Huntingdon Rd	1.5
R5	118 Girton Road	4.5
R6	102 Girton Road	1.5
R7	91 Girton Road	1.5
R8	84 Girton Road	1.5
R9	2 Girton Road	1.5
R10	1 Huntingdon Road A14	1.5
R11	Nurseries, Huntington Road	1.5
R12	71- 81 Huntingdon Road	1.5
R13	141 Huntingdon Road	1.5
R14	139 Huntingdon Road	1.5
R15	1 to 81 Victoria Road	4.5
R16	38 Northampton Street	1.5
R17	9 Madingley Road	1.5
R18	11 Madingley Road	1.5
R19	19 to 39 Benians Ct	1.5
R20	23 Madingley Road	1.5
R21	53 Madingley Road	1.5
R22*	14 Conduit Head Road	1.5
R23*	Whitehouse, Conduit Head Road	1.5
R24*	2 Merton Hall, Madingley Road	1.5
R25*	36 Madingley Road	1.5
R26*	2 Lansdowne Road	1.5
R27*	2 Rosemary Cottages, Madingley Road	1.5
R28*	1 to 10 Refectory Farm Chalets	1.5
R29*	77 The Footpath	1.5
R30	3 St Neods Road	1.5
R31	Mill Farm, St Neods Rd	1.5
On-Site Receptors		
On Site 1*	Residential and Nursery (ground floor only)	1.5, 3, 4.5 and 6
On Site 2*	Residential	1.5, 3, 4.5 and 6
On Site 3*	Nursery (ground floor only)	1.5

Receptors marked with an * are used in the energy centre modelling

Appendix 11.2 Air quality model verification

Nitrogen dioxide

Most nitrogen dioxide is produce in the atmosphere by the reaction of nitric oxide (NO) with ozone. It is therefore most appropriate to verify the model in terms of primary pollutant emission of nitrogen oxides (NOx = NO + NO2). The model has been run to predict the 2016 annual mean road-NO_x contribution at seven roadside and kerbside monitoring locations (both automatic and diffusion tubes) in close proximity to the proposed development and within the two closest declared AQMAs (described in Table 10.11). Table 10.2.1 below describes the heights at which the monitoring locations were modelled.

Table 11.2.1 Modelled Heights of Monitoring Locations

ID	Site Type	Within AQMA	Model Height (m)
Automatic Sites (SCDC)			
Girton	Roadside	N	1.5
Diffusion Tubes (SCDC)			
1 Catchall Farm Cottages	Roadside	Y	1.5
Hackers Fruit Farm	Roadside	Y	1.5
Diffusion Tubes (CCC)			
Madingley Road	Kerbside	N	1
Histon Road 1 NEW	Kerbside	N	1.5
Huntingdon Road 1	Roadside	N	1
Huntingdon Road 2	Roadside	N	1

The model output of road-NO_x has been compared with the 'measured' road-NO_x, which was calculated from the measured NO_2 concentrations and the adjusted background NO_2 concentrations within the NO_x from NO_2 calculator published by Defra.

A primary adjustment factor was determined as the slope of the best fit line between the 'measured' road contribution and the model derived road contribution, forced through zero (Figure 11.2.1). This factor was then applied to the modelled road-NO_x concentration for each monitoring Site to provide adjusted modelled road-NO_x concentrations. The total NO_2 concentrations were then determined by combining the adjusted modelled road-NO_x concentrations with the predicted background NO_2 concentration within the NO_x from NO_2 calculator. A secondary adjustment factor was finally calculated as the slope of the best fit line applied to the adjusted data and forced through zero (Figure 11.2.2).

The following primary and secondary adjustment factors have been applied to all modelled NO_2 data:

- Primary adjustment factor: 1.9381
- Secondary adjustment factor: 1.0002

The results imply that the model was under-predicting the road-NO_x contribution. This is a common experience with this and most other models. The final NO_2 adjustment is minor.

Figure 11.2.3 compares final adjusted modelled total NO_2 at each of the monitoring sites, to measured total NO_2, and shows the 1:1 relationship, as well as ±10% and ±25% of the 1:1 line. The majority of the points lie within the ±25% line with the exception of monitoring location Madingley Road, which measured 37.2 µg/m^3 in 2016. This monitoring point was left within the verification as it provided a slightly higher verification factor that otherwise would have been obtained without the monitoring point. The reasons for the under-prediction at this point could not be ascertained.

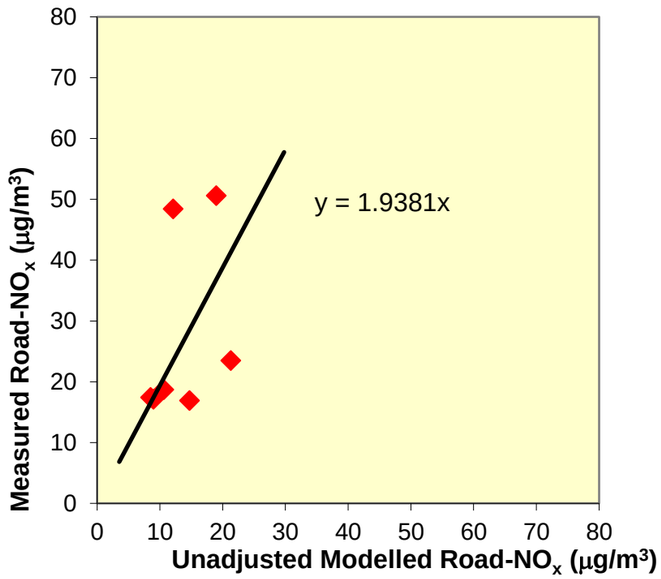


Figure 11.2.1: Comparison of Measured Road-NO_x with Unadjusted Modelled Road-NO_x Concentrations

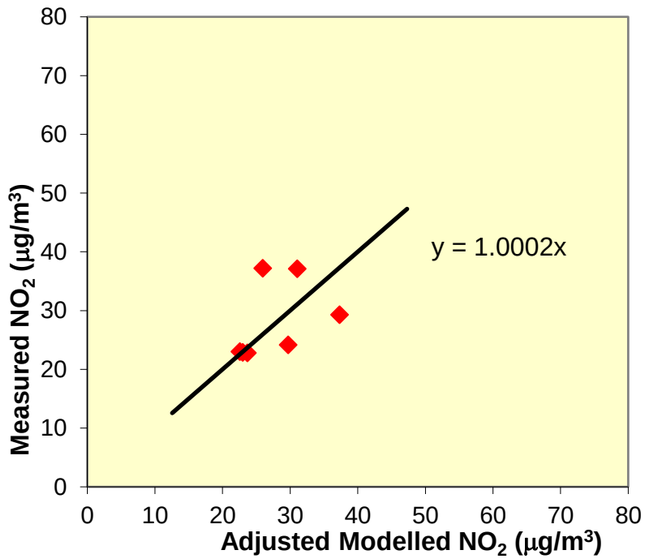


Figure 11.2.2: Comparison of Measured NO_2 with Adjusted Modelled NO_2 Concentrations

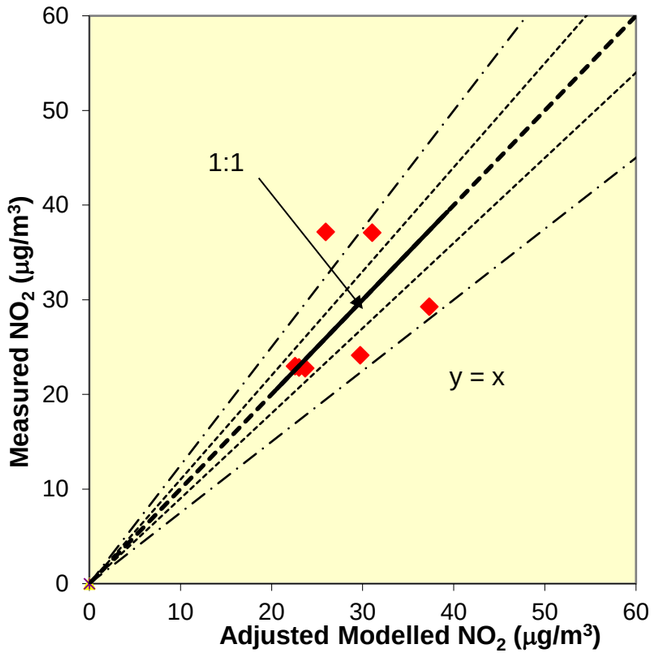


Figure 11.2.3: Comparison of Measured NO_2 with Fully Adjusted Modelled NO_2 Concentrations

PM_{10} and $PM_{2.5}$

Automatic monitors Girton and Impington (A14) undertake PM_{10} monitoring. However, as the Impington monitor measured PM_{10} concentrations below the background in 2016 and the Girton monitor was only just above the background, it was considered conservative to apply the primary adjustment factor calculated for NO_2 concentrations to the modelled-road PM_{10} concentrations.

The Girton monitor also undertakes $PM_{2.5}$ monitoring. Results from 2016 were used to calculate a verification factor for $PM_{2.5}$. This resulted in a verification factor of 3.2933 which was used to adjust modelled-road $PM_{2.5}$ concentrations.

Appendix 11.3 Traffic data

Table 11.3.1 Traffic data used for air quality modelling

Road Link	Description	2016 Baseline		2021 Without Development		2021 With Development (Phase I)		2031 Baseline with Phase I		2031 With Full Development	
		AADT	%HDV	AADT	%HDV	AADT	%HDV	AADT	%HDV	AADT	%HDV
1.0	M11 – J12 – J13	87,403	15.53	93,277	15.53	93,857	15.53	97,061	15.53	99,529	15.53
1.1	M11 – J13 – J14	64,141	15.53	67,076	15.53	66,632	15.53	69,310	15.53	68,667	15.53
1.2	M11 between A14 Ebd on-slip / Huntington Road on slip	46,172	15.53	48,460	15.53	48,091	15.53	50,438	15.53	49,910	15.53
1.3	M11 J13 off-slip	17,265	15.53	20,208	15.53	21,229	15.53	21,742	15.53	24,865	15.53
2.0	A14 West of J30 (Bar Hill)	75,202	18.33	76,326	18.33	77,674	18.33	77,544	18.33	80,828	18.33
2.1	A14 North West of M11 J154	73,408	18.33	74,906	18.33	79,774	18.33	77,436	18.33	86,421	18.33
2.2	A14 West of J32 Interchange	76,924	18.33	79,916	18.33	79,502	18.33	82,445	18.33	81,871	18.33
2.3	A428 – West of M11 J14	22,285	18.33	23,008	18.33	22,922	18.33	24,131	18.33	23,908	18.33
3.0	A1303 East of Madingley Mulch Roundabout	18,031	5.47	19,682	5.47	20,050	5.47	21,309	5.47	22,480	5.47
3.1	Madingley Rd – East of Cambrirdge Rd Crossroads	19,510	5.47	19,762	5.47	20,168	5.47	21,396	5.47	22,707	5.47
3.2	Madingley Rd on Over Bridge M11	17,000	5.47	17,976	5.47	19,150	5.47	19,724	5.47	23,053	5.47
3.3	Madingley Rd between M11 Sbd On Slip – Proposed Madingley Road West Access	19,311	3.4	21,109	3.4	22,611	3.4	22,859	3.4	27,397	3.4
3.4	Madingley Rd – West of P&R Access	19,311	3.4	21,109	3.4	22,611	3.4	22,859	3.4	27,397	3.4
3.5	Madingley Rd – East of P&R Access	17,835	3.4	19,634	3.4	21,957	3.4	21,384	3.4	18,811	3.4
3.6	Madingley Rd – East of Proposed High Cross Access	15,573	3.4	17,207	3.4	21,293	3.4	18,634	3.4	22,976	3.4
3.7	Madingley Rd – East of JJ Thomson Ave	17,085	3.4	18,642	3.4	20,604	3.4	19,886	3.4	25,098	3.4
3.8	Madingley Rd – East of Clerk Maxwell Rd	16,805	3.4	18,416	3.4	21,438	3.4	19,660	3.4	26,554	3.4
3.9	Madingely Rd – East of Storey's Way	15,112	3.4	17,000	3.4	20,230	3.4	18,213	3.4	25,316	3.4
3.10	Madingley Rd – East of Grange Road	15,112	3.4	16,928	3.4	20,040	3.4	18,123	3.4	25,036	3.4
3.11	Madingley Rd – West of Queen's Rd / Northampton Road Roundabout	16,317	3.4	18,806	3.4	19,223	3.4	19,660	3.4	22,149	3.4
3.12	Northampton Rd – West of Pound Hill	13,706	3.4	15,725	3.4	15,793	3.4	16,664	3.4	18,052	3.4
4.0	Huntingdon Rd- West of Proposed NWC HRW Access	10,644	3.4	13,874	3.4	15,840	3.4	15,410	3.4	20,434	3.4
4.1	Huntingdon Rd – South East of Grange Drive opposite Girton College	10,644	3.4	11,746	3.4	11,613	3.4	13,057	3.4	12,870	3.4
4.2	Huntingdon Rd – East of NWC HRW Access	14,955	3.4	20,294	3.4	19,716	3.4	22,367	3.4	22,197	3.4
4.3	Huntingdon Rd – East of NIAB Access	17,671	3.4	23,062	3.4	22,315	3.4	25,215	3.4	24,339	3.4
4.4	Huntingdon Rd – East of Storey's Way	16,411	3.4	21,790	3.4	20,891	3.4	23,882	3.4	22,650	3.4
6.0	Queen's Rd – North of West Road	14,928	3.4	15,788	3.4	16,982	3.4	16,508	3.4	19,031	3.4
7.0	Histon Road – South of A14	34,192	3.4	36,331	3.4	38,542	3.4	38,014	3.4	41,154	3.4

Road Link	Description	2016 Baseline		2021 Without Development		2021 With Development (Phase I)		2031 Baseline with Phase I		2031 With Full Development	
		AADT	%HDV	AADT	%HDV	AADT	%HDV	AADT	%HDV	AADT	%HDV
8.0	Grange Road – South of Madingley Road	4,292	4.43	4,430	4.43	4,512	4.43	4,524	4.43	4,664	4.43
9.0	Storey's Way – between Madingley Rd and Huntingdon Road	3,215	4.43	2,800	4.43	2,799	4.43	2,825	4.43	2,817	4.43
10.0	Girton Road – North of Huntingdon Road	5,019	4.43	5,446	4.43	5,476	4.43	5,535	4.43	5,717	4.43
11.0	Proposed NIAB Access – between Huntingdon Rd and Histon Rd	0	0	768	6.26	827	6.26	1,626	6.26	1,774	6.26
11.1	Proposed Madingley Rd West Access to NWC	0	0	3,650	6.26	5,282	6.26	4,530	6.26	8,718	6.26
11.2	Proposed Huntingdon Rd West Access to NWC	0	0	1,260	6.26	2,510	6.26	1,409	6.26	4,494	6.26
11.3	Proposed Huntingdon Rd East Access to NWC	0	0	3,292	6.26	2,947	6.26	4,190	6.26	4,151	6.26
12.0	Western Access to Madingley Rd	0	0	0	0	0	0	0	0	4,870	6.26
12.1	High Cross Access to Madingley Rd	2,223	6.26	1,750	6.26	5,425	6.26	1,750	6.26	5,798	6.26
12.2	JJ Thomson Ave Access to Madingley Rd	2,289	6.26	2,365	6.26	2,347	6.26	2,365	6.26	4,599	6.26
12.3	Clerk Maxwell Rd	322	6.26	312	6.26	102	6.26	312	6.26	102	6.26

Appendix 11.5 Predicted baseline concentrations

Predicted Concentrations of NO_2, PM_{10} and $PM_{2.5}$ at Receptors in 2016, 2021 and 2031

Table 11.5.1 Human Health Receptors

Receptor	Annual Mean (µg/m3)								
	2016 Baseline			2021 Without Development			2031 Without Full Development		
	NO2	PM10	PM2.5	NO2	PM10	PM2.5	NO2	PM10	PM2.5
R1	31.9	20.5	14.8	26.7	20.0	14.2	17.9	19.3	13.4
R2	29.1	19.5	14.1	24.4	19.0	13.5	16.5	18.4	12.8
R3	28.9	21.1	14.8	24.4	20.7	14.3	16.6	20.0	13.5
R4	29.5	20.1	14.3	26.2	19.8	14.0	18.2	19.2	13.2
R5	29.4	20.0	14.4	25.2	19.6	13.9	17.1	18.9	13.2
R6	29.2	20.0	14.4	25.0	19.6	13.9	17.0	18.9	13.2
R7	21.9	18.8	13.1	19.2	18.5	12.8	13.7	17.9	12.2
R8	21.7	18.8	13.1	19.1	18.5	12.8	13.6	17.9	12.2
R9	19.6	17.7	12.5	17.5	17.5	12.2	12.6	17.0	11.7
R10	22.2	18.1	12.9	19.8	17.9	12.6	14.0	17.4	12.1
R11	17.5	17.5	12.3	16.1	17.4	12.1	12.0	16.9	11.6
R12	19.9	16.8	12.1	19.1	16.8	12.1	13.6	16.3	11.6
R13	18.3	16.7	12.0	16.7	16.5	11.8	12.4	16.0	11.3
R14	18.6	16.7	12.0	16.8	16.5	11.8	12.4	16.0	11.3
R15	27.0	17.5	13.0	25.1	17.4	12.8	18.2	16.9	12.2
R16	23.4	16.5	12.1	21.4	16.2	11.9	16.1	15.7	11.3
R17	23.2	16.9	12.4	21.1	16.7	12.1	15.8	16.1	11.5
R18	21.9	16.7	12.1	19.9	16.5	11.9	15.2	15.9	11.3
R19	18.0	16.7	11.9	16.2	16.4	11.7	12.1	15.9	11.2
R20	18.6	16.7	12.0	16.7	16.5	11.7	12.3	15.9	11.2
R21	16.9	16.4	11.7	15.2	16.2	11.4	11.5	15.7	11.0
R22	18.6	17.9	12.5	16.6	17.7	12.3	12.2	17.2	11.8
R23	18.3	17.8	12.5	16.4	17.6	12.3	12.0	17.1	11.8
R24	17.3	17.6	12.3	15.5	17.4	12.0	11.5	16.9	11.5
R25	19.5	18.1	12.7	17.5	17.9	12.5	12.7	17.4	12.0
R26	19.6	18.1	12.7	17.5	17.9	12.5	12.7	17.4	12.0
R27	19.1	17.9	12.6	17.1	17.7	12.4	12.5	17.2	11.9
R28	15.5	16.1	11.4	13.7	15.8	11.2	10.1	15.3	10.7
R29	14.8	17.1	11.8	13.2	16.8	11.6	10.0	16.3	11.1
R30	31.9	16.7	12.1	16.3	16.4	11.7	11.8	15.9	11.2
R31	29.1	16.6	11.9	15.6	16.3	11.7	11.4	15.8	11.2
On site 1A	13.7	17.3	11.8	12.3	17.0	11.6	9.5	16.5	11.1
On site 1B	13.7	17.3	11.8	12.3	17.0	11.6	9.5	16.5	11.1
On site 1C	13.7	17.3	11.8	12.3	17.0	11.6	9.5	16.5	11.1
On site 1D	13.7	17.3	11.8	12.3	17.0	11.6	9.5	16.5	11.1
On site 2A	13.6	17.3	11.8	12.3	17.0	11.6	9.4	16.5	11.1
On site 2B	13.6	17.3	11.8	12.3	17.0	11.6	9.4	16.5	11.1
On site 2C	13.6	17.3	11.8	12.3	17.0	11.6	9.4	16.5	11.1
On site 2D	13.6	17.3	11.8	12.3	17.0	11.6	9.4	16.5	11.1
On site 3A	13.8	17.3	11.8	12.4	17.0	11.6	9.5	16.5	11.1
Objectives	40	40	25	40	40	25	40	40	25

Table 11.5.2 Ecological Receptors (2016)

Receptor and Distance in Habitat	Distance from kerb (m)	Total NOx (µg/m3)	Nitrogen Deposition (kgN/ha/yr)	Acid Deposition (keq/ha/yr)
Madingley Wood SSSI				
T1- 0m	0	43.8	31.6	2.468
T1- 5m	5	32.2	30.0	2.351
T1- 10m	10	27.3	29.3	2.300
T1- 15m	15	24.7	28.9	2.272
T1- 20m	20	23.0	28.6	2.254
T1- 30m	30	21.0	28.3	2.232
T1- 40m	40	19.9	28.2	2.221
T1- 50m	50	19.2	28.0	2.213
T1- 75m	75	18.2	27.9	2.202
T1- 100m	100	17.6	27.8	2.196
T1- 125m	125	17.3	27.7	2.192
T1- 150m	150	17.0	27.7	2.189
T1- 175m	175	16.9	27.7	2.187
T1- 200m	200	16.7	27.7	2.186
CRITICAL LEVEL / LOAD		30	15 - 20	1.859
Exceedences of the Critical Level / Load in bold				

Table 11.5.3 Ecological Receptors (2021)

Receptor and Distance in Habitat	Distance from kerb (m)	Total NOx (µg/m3)	Nitrogen Deposition (kgN/ha/yr)	Acid Deposition (keqN/ha/yr)
Madingley Wood SSSI				
T1- 0m	0	38.2	31.1	2.430
T1- 5m	5	28.2	29.6	2.327
T1- 10m	10	24.0	29.0	2.282
T1- 15m	15	21.7	28.7	2.258
T1- 20m	20	20.3	28.5	2.243
T1- 30m	30	18.6	28.2	2.224
T1- 40m	40	17.7	28.1	2.214
T1- 50m	50	17.1	28.0	2.207
T1- 75m	75	16.2	27.8	2.197
T1- 100m	100	15.7	27.7	2.192
T1- 125m	125	15.4	27.7	2.189
T1- 150m	150	15.2	27.7	2.186
T1- 175m	175	15.1	27.6	2.185
T1- 200m	200	15.0	27.6	2.183
CRITICAL LEVEL / LOAD		30	15 - 20	1.859
Exceedences of the Critical Level / Load in bold				

Table 11.5.4 Ecological receptors (2031)

Receptor and Distance in Habitat	Distance from kerb (m)	Total NOx (µg/m3)	Nitrogen Deposition (kgN/ha/yr)	Acid Deposition (keqN/ha/yr)
Madingley Wood SSSI				
T1- 0m	0	25.8	29.7	2.333
T1- 5m	5	19.6	28.8	2.268
T1- 10m	10	17.0	28.4	2.239
T1- 15m	15	15.6	28.2	2.224
T1- 20m	20	14.7	28.1	2.215
T1- 30m	30	13.7	27.9	2.203
T1- 40m	40	13.1	27.8	2.197
T1- 50m	50	12.7	27.8	2.192
T1- 75m	75	12.2	27.7	2.186
T1- 100m	100	11.9	27.6	2.183
T1- 125m	125	11.7	27.6	2.181
T1- 150m	150	11.6	27.6	2.180
T1- 175m	175	11.5	27.6	2.179
T1- 200m	200	11.4	27.6	2.178
CRITICAL LEVEL / LOAD		30	15 - 20	1.859
Exceedences of the Critical Level / Load in bold				

Appendix 11.6 Predicted future concentrations (human health receptors)

Table 11.6.1 Predicted concentrations of NO_2, PM_{10} and $PM_{2.5}$ at existing receptors in 2021

Receptor	Annual Mean (µg/m3)					
	2021 Without Development			2021 With Development (Interim Scenario)		
	NO2	PM10	PM2.5	NO2	PM10	PM2.5
R1	26.7	20.0	14.2	26.9	20.0	14.2
R2	24.4	19.0	13.5	25.2	19.1	13.7
R3	24.4	20.7	14.3	25.0	20.7	14.4
R4	26.2	19.8	14.0	26.7	19.9	14.1
R5	25.2	19.6	13.9	25.2	19.6	13.9
R6	25.0	19.6	13.9	25.0	19.6	13.9
R7	19.2	18.5	12.8	19.2	18.5	12.8
R8	19.1	18.5	12.8	19.1	18.5	12.8
R9	17.5	17.5	12.2	17.5	17.5	12.2
R10	19.8	17.9	12.6	19.8	17.9	12.6
R11	16.1	17.4	12.1	16.1	17.3	12.1
R12	19.1	16.8	12.1	18.9	16.8	12.1
R13	16.7	16.5	11.8	16.7	16.5	11.8
R14	16.8	16.5	11.8	16.8	16.5	11.8
R15	25.1	17.4	12.8	25.2	17.4	12.8
R16	21.4	16.2	11.9	21.6	16.3	11.9
R17	21.1	16.7	12.1	21.7	16.8	12.2
R18	19.9	16.5	11.9	20.3	16.5	12.0
R19	16.2	16.4	11.7	16.7	16.5	11.8
R20	16.7	16.5	11.7	17.2	16.6	11.8
R21	15.2	16.2	11.4	15.5	16.2	11.5
R22	16.6	17.7	12.3	17.3	17.8	12.5
R23	16.4	17.6	12.3	17.1	17.8	12.4
R24	15.5	17.4	12.0	16.0	17.5	12.1
R25	17.5	17.9	12.5	18.4	18.1	12.7
R26	17.5	17.9	12.5	18.4	18.1	12.7
R27	17.1	17.7	12.4	17.9	17.9	12.5
R28	13.7	15.8	11.2	13.7	15.8	11.2
R29	13.2	16.8	11.6	13.2	16.8	11.6
R30	16.3	16.4	11.7	16.4	16.4	11.8
R31	15.6	16.3	11.7	15.7	16.4	11.7
On site 1A	12.3	17.0	11.6	12.4	17.0	11.6
On site 1B	12.3	17.0	11.6	12.4	17.0	11.6
On site 1C	12.3	17.0	11.6	12.4	17.0	11.6
On site 1D	12.3	17.0	11.6	12.4	17.0	11.6
On site 2A	12.3	17.0	11.6	12.3	17.0	11.6
On site 2B	12.3	17.0	11.6	12.3	17.0	11.6
On site 2C	12.3	17.0	11.6	12.3	17.0	11.6
On site 2D	12.3	17.0	11.6	12.3	17.0	11.6
On site 3A	12.4	17.0	11.6	12.4	17.0	11.6
Objectives	40	40	25	40	40	25

Table 11.6.2 Change in predicted concentrations brought about by the Proposed Development in 2021

Receptor	Annual Mean (µg/m3)		
	NO2	PM10	PM2.5
R1	0.46	0.03	0.03
R2	1.57	0.10	0.12
R3	1.24	0.08	0.10
R4	1.06	0.10	0.10
R5	-0.04	-0.01	0.00
R6	-0.03	0.00	0.00
R7	0.02	0.00	0.00
R8	0.03	0.00	0.00
R9	0.00	0.00	0.00
R10	-0.08	-0.01	-0.01
R11	-0.09	-0.01	-0.01
R12	-0.31	-0.03	-0.03

Receptor	Annual Mean (µg/m3)		
	NO2	PM10	PM2.5
R13	-0.12	-0.02	-0.01
R14	-0.11	-0.01	-0.01
R15	0.13	0.01	0.01
R16	0.42	0.04	0.04
R17	1.20	0.11	0.11
R18	0.84	0.08	0.08
R19	0.92	0.11	0.10
R20	1.05	0.11	0.11
R21	0.49	0.05	0.05
R22	1.35	0.17	0.17
R23	1.24	0.16	0.15
R24	0.84	0.10	0.10
R25	1.71	0.22	0.21
R26	1.72	0.22	0.21
R27	1.55	0.18	0.18
R28	0.10	0.01	0.01
R29	0.03	0.00	0.00
R30	0.22	0.02	0.02
R31	0.18	0.02	0.02
On site 1A	0.09	0.01	0.01
On site 1B	0.09	0.01	0.01
On site 1C	0.09	0.01	0.01
On site 1D	0.09	0.01	0.01
On site 2A	0.07	0.01	0.01
On site 2B	0.07	0.01	0.01
On site 2C	0.07	0.01	0.01
On site 2D	0.07	0.01	0.01
On site 3A	0.07	0.01	0.01
Based on unrounded numbers			

Table 11.6.3 Predicted concentrations of NO_2, PM_{10} and $PM_{2.5}$ at existing receptors in 2031

Receptor	Annual Mean (µg/m3)					
	2031 Without Development			2031 With Full Development		
	NO2	PM10	PM2.5	NO2	PM10	PM2.5
R1	17.9	19.3	13.4	18.2	19.3	13.5
R2	16.5	18.4	12.8	17.3	18.5	13.0
R3	16.6	20.0	13.5	17.2	20.2	13.7
R4	18.2	19.2	13.2	19.0	19.4	13.5
R5	17.1	18.9	13.2	17.1	19.0	13.2
R6	17.0	18.9	13.2	17.0	19.0	13.2
R7	13.7	17.9	12.2	13.7	18.0	12.2
R8	13.6	17.9	12.2	13.6	17.9	12.2
R9	12.6	17.0	11.7	12.6	17.0	11.7
R10	14.0	17.4	12.1	14.0	17.4	12.1
R11	12.0	16.9	11.6	12.0	16.9	11.6
R12	13.6	16.3	11.6	13.6	16.3	11.6
R13	12.4	16.0	11.3	12.3	16.0	11.3
R14	12.4	16.0	11.3	12.4	16.0	11.3
R15	18.2	16.9	12.2	18.3	16.9	12.3
R16	16.1	15.7	11.3	16.5	15.8	11.4
R17	15.8	16.1	11.5	16.5	16.4	11.7
R18	15.2	15.9	11.3	15.7	16.1	11.5
R19	12.1	15.9	11.2	12.7	16.1	11.4
R20	12.3	15.9	11.2	13.0	16.2	11.4
R21	11.5	15.7	11.0	11.8	15.8	11.1
R22	12.2	17.2	11.8	12.6	17.3	12.0
R23	12.0	17.1	11.8	12.4	17.3	11.9
R24	11.5	16.9	11.5	11.8	17.0	11.6
R25	12.7	17.4	12.0	13.2	17.6	12.2
R26	12.7	17.4	12.0	13.3	17.6	12.2
R27	12.5	17.2	11.9	13.0	17.4	12.0
R28	10.1	15.3	10.7	10.2	15.3	10.7
R29	10.0	16.3	11.1	10.0	16.3	11.1
R30	11.8	15.9	11.2	12.0	16.0	11.3

Receptor	Annual Mean (µg/m3)					
	2031 Without Development			2031 With Full Development		
	NO2	PM10	PM2.5	NO2	PM10	PM2.5
R31	11.4	15.8	11.2	11.6	15.9	11.2
On site 1A	9.5	16.5	11.1	9.6	16.5	11.1
On site 1B	9.5	16.5	11.1	9.5	16.5	11.1
On site 1C	9.5	16.5	11.1	9.5	16.5	11.1
On site 1D	9.5	16.5	11.1	9.5	16.5	11.1
On site 2A	9.4	16.5	11.1	9.5	16.5	11.1
On site 2B	9.4	16.5	11.1	9.5	16.5	11.1
On site 2C	9.4	16.5	11.1	9.5	16.5	11.1
On site 2D	9.4	16.5	11.1	9.5	16.5	11.1
On site 3A	9.5	16.5	11.1	9.6	16.5	11.1
Objectives	40	40	25	40	40	25

Table 11.6.4 Change in predicted concentrations brought about by the Proposed Development in 2031

Receptor	Annual Mean (µg/m3)		
	NO2	PM10	PM2.5
R1	0.07	0.07	0.07
R2	0.18	0.18	0.18
R3	0.14	0.14	0.14
R4	0.22	0.22	0.22
R5	0.00	0.00	0.00
R6	0.01	0.01	0.01
R7	0.01	0.01	0.01
R8	0.01	0.01	0.01
R9	0.01	0.01	0.01
R10	0.00	0.00	0.00
R11	0.00	0.00	0.00
R12	0.00	0.00	0.00
R13	-0.01	-0.01	-0.01
R14	-0.01	-0.01	-0.01
R15	0.02	0.02	0.02
R16	0.11	0.11	0.11
R17	0.22	0.22	0.22
R18	0.15	0.15	0.15
R19	0.21	0.21	0.21
R20	0.22	0.22	0.22
R21	0.11	0.11	0.11
R22	0.17	0.17	0.17
R23	0.16	0.16	0.16
R24	0.11	0.11	0.11
R25	0.21	0.21	0.21
R26	0.21	0.21	0.21
R27	0.18	0.18	0.18
R28	0.03	0.03	0.03
R29	0.01	0.01	0.01
R30	0.06	0.06	0.06
R31	0.05	0.05	0.05
On site 1A	0.06	0.02	0.02
On site 1B	0.05	0.02	0.02
On site 1C	0.05	0.02	0.02
On site 1D	0.06	0.02	0.02
On site 2A	0.05	0.01	0.01
On site 2B	0.05	0.01	0.01
On site 2C	0.05	0.01	0.01
On site 2D	0.04	0.01	0.01
On site 3A	0.04	0.01	0.01
Based on unrounded numbers			

Appendix 11.7 Predicted future concentrations (ecological receptors)

Table 11.7.1 Predicted concentrations at ecological receptors in 2021 without and with the Proposed Development in place

Receptor and Distance in Habitat	Distance from kerb (m)	2021 Without Development			2021 With Development (Interim Scenario)		
		Total NOx (µg/m3)	Nitrogen Deposition (kgN/ha/yr)	Acid Deposition (keq/ha/yr)	Total NOx (µg/m3)	Nitrogen Deposition (kgN/ha/yr)	Acid Deposition (keq/ha/yr)
Madingley Wood SSSI							
T1- 0m	0	38.2	31.1	2.430	38.6	31.1	2.435
T1- 5m	5	28.2	29.6	2.327	28.5	29.7	2.330
T1- 10m	10	24.0	29.0	2.282	24.2	29.0	2.284
T1- 15m	15	21.7	28.7	2.258	21.9	28.7	2.260
T1- 20m	20	20.3	28.5	2.243	20.4	28.5	2.244
T1- 30m	30	18.6	28.2	2.224	18.7	28.2	2.225
T1- 40m	40	17.7	28.1	2.214	17.8	28.1	2.215
T1- 50m	50	17.1	28.0	2.207	17.1	28.0	2.207
T1- 75m	75	16.2	27.8	2.197	16.2	27.8	2.198
T1- 100m	100	15.7	27.7	2.192	15.8	27.8	2.192
T1- 125m	125	15.4	27.7	2.189	15.4	27.7	2.189
T1- 150m	150	15.2	27.7	2.186	15.2	27.7	2.186
T1- 175m	175	15.1	27.6	2.185	15.1	27.6	2.185
T1- 200m	200	15.0	27.6	2.183	15.0	27.6	2.184
CRITICAL LEVEL / LOAD		30	15 - 20	1.859	30	15 - 20	1.859
Exceedences of the Critical Level / Load in bold Exceedences of the objectives in bold.							

Table 11.7.2 Predicted Proposed Development contribution in 2021

Receptor and Distance in Habitat	Distance from kerb (m)	2021 Scheme Contribution					
		Total NOx (µg/m3)		Nitrogen Deposition (kgN/ha/yr)		Acid Deposition (keqN/ha/yr)	
		NOx	%	N Deposition	%	Acid Deposition	%
Madingley Wood SSSI							
T1- 0m	0	0.4	1.5	0.06	0.4	0.005	0.2
T1- 5m	5	0.3	0.9	0.04	0.3	0.003	0.2
T1- 10m	10	0.2	0.6	0.03	0.2	0.002	0.1
T1- 15m	15	0.1	0.5	0.02	0.1	0.001	0.1
T1- 20m	20	0.1	0.4	0.02	0.1	0.001	0.1
T1- 30m	30	0.1	0.3	0.01	0.1	0.001	0.1
T1- 40m	40	0.1	0.2	0.01	0.1	0.001	0.0
T1- 50m	50	0.1	0.2	0.01	0.1	0.001	0.0
T1- 75m	75	0.0	0.1	0.01	0.0	0.000	0.0
T1- 100m	100	0.0	0.1	0.01	0.0	0.000	0.0
T1- 125m	125	0.0	0.1	0.01	0.0	0.000	0.0
T1- 150m	150	0.0	0.1	0.00	0.0	0.000	0.0
T1- 175m	175	0.0	0.1	0.00	0.0	0.000	0.0
T1- 200m	200	0.0	0.1	0.00	0.0	0.000	0.0
Exceedences of 1% of the critical level/ load highlighted in bold							

Table 11.7.3 Predicted concentrations at ecological receptors in 2031 without and with the Proposed Development in place

Receptor and Distance in Habitat	Distance from kerb (m)	2031 Without Development			2031 With Full Development		
		Total NOx (µg/m3)	Nitrogen Deposition (kgN/ha/yr)	Acid Deposition (keqN/ha/yr)	Total NOx (µg/m3)	Nitrogen Deposition (kgN/ha/yr)	Acid Deposition (keq/ha/yr)
Madingley Wood SSSI							
T1- 0m	0	25.8	29.7	2.333	26.6	29.8	2.342
T1- 5m	5	19.6	28.8	2.268	20.1	28.9	2.273
T1- 10m	10	17.0	28.4	2.239	17.3	28.5	2.243
T1- 15m	15	15.6	28.2	2.224	15.9	28.2	2.227
T1- 20m	20	14.7	28.1	2.215	14.9	28.1	2.217
T1- 30m	30	13.7	27.9	2.203	13.8	27.9	2.205
T1- 40m	40	13.1	27.8	2.197	13.2	27.8	2.198
T1- 50m	50	12.7	27.8	2.192	12.8	27.8	2.193
T1- 75m	75	12.2	27.7	2.186	12.2	27.7	2.187
T1- 100m	100	11.9	27.6	2.183	11.9	27.6	2.184
T1- 125m	125	11.7	27.6	2.181	11.7	27.6	2.182
T1- 150m	150	11.6	27.6	2.180	11.6	27.6	2.180
T1- 175m	175	11.5	27.6	2.179	11.5	27.6	2.179
T1- 200m	200	11.4	27.6	2.178	11.4	27.6	2.178
CRITICAL LEVEL / LOAD		30	15 - 20	0.214 – 1.860	30	15 - 20	1.859
Exceedences of the Critical Level / Load in bold Exceedences of the objectives in bold.							

Table 11.7.4 Predicted Proposed Development contribution in 2031

Receptor and Distance in Habitat	Distance from kerb (m)	2021 Scheme Contribution					
		Total NOx (µg/m3)		Nitrogen Deposition (kgN/ha/yr)		Acid Deposition (keqN/ha/yr)	
		NOx	%	N Deposition	%	Acid Deposition	%
Madingley Wood SSSI							
T1- 0m	0	0.8	2.7	0.12	0.8	0.008	0.5
T1- 5m	5	0.5	1.6	0.07	0.5	0.005	0.3
T1- 10m	10	0.3	1.1	0.05	0.3	0.004	0.2
T1- 15m	15	0.3	0.9	0.04	0.3	0.003	0.2
T1- 20m	20	0.2	0.7	0.03	0.2	0.002	0.1
T1- 30m	30	0.2	0.5	0.02	0.2	0.002	0.1
T1- 40m	40	0.1	0.4	0.02	0.1	0.001	0.1
T1- 50m	50	0.1	0.4	0.01	0.1	0.001	0.1
T1- 75m	75	0.1	0.3	0.01	0.1	0.001	0.0
T1- 100m	100	0.1	0.2	0.01	0.1	0.001	0.0
T1- 125m	125	0.1	0.2	0.01	0.1	0.001	0.0
T1- 150m	150	0.0	0.1	0.01	0.1	0.001	0.0
T1- 175m	175	0.0	0.1	0.01	0.0	0.000	0.0
T1- 200m	200	0.0	0.1	0.01	0.0	0.000	0.0

Appendix 11.8 Predicted energy centre emissions concentrations

The predicted Process Contribution (PC) at human health receptors

Table 11.8.1 Maximum NO_2 process contribution (PC) at human health receptors

Receptor	Averaging	Units	PC	EAL	%EAL
22	Annual	µg/m3	0.3	40	0.82
	Hourly		45.1	200	22.5
23	Annual	µg/m3	0.4	40	1.02
	Hourly		45.1	200	22.5
24	Annual	µg/m3	0.4	40	1.02
	Hourly		45.1	200	22.5
25	Annual	µg/m3	0.5	40	1.16
	Hourly		36.0	200	18.0
26	Annual	µg/m3	0.6	40	1.45
	Hourly		36.2	200	18.1
27	Annual	µg/m3	0.6	40	1.58
	Hourly		37.2	200	18.6
28	Annual	µg/m3	0.6	40	1.46
	Hourly		20.2	200	10.1
29	Annual	µg/m3	0.2	40	0.44
	Hourly		13.1	200	6.5
1A	Annual	µg/m3	0.3	40	0.79
	Hourly		45.6	200	22.8
1B	Annual	µg/m3	0.3	40	0.79
	Hourly		45.6	200	22.8
1C	Annual	µg/m3	0.3	40	0.79
	Hourly		45.6	200	22.8
1D	Annual	µg/m3	0.3	40	0.79
	Hourly		45.6	200	22.8
2A	Annual	µg/m3	0.2	40	0.48
	Hourly		44.7	200	22.3
2B	Annual	µg/m3	0.2	40	0.48
	Hourly		44.7	200	22.3
2C	Annual	µg/m3	0.2	40	0.48
	Hourly		44.7	200	22.3
2D	Annual	µg/m3	0.2	40	0.48
	Hourly		44.7	200	22.3
3A	Annual	µg/m3	0.2	40	0.54
	Hourly		14.7	200	7.3

The predicted PC is potentially significant, but below the assessment level. The predicted environmental concentrations (taking into account the baseline concentrations) are shown in the following Tables 11.8.2 and 11.8.3 for 2021 and 2031 respectively.

Table 11.8.2 Total NO_2 predicted environmental concentration in 2021

Receptor	Averaging	Baseline (µg/m3)	PEC	EAL	%EAL
22	Annual	17.3	17.7	40	44.2
	Hourly	34.7	79.7	200	39.9
23	Annual	17.1	17.5	40	43.7
	Hourly	34.1	79.2	200	39.6
24	Annual	16.0	16.4	40	40.9
	Hourly	31.9	77.0	200	38.5
25	Annual	18.4	18.8	40	47.1
	Hourly	36.7	72.7	200	36.4
26	Annual	18.4	19.0	40	47.5
	Hourly	36.8	73.0	200	36.5
27	Annual	17.9	18.6	40	46.4
	Hourly	35.9	73.1	200	36.5
28	Annual	13.8	14.4	40	36.0
	Hourly	27.6	47.8	200	23.9
29	Annual	13.2	13.4	40	33.4
	Hourly	26.4	39.5	200	19.7
1A	Annual	12.4	12.7	40	31.8
	Hourly	24.8	70.3	200	35.2
1B	Annual	12.4	12.7	40	31.8
	Hourly	24.8	70.3	200	35.2
1C	Annual	12.4	12.7	40	31.8

Receptor	Averaging	Baseline (µg/m3)	PEC	EAL	%EAL
	Hourly	24.8	70.3	200	35.2
1D	Annual	12.4	12.7	40	31.7
	Hourly	24.8	70.3	200	35.2
2A	Annual	12.3	12.5	40	31.2
	Hourly	24.6	69.3	200	34.6
2B	Annual	12.3	12.5	40	31.2
	Hourly	24.6	69.3	200	34.6
2C	Annual	12.3	12.5	40	31.2
	Hourly	24.6	69.3	200	34.6
2D	Annual	12.3	12.5	40	31.2
	Hourly	24.6	69.3	200	34.6
3A	Annual	12.4	12.7	40	31.7
	Hourly	24.9	39.5	200	19.8

Table 11.8.3 Total NO_2 Predicted Environmental Concentration in 2031

Receptor	Averaging	Baseline (µg/m3)	PEC	EAL	%EAL
22	Annual	12.6	12.9	40	32.3
	Hourly	25.2	70.3	200	35.2
23	Annual	12.4	12.9	40	32.1
	Hourly	24.9	70.0	200	35.0
24	Annual	11.8	12.2	40	30.5
	Hourly	23.5	68.6	200	34.3
25	Annual	13.2	13.7	40	34.3
	Hourly	26.5	62.5	200	31.2
26	Annual	13.3	13.9	40	34.6
	Hourly	26.5	62.8	200	31.4
27	Annual	13.0	13.6	40	34.0
	Hourly	25.9	63.1	200	31.6
28	Annual	10.2	10.8	40	26.9
	Hourly	20.4	40.5	200	20.3
29	Annual	10.0	10.2	40	25.5
	Hourly	20.0	33.1	200	16.5
1A	Annual	9.6	9.9	40	24.7
	Hourly	19.1	64.7	200	32.3
1B	Annual	9.5	9.9	40	24.6
	Hourly	19.1	64.6	200	32.3
1C	Annual	9.5	9.9	40	24.6
	Hourly	19.1	64.6	200	32.3
1D	Annual	9.5	9.9	40	24.6
	Hourly	19.1	64.6	200	32.3
2A	Annual	9.5	9.7	40	24.2
	Hourly	19.0	63.6	200	31.8
2B	Annual	9.5	9.7	40	24.2
	Hourly	19.0	63.6	200	31.8
2C	Annual	9.5	9.7	40	24.2
	Hourly	19.0	63.6	200	31.8
2D	Annual	9.5	9.7	40	24.2
	Hourly	19.0	63.6	200	31.8
3A	Annual	9.6	9.8	40	24.4
	Hourly	19.1	33.8	200	16.9

The maximum predicted environmental concentrations are well below the assessments levels. The combined effect of emissions from road traffic and the Energy Centre will not lead to a breach of national air quality strategy objectives.

Appendix 11.9 Road traffic emission factors

Introduction

Atmospheric dispersion modelling is used to determine the effect of future development traffic on local air quality. The modelling utilises predictions of the composition and emissions profile of the vehicle fleet which are produced by Defra in the emissions factor toolkit (EFT). The composition and emissions profiles are provided on a year by year basis from 2013 to 2030, with the database being periodically updated.

The main issue with regard to the modelling of future traffic impacts is the choice of emission factors to use given that there is a degree of uncertainty as to the accuracy of the emission factors, as well as uncertainty introduced by the modelling process and the traffic data on which the predictions are based. This has become more important in recent years as it has been realised that previous versions of the EFT were likely to have significantly underestimated the real world emissions of the vehicle fleet, as well as the more recent revelations concerning the use of 'defeat devices' on VW group vehicles.

This note therefore sets out PBAs approach to the choice of vehicle emission factors for future year assessments. The note has been revised following updating of the Defra Emissions Factor Toolkit in July 2016.

Modelling method

As a prelude to the discussion of emission factors, it is useful to recap on the general method that is used for dispersion modelling of road traffic emissions:

- Traffic data is entered into the dispersion model to represent the baseline situation and the model is used to predict how NO_x emissions are dispersed in the environment.
- The dispersion modelling predictions are compared to monitoring data to obtain a verification factor; the factor by which the predicted road traffic concentration must be multiplied by to agree with the monitored concentration.
- The modelling is repeated for the future year situation; with traffic data representing the situation without the development in place (the 'without' scheme scenario) and with the development in place ('with' scheme). In both cases, the verification factor obtained from the baseline modelling is used to multiply the model results by, in essence assuming that the model is equally as accurate in the future as it was for the baseline scenario.

The verification factor is one of the key elements in the discussion regarding vehicle emission factors. One element of uncertainty in the modelling is the degree to which the emission factors in the EFT are different to actual emissions of the vehicle fleet on the local road network. The use of the verification factor for the future year predictions essentially assumes that the difference between the EFT emission factors and real world emissions is the same in the future as it was in the baseline year. In other words, unless there is some reason to believe that the future year emission factors are less accurate than the baseline year emission factors, the degree to which the EFT emission factors and real world emission factors differ is taken into account in the modelling by the use of the verification factor. This is discussed further in the following sections.

Emission factor toolkit

The EFT contains estimates of the future composition of the vehicle fleet in terms of the age and type of vehicles. The composition of the vehicle fleet is primarily related to the age of the vehicles (in terms of their emissions class) and the fuel that they use (i.e. petrol or diesel). In general terms, the majority of new vehicles replace much older vehicles, and as the emissions performance of vehicles is generally taken to improve over time, both current and historical versions of the EFT predict very large reductions in NOx emissions in the future. It is also obvious that the further one looks into the future, the more uncertain the predictions become as they depend on the rate of vehicle renewal and the size and fuel mix of the vehicles bought; which are all estimates.

The emissions performance of the vehicles is classified in terms of Euro type approval testing; Euro 1 to 6 concerning light duty vehicles and Euro I to VI heavy duty vehicles. Whilst the introduction of each Euro class has generally seen a tightening of emission standards, the standards up until now have been based on laboratory testing of vehicles. The emissions performance of the vehicles in real world driving conditions has been higher than the laboratory testing results, especially for diesel vehicles. This factor was not recognised in earlier versions of the EFT, and combined with the fact that diesel vehicles have much higher NOx emissions than petrol vehicles and there has been a very large increase in the number of diesel vehicles on the road, has meant that the NOx emissions and NO2 concentrations have not reduced as previously predicted.

The trends in NOx emissions in the vehicle fleet, especially diesel vehicles and the accuracy of the current version of the EFT, is therefore critical in terms of the choice of emission factors in modelling.

Trends in NO_x emissions

For light duty vehicles, the latest Euro standard is Euro 6, which was introduced from September 2015 (with a derogation in the UK for the registration of new vehicles until September 2016).

The emissions standards currently relate to a laboratory test whereby the average emission rate is calculated over an idealised drive cycle. The cycle used is the New European Drive Cycle (NEDC) and there has been extensive criticism that the drive cycle does not represent real world driving conditions. It has therefore been agreed that a new drive cycle will be introduced, the World Light-duty Test Cycle (WLDTC), as well as an on-road test termed Real Driving Emissions (RDE).

Current Euro 6 vehicles are only tested in the laboratory against the NEDC, and these vehicles are termed Euro 6ab. However, from September 2017, new models will be tested against the WLDTC and will also have a RDE test. The initial introduction of the RDE test will allow vehicles to have average RDE test emissions of 2.1 times the WLDTC test; in other words, real life emissions will be allowed to be 2.1 times the laboratory emissions. The 2.1 factor is termed the conformity factor and will apply to new models from September 2017 and new vehicles from September 2019. From January 2020, the conformity factor will reduce to 1.5 for new models (January 2021 for new vehicles).

Air Quality Consultants have undertaken some research into the performance of diesel vehicles to support a method that they have adopted for undertaking air quality assessments1. As part of the analysis, they compared the real word test results of current Euro 6ab diesel vehicles and calculated an average conformity factor of 3.9 from the tests that were assessed.

[1] Emissions of Nitrogen Oxides from Modern Diesel Vehicles. AQC January 2016

Subsequently, Department for Transport have undertaken testing of Euro 5 and 6ab diesel vehicles and found that the average NOx emissions were 1135 mg/km for Euro 5 vehicles and 500 mg/km for Euro 6ab vehicles2. These work out to be a conformity factor of 6.30 and 6.25 for Euro 5 and Euro 6ab respectively. Adding in the DfTr results to the AQC results gives an overall average conformity factor for Euro 6ab vehicles tested of 4.1.

A paper presented by Dr Marc Stettler at the recent Westminster Energy, Environment & Transport Forum3 included results of RDE testing of existing Euro 6ab vehicles. Whilst there was wide range in the results, a number of the vehicles tested did already comply with the Euro 6c standard.

From the emissions testing work undertaken to date on Euro 6ab vehicles it is clear that the NOx emissions performance of Euro 6ab vehicles is significantly better than Euro 5 vehicles, although not in line with the laboratory standards. The introduction of Euro 6 should therefore see a significant reduction in NOx emissions in the future, as outlined in Table 11.10.1.

Table 11.9.1 Comparison of emissions

Emission Standard	Real Driving Emissions NOx mg/km
Euro 5, DfTr testing	1135
Euro 6ab, DfTr testing	500
Euro 6c, September 2017 models	168
Euro 6c, January 2020 models	120

In terms of modelling, the issue therefore becomes how well does the EFT represent the real world emissions performance of the vehicles.

Emissions in the EFT

As noted in Section 3, the EFT contains estimates of vehicle emissions by Euro Class. The database has recently been updated in July 2016 from v6.02 to v7.0. It now uses NOx emissions factors for the vehicles taken from the European Environment Agency's COPERT 4 V11 database compared to the previous version V10. In the latest submissions to the European Union for compliance against EU Limit Values, Defra used COPERT 4 V11 factors. The latest emission factors are lower than those in the previous version of the EFT.

The AQC paper provides a representation of the emissions from Euro 6 vehicles at different speeds in terms of the conformity factor. The results are shown in the following graph.

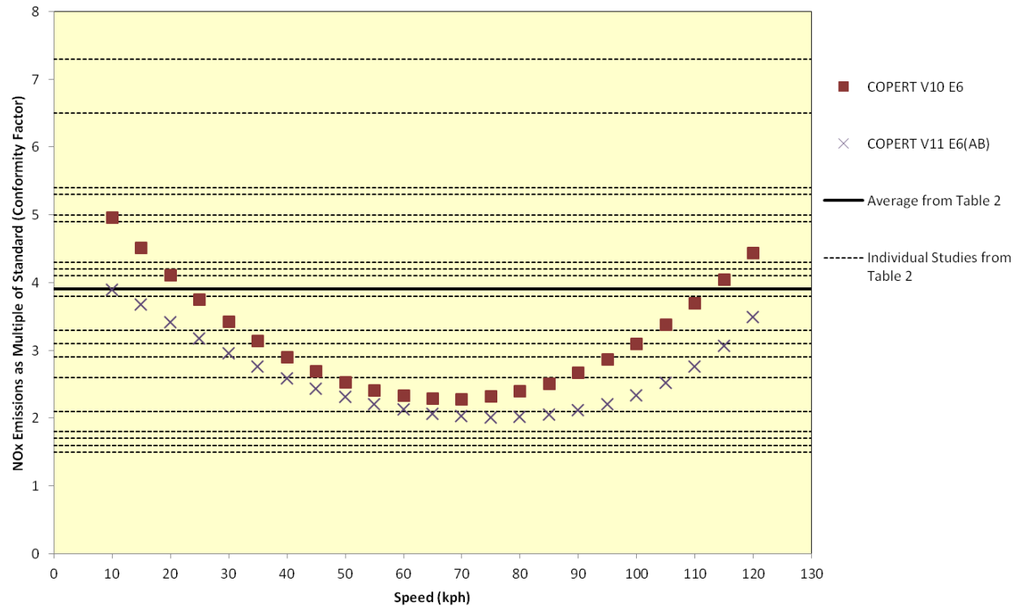


Figure 11.9.1 Emissions from Euro 6 vehicles at different speeds in terms of the conformity factor

The graph shows that the EFT emissions have a conformity factor ranging from 2.3 to 5. The conformity factor is higher at low and high speeds. Overall, the average conformity factor is less than the factor determined from the testing of Euro 6ab vehicles to date, but higher than the conformity factor that will be required by the introduction of Euro 6c. The COPERT v11 factors for Euro 6ab vehicles would appear to be, on average, approximately 80% of the V10 factors.

In terms of light duty vehicles, the AQC report concluded that for future year assessments, the base case modelling should use the EFT v6.02 factors for the future year of the traffic data, i.e. unaltered. However, a sensitivity test was also recommended, whereby the average conformity factor for Euro 6 diesel vehicles is raised to 5, with the following result in terms of the EFT.

[2] Vehicle Emissions Testing Programme DfTr Cm 9259 April 2016

[3] Priorities for reducing air quality impacts of road vehicles. Dr Marc Stettler 17th May 2016

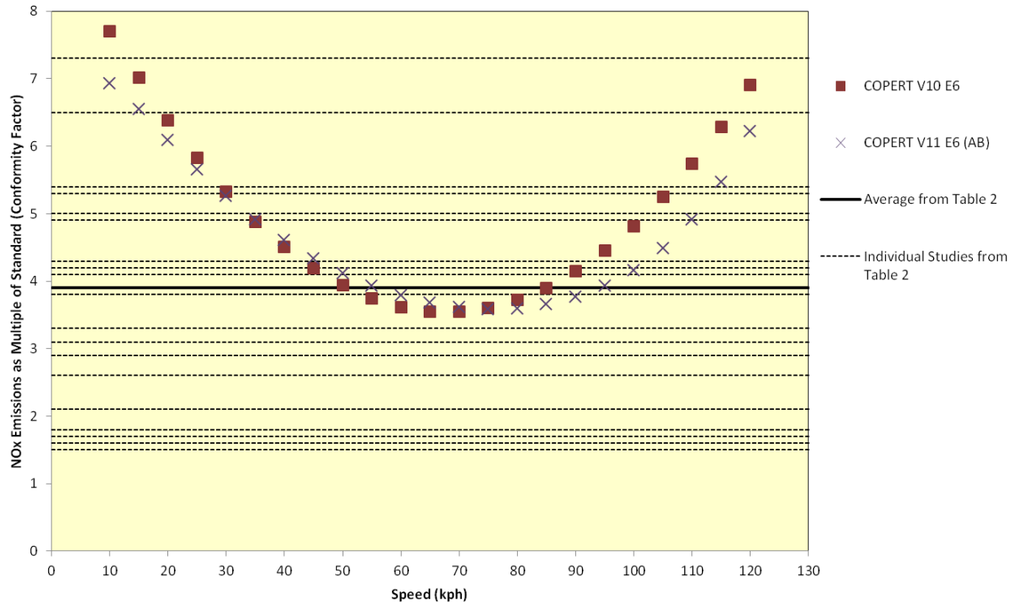


Figure 11.9.1 Sensitivity test results

Clearly, using the sensitivity test, the average emission rate in the EFT is higher than the average from the Euro 6ab testing to date, for either COPERT v10 or v11 factors. The AQC report concluded that if the two assessments were undertaken, then the likely pollutant concentration would lie between the two estimates.

However, the AQC report also acknowledges that the EFT does not include Euro 6c vehicles which should have significantly lower NO_x emissions than current Euro 6ab vehicles, and therefore both sets of results could be conservative.

Clearly, using the sensitivity test, the average emission rate in the EFT is higher than the average from the Euro 6ab testing to date, for either COPERT v10 or v11 factors. The AQC report concluded that if the two assessments were undertaken, then the likely pollutant concentration would lie between the two estimates.

However, the AQC report also acknowledges that the EFT does not include Euro 6c vehicles which should have significantly lower NO_x emissions than current Euro 6ab vehicles, and therefore both sets of results could be conservative.

Future year assessment method

The selection of emission factors for a future year assessment depends partly on the situation regarding the assessment to be undertaken. Where pollutant concentrations are low and are unlikely to exceed threshold levels, then one may take a conservative approach and keep emission factors at current levels. This will produce a conservative result, but as the result will be 'acceptable' in terms of leading to no exceedances of National Air Quality Strategy Objectives, then it is a reasonable approach to adopt as it avoids uncertainty as to whether there will be exceedances in the future.

In contrast, where pollutant concentrations are high, then a different approach to uncertainty is required. In addition, for a formal Environmental Impact Assessment the legal requirement is to assess 'likely significant effects'. This is not 'worst case' significant effects, but 'likely' significant effects and therefore must allow for a degree of uncertainty in the predictions.

The approach taken to date by PBA for the assessment of future year effects when the development is completed a number of years into the future is to choose an intermediate year between the baseline model verification year and the completed development year. This approach requires revisiting in light of the latest information regarding vehicle emission factors.

As noted in Section 6, the AQC approach is to undertake two assessments; one using the EFT for the assessment year and one using higher emission factors for a sensitivity test. In addition to consideration of diesel car emissions, the AQC approach also considers taxis, light goods vehicles and heavy duty vehicles (HDVs). For taxis and light goods vehicles, a similar approach to diesel cars is proposed.

The evidence on the performance of Euro VI HDVs is more difficult to interpret; but it indicates significantly reduced NOx emissions between Euro V and VI, although the AQC report concludes that the EFT may underestimate emissions of Euro VI HDVs. The approach proposed by AQC for HDVs for COPERT v10 emissions is to keep Euro IV and Euro V emissions the same as Euro III and make Euro VI emissions 20% of Euro V. This approach was considered to result in slightly high HDV emissions. The average COPERT v11 HDV emission factors are higher than v10 at speeds above 40 kph and lower at speeds less than 40 kph (AQC, Figure 23). Overall therefore, it would appear to be appropriate to continue the proposed AQC approach for HDV emissions for COPERT v11 emission factors.

The following graph has been prepared using the AQC approach (CURED v2A) and the EFT v7 for urban vehicles outside of London at 30kph with a 5% heavy duty vehicles mix. Given that both emissions estimates would need to be verified against the same monitoring data, then the predictions would be the same for the same initial model verification year (i.e. 2015 in this case). The relative difference in the predicted emissions in the future is therefore the important factor.

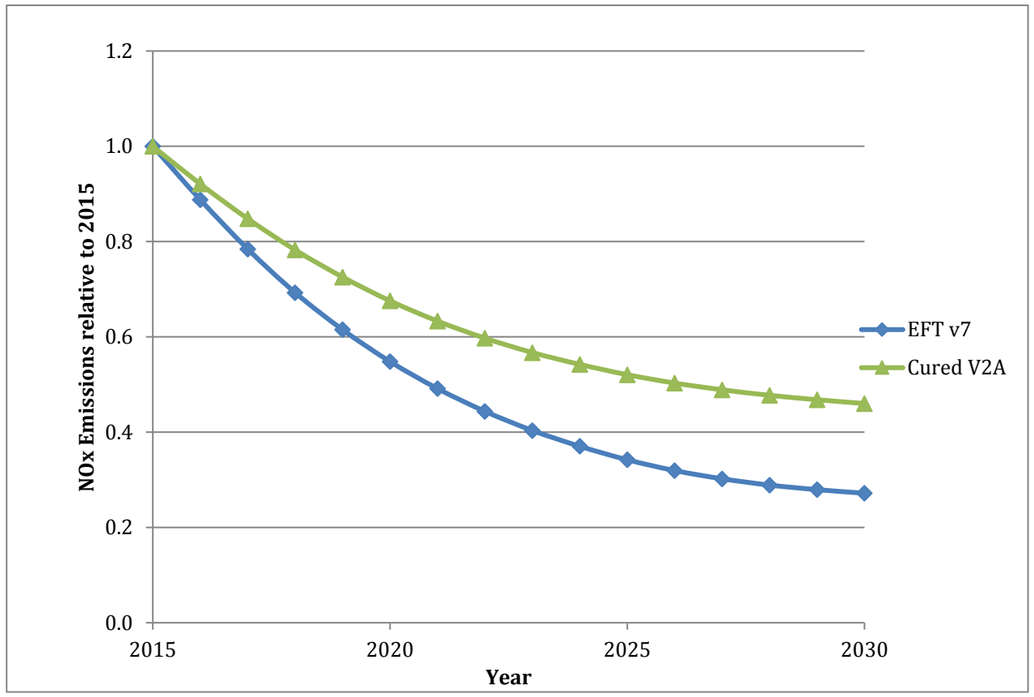


Figure 11.9.3 Comparison of AQC and EFT

Prior to 2020, the difference between the emission factors amounts to less than 2 years; it rises to approximately 9 years by 2030 as a greater proportion of Euro 6 vehicles is contained in the vehicle fleet and the AQC Cured emissions remain essentially at Euro 6ab levels.

As noted in Section 5, the EFT does not take account of the introduction of Euro 6c vehicles, which will begin to be introduced from 2017 with a conformity factor of 2.1, and from 2020 with a conformity factor of 1.5, significantly lower than the average for v7 of the EFT. Beyond 2020 therefore, as Euro 6c vehicles become more prominent in the vehicle fleet, the EFT is likely to become more representative of real world emissions than it currently is.

As discussed in Section 2, the use of the verification factor in the modelling takes account, amongst other things, of the difference in the real world emissions performance of vehicles in the fleet. Data contained within the AQC report indicates that the EFT may have underestimated emissions of earlier classes of vehicles to a similar extent as for Euro 6ab vehicles. As such, one could be justified in using the emission factors from the year of the assessment as the uncertainty in the emission factors is taken account of by using the verification factor.

The verification factor is not the only consideration however:

- The emission factors are in terms of NOx which is a combination of NO and NO2. Historically, most of the NOx emission was NO, with a small proportion of NO2. There is some evidence that the proportion of NO2 in the NOx is rising, which would counteract reductions in overall NOx emissions when one considers compliance with NO2 National Air Quality Strategy Objectives.
- There is uncertainty in the production of the traffic data on which the air quality modelling is based, as well as uncertainty within the EFT as it is based on assumptions regarding the replacement of vehicles into the vehicle fleet (over and above assumptions on the actual emissions performance of those vehicles).
- The predicted pollutant concentration from the road traffic modelling is added to an estimate of the background concentration, which itself, is subject to uncertainty.

The above factors justify a more conservative approach to future year emissions than simply using the EFT emission factors for the year of the assessment.

Taking into account the various factors discussed above, it is proposed that for the determination of likely significant effects we will use an emissions year two years earlier for future year assessments up until 2025, and three years earlier from 2026. This is likely to be conservative given the introduction of Euro 6c vehicles into the fleet (from 2017), but recognising increasing uncertainty regarding predicting the composition of the vehicle fleet and vehicle emissions in the future. Table 11.10.2 shows the effect of the proposals.

Table 11.9.2 Effect of the proposals

Assessment Year	Emission Factor Year
2015	2015
2016	2015
2017	2015
2018	2016
2019	2017
2020	2018
2021	2019
2022	2020
2023	2021
2024	2022
2025	2023
2026	2023
2027	2024
2028	2025
2029	2026
2030	2027
2031	2028
2032	2029
2033 and beyond	2030

The choice of emission factors and background concentrations needs to take into account the specific circumstances of the assessment being undertaken, but the above approach is considered to provide a conservative basis on which to assess likely future pollutant concentrations.

Appendix 12.4 Traffic data used for noise modelling

No.	Link / Notes Refer to Reference Link Plan	2021 DM		2021 DS		2031 DM		2031 DS	
		Observed / estimated Combined one-way 18hr Base 5d flows	Observed / estimated 18 hr 5d >3.5t %	Observed / estimated Combined one-way 18hr Base 5d flows	Observed / estimated 18 hr 5d >3.5t %	Observed / estimated Combined one-way 18hr Base 5d flows	Observed / estimated 18 hr 5d >3.5t %	Observed / estimated Combined one-way 18hr Base 5d flows	Observed / estimated 18 hr 5d >3.5t %
1.0	M11 - J12 - J13 - Nbd	46509	16%	46943	16%	48166	16%	49630	16%
1.0	M11 - J12 - J13 - Sbd	46924	16%	47072	16%	49057	16%	50066	16%
1.1	M11 J13 -J14 - Nbd	33816	16%	33589	16%	34806	16%	34511	16%
1.1	M11 J13 -J14 - Sbd	33370	16%	33154	16%	34620	16%	34272	16%
1.2	M11 between A14 Ebd on-slip / Huntingdon Rd on slip - Nbd	24053	16%	23865	16%	24961	16%	24709	16%
1.2	M11 between A14 Ebd on-slip / Huntingdon Rd on slip - Sbd	24488	16%	24306	16%	25561	16%	25284	16%
1.3	M11 J13 off-slip - Nbd	11359	16%	12012	16%	12013	16%	13778	16%
1.3	M11 J13 on-slip - Sbd	8883	16%	9252	16%	9765	16%	11129	16%
3.0	A1303 East of Madingley Mulch R'bout Ebd	7695	6%	7930	6%	8563	6%	9253	6%
3.0	A1303 East of Madingley Mulch R'bout Wbd	12705	6%	12851	6%	13523	6%	14046	6%
3.1	Madingley Rd - East of Cambridge Rd Crossroads Wbd	11789	6%	11945	6%	12607	6%	13195	6%
3.1	Madingley Rd - East of Cambridge Rd Crossroads Ebd	8694	6%	8958	6%	9568	6%	10340	6%
3.2	Madingley Rd on Over Bridge M11 Ebd	12599	6%	13614	6%	13889	6%	16669	6%
3.2	Madingley Rd on Over Bridge M11 Wbd	6033	6%	6234	6%	6553	6%	7225	6%
3.3	Madingley Rd between M11 Sbd On Slip - Proposed Madingley Rd West Access Ebd	11266	4%	12242	4%	12091	4%	14738	4%
3.3	Madingley Rd between M11 Sbd On Slip - Proposed Madingley Rd West Access Wbd	10707	4%	11294	4%	11704	4%	13780	4%
3.4	Madingley Rd - West of P&R Access Wbd	10707	4%	11818	4%	11704	4%	10181	4%
3.4	Madingley Rd - West of P&R Access Ebd	11266	4%	12580	4%	12091	4%	10942	4%
3.5	Madingley Rd - East of P&R Access Wbd	9787	4%	10765	4%	10783	4%	9127	4%
3.5	Madingley Rd - East of P&R Access Ebd	10650	4%	12091	4%	11475	4%	10454	4%
3.6	Madingley Rd - East of Proposed High Cross Access Ebd	9363	4%	11812	4%	10036	4%	12478	4%
3.6	Madingley Rd - East of Proposed High Cross Access Wbd	8548	4%	10352	4%	9360	4%	11437	4%
3.7	Madingley Rd - East of JJ Thomson Ave Ebd	10352	4%	11380	4%	11038	4%	13494	4%
3.7	Madingley Rd - East of JJ Thomson Ave Wbd	9052	4%	10066	4%	9661	4%	12631	4%
3.8	Madingley Rd - East of Clerk Maxwell Rd Ebd	10158	4%	11521	4%	10843	4%	14031	4%
3.8	Madingley Rd - East of Clerk Maxwell Rd Wbd	9011	4%	10794	4%	9621	4%	13610	4%
12.0	Western Access to Madingley Rd Nbd	0	7%	0	7%	0	7%	3144	7%
12.0	Western Access to Madingley Rd Sbd	0	7%	0	7%	0	7%	3177	7%
12.1	High Cross Access to Madingley Rd Nbd	1031	7%	3426	7%	1031	7%	3379	7%
12.1	High Cross Access to Madingley Rd Sbd	1240	7%	3614	7%	1240	7%	4145	7%
12.2	JJ Thomson Ave Access to Madingley Rd Nbd	1740	7%	1457	7%	1740	7%	2885	7%
12.2	JJ Thomson Ave Access to Madingley Rd Sbd	1329	7%	1588	7%	1329	7%	3083	7%
12.3	Clerk Maxwell Rd Nbd - south of Car Park Access	199	7%	65	7%	199	7%	65	7%
12.3	Clerk Maxwell Rd Sbd - south of Car Park Access	194	7%	62	7%	194	7%	62	7%
12.4	Clerk Maxwell Rd Sbd - north of Car Park Access	498	7%	1002	7%	498	7%	1036	7%
12.4	Clerk Maxwell Rd Nbd - north of Car Park Access	508	7%	1021	7%	508	7%	1056	7%

Appendix 12.5 Ramboll noise survey for the Cavendish III Laboratories 2016

Intended for
Jestico & Whiles

Document reference
R01/rev.01

Date
06 April 2016

UNIVERSITY OF CAMBRIDGE DEPARTMENT OF PHYSICS CAVENDISH III PROJECT

NOISE SURVEY REPORT

(INCLUDING ADDITIONAL MEASUREMENTS)

RAMBOLL ENVIRON

CAVENDISH III PROJECT (INCLUDING ADDITIONAL MEASUREMENTS)

Revision	**01**
Date	**06/04/2016**
Made by	**Emilie Carayol**
Checked by	**Raf Orlowski**
Approved by	**Raf Orlowski**
Description	**Noise survey report**
Job number	**1620001378**

Rev no.	Date	Document Ref.	Comments
01	06/04/2016	R01/rev 01 – Noise Survey Report	Additional measurements carried out to define zone where natural ventilation is possible
-	30/03/2016	R01– Noise Survey Report	

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APPENDICES

Appendix 1
Noise Survey Data

Appendix 2
Acoustic Terminology

1. INTRODUCTION

A baseline noise survey has been carried out at the site of the proposed new building for the Department of Physics Cavendish III project at the University of Cambridge.

External noise measurements were made continuously from Friday 26th February 2016 until Friday 4th March 2016.

The survey was conducted to ascertain the external noise levels at the facades of the proposed new building. The results of the survey will be used to inform the design of the building envelope to provide the required internal ambient noise levels in the new building.

Additional measurements were carried out on 5th April 2016 to define more precisely the zone where natural ventilation is possible.

It is anticipated that noise emission limits from the new building will be required by planning conditions. The results of this survey present the background noise levels at the northern and southern site boundaries, and may be used to set noise emission limits at these locations.

2. SITE DESCRIPTION

The site of the proposed new building is bound by the A1303 (Madingley Rd) to the North, a field to the South (intended to be the site of the proposed Shared Hub facilities), JJ Thomson Avenue to the East and an access road to the Department of Veterinary Medicine to the West. The site boundary is indicated in red in Figure 1.

The site currently consists of several fields with an access road running East to West between them.

2.1 Noise climate

The noise climate around the site is dominated by road traffic noise from Madingley Road. Other significant noise sources were vehicles on JJ Thomson Avenue, the access road to the Department of Veterinary Medicine, nearby construction and distant traffic on the M11.

3. SURVEY METHODOLOGY

Noise loggers were used to measure continuously at the North and South of the site from Friday 26th February to Friday 4th March 2016.

In addition, manned noise measurements were conducted between 16:00 and 17:30 on Friday 26 February 2016, and 08:00 and 11:00, and 16:00 and 18:30 on Thursday 3 March 2016 by Emilie Carayol and George Xanthoulis of Ramboll Acoustics.

Noise measurements were taken at approximately 1.2 metres above ground level and at a distance of at least 3 metres from the façade of any buildings and are considered representative of free-field measurements. The measurement duration was 15 minutes on 26 February and 10 minutes on 3 March. These measurement durations are considered representative of the reasonably consistent ambient noise climate at these locations.

The sound level meter calibration was checked immediately before and after the measurement periods. No significant drift in calibration was detected.

3.1 Weather

During the measurement periods on 26 February and 3 March, weather conditions were noted as dry and there was no significant wind at ground level.

3.2 Measurement locations

Figure 1 shows the measurement locations. The site boundary is indicated in red. ST1-4 are considered representative of the position of the corners of the proposed new building. LT1 and LT2 are considered representative of the northern and southern façades.

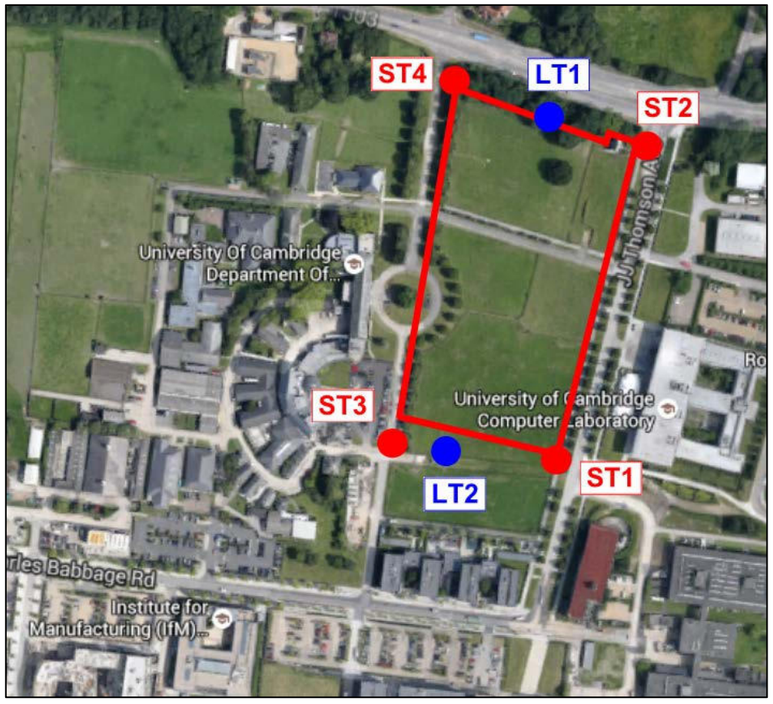


Figure 1 Site plan showing noise survey measurement locations

The locations are described as follows:

ST1: SE corner of the site, adjacent to JJ Thompson Avenue
ST2: NE corner of the site close to the junction of JJ Thomson Avenue and Madingley Rd
ST3: Representative of the SW corner of the site, adjacent to the access road for the Department of Veterinary Medicine
ST4: NW corner of the site, at the junction of the access road and Madingley Rd
LT1: North boundary between ST2 and ST4. 50m from eastern site boundary.
LT2: South boundary between ST1 and ST3. 70m from eastern site boundary.

3.3 Additional measurements

Five-minute measurements were undertaken on 5th April 2016 in the morning by Emilie Carayol to assess the noise level variations across the south half of the site.

The locations are represented on Figure 3 along with the noise results in Table 1.

The weather was noted as dry and there was no significant wind at ground level.

3.4 Equipment

The following measurement equipment was used to conduct the survey:

- Brüel and Kjær 2270 'Class 1' Sound Level Analyser
- Brüel and Kjær 4189 'Class 1' Pre-polarised ½" microphone
- Norsonic 118 'Class 1' Sound Level Analysers
- GRAS 40AS 'Class 1' Pre-polarised ½" microphones

All measurement equipment owned or hired and operated by Ramboll Acoustics has annual calibration checks carried out by external companies traceable to national standards. Copies of all calibration records are kept and can be provided upon request.

4. SURVEY RESULTS

A summary of the noise survey results at each manned measurement location is shown on a site plan in Figure 2. A sample of results for these locations and time history graphs for LT1 and LT2 are presented in Appendix A. The full set of data is available on request.

The results in Figure 2 show that higher sound levels were measured at the northern boundary of the site compared with the southern boundary of the site. The highest sound levels were measured at the North East corner of the site (ST2) and the lowest sound levels were measured at the South West corner of the site (ST3).

The time history graphs in Appendix 1 show the pattern of sound levels at the noise logger locations. For both noise loggers, the sound levels were lower during the night-time than the daytime, but there was a higher difference between the day and night-time levels for the north, where a sharp increase in level during the morning rush hour period was shown, due to traffic on Madingley Road.

During the daytime, the levels were fairly consistent and the levels reduced in the afternoon to evening period. The quietest period was around 01:00 – 03:00. At the north location, the larger difference between the background noise (L_{A90}) and average sound level (L_{Aeq}), is due to shorter term events from traffic noise. The L_{A90} and L_{Aeq} values at the south noise logger are closer in value, as this position is less affected by the traffic noise.

ST1	Start Time	LAeq	LAFmax	LA90
Morning	03/03/2016 08:14	59.5	73.3	55.8
	03/03/2016 09:08	59.4	71.1	55.2
	03/03/2016 10:06	57.9	70.2	53.4
Afternoon	03/03/2016 16:57	57.7	70.3	50.0
	03/03/2016 17:50	59.4	71.6	51.7
	03/03/2016 18:45	56.3	71.5	50.6
	26/02/2016 16:19	56.3	74.8	46.1
Afternoon	26/02/2016 16:54	56.5	77.2	46.0

ST2	Start Time	LAeq	LAFmax	LA90
Morning	03/03/2016 08:28	62.7	74.5	54.5
	03/03/2016 09:23	62.1	74.4	54.7
	03/03/2016 10:21	61.2	74.8	51.4
Afternoon	03/03/2016 16:14	62.1	73.3	53.5
	03/03/2016 17:10	61.5	73.8	51.3
	03/03/2016 18:05	62.0	74.0	53.8

ST3	Start Time	LAeq	LAFmax	LA90
Morning	03/03/2016 08:54	55.7	73.4	52.8
	03/03/2016 09:51	53.1	64.4	51.3
	03/03/2016 10:53	50.7	62.3	48.6
Afternoon	03/03/2016 16:43	53.0	65.5	50.2
	03/03/2016 17:37	54.3	70.3	51.1
	03/03/2016 18:31	53.7	63.2	52.2
	26/02/2016 16:37	51.0	70.3	46.3
Afternoon	26/02/2016 17:12	54.3	88.7	44.8

ST4	Start Time	LAeq	LAFmax	LA90
Morning	03/03/2016 08:51	60.2	67.0	56.9
	03/03/2016 09:37	60.6	76.5	55.7
	03/03/2016 10:39	59.0	74.7	52.9
Afternoon	03/03/2016 16:29	60.1	67.7	54.2
	03/03/2016 17:23	56.4	71.3	51.3
	03/03/2016 18:18	59.6	67.3	54.5

Figure 2 Summary of noise survey results at each measurement location (L_{Aeq} is ambient noise level and L_{A90} is background noise level)

The additional measurements, whose locations are shown in Figure 3, indicate that the levels in the south west quarter were below 50 dB and those in the south east quarter were below 55dB. The results are presented in Table 1.

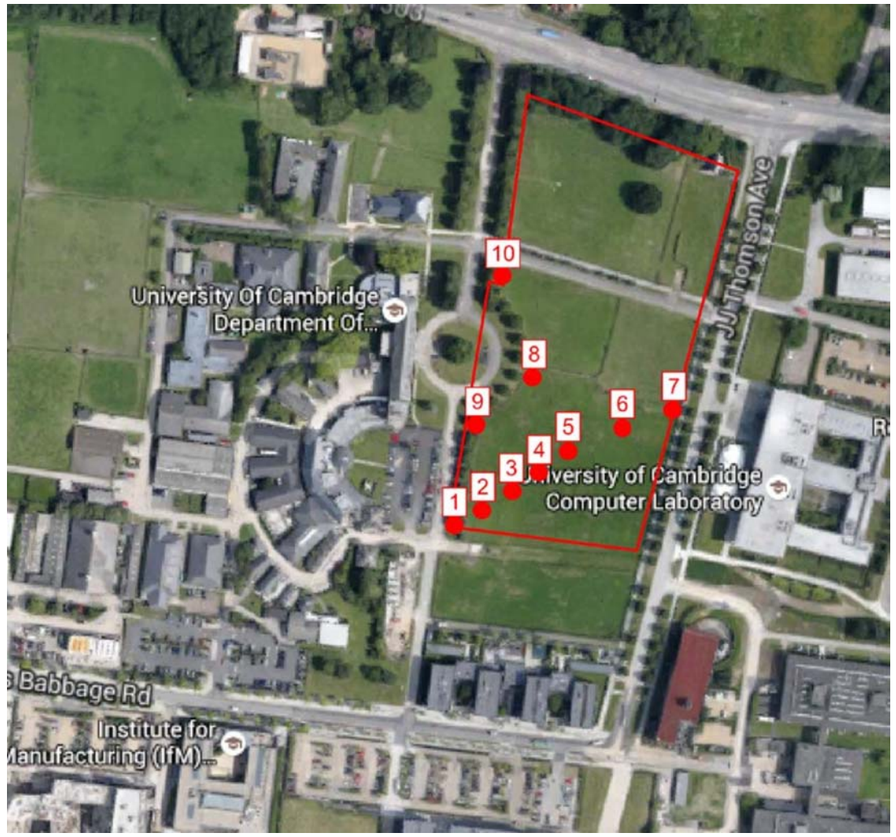


Figure 3 Additional noise monitoring locations at the south part of the site

Location	Time hh :mm	Ambient Noise Level $dBL_{Aeq,\ 5min}$	Background Noise Level $dBL_{A90,\ 5min}$
1	08 :44	50	49
2	09 :08	47	46
3	09 :20	49	48
4	09 :31	48	46
5	09 :38	50	48
6	09 :52	51	50
7	09 :57	55	49
8	10 :04	50	48
9	10 :10	48	45
10	10 :17	48	46

Table 1 Additional noise results at different locations across the south part of the site

This assessment has defined the areas where natural ventilation is suitable for rooms requiring an internal ambient noise level of 35 dBL_{Aeq} (private offices) and 40 dBL_{Aeq} (meeting/lecture rooms). These areas are respectively coloured in blue and yellow in Figure 4.

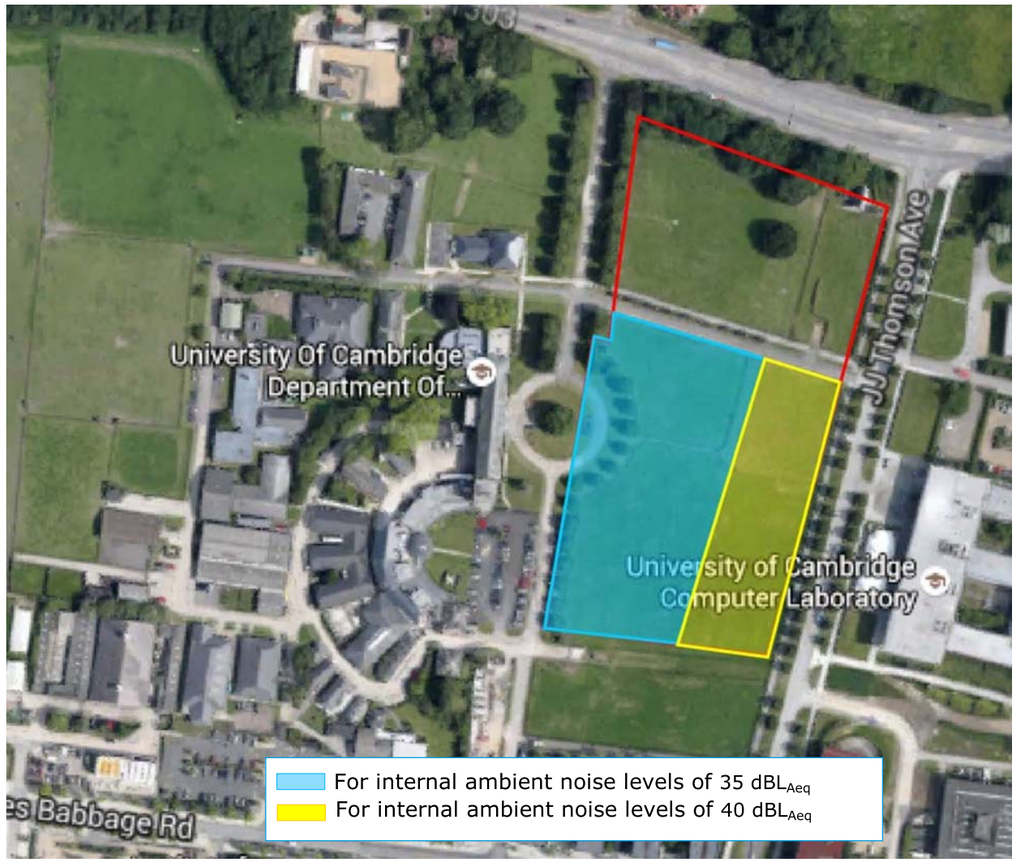


Figure 4 Natural ventilation area for internal ambient noise level of 35 dBL_{Aeq} and 40 dBL_{Aeq}

5. DESIGN IMPLICATIONS

5.1 Sound insulation of the building envelope

The manned measurements taken during the daytime ranged from 51 dB L_{Aeq} at the South of the site (ST3) to 63 dB L_{Aeq} at the North of the site (ST2).

Based on guidance given in BS 8233:2014, the appropriate criterion for indoor ambient noise levels in private offices is 35 dBL_{Aeq} and is 40 dB L_{Aeq} in meeting/lecture rooms. In the case of the laboratories; the ambient noise criterion will vary depending on the use of the laboratory.

The noise survey has indicated that the south of the site is significantly quieter than the north of the site which implies that the most noise sensitive spaces should be located in the southern section. Detailed design implications for north and south sections are discussed below.

5.1.1 North section of site

The least noise-sensitive spaces should be located in the north section of the site. Natural ventilation will be difficult to achieve in this section for offices and similar rooms. With mechanical ventilation, standard thermal double glazing will be sufficient providing a sound reduction of R_w 30 dB. The building fabric should provide sound reduction of at least 35 dB which is achievable with most building envelope materials.

5.1.2 South section of site – zone suitable for natural ventilation

Noise sensitive spaces can be located in the south section with the South West section being the quietest. Private offices and similar spaces which require an internal noise criterion of 35 dBL_{Aeq} can be naturally ventilated if located in the south west part of the site as represented in Figure 4. Meeting rooms and lecture rooms with a noise criterion of 40 dBL_{Aeq} can be located in the yellow area as described in Figure 4. For laboratories which are particularly noise sensitive or generate particularly high noise levels, fixed windows will need to be used with mechanical ventilation.

5.2 Noise emission limits

Measurement positions LT1 and LT2 are considered representative of the existing noise climate at the northern and southern site boundaries respectively. At LT1, the lowest measured background noise level (L_{A90}) in the daytime was 39 dB and at night-time was 34 dB. At LT2, the lowest measured background noise level in the daytime was 41 dB and at night-time was 39 dB.

These values can be used to set plant noise emission limits for any plant associated with the proposed new building at the site boundary which are likely to be subject to planning requirements.

For building services plant, noise emission will be controlled to meet the planning requirement using standard noise control measures, such as attenuators, enclosures or screens.

For specialised laboratory equipment which is installed externally, each installation will need to be assessed separately to apply appropriate noise control measures to meet the required condition. These measures could be in the form of enclosures, screens and barriers.

Where the specialised laboratory equipment is installed internally, the sound insulation of the laboratory in question may require higher performance double glazing and a higher sound insulating envelope.

This will be developed as the design progresses.

6. CONCLUSION

The results of the baseline noise survey are considered to be suitable to inform the design of the building envelope of the proposed new building to ensure that the internal ambient noise level requirements are achieved. The southern boundary is significantly quieter than the northern boundary and two areas have been identified where natural ventilation is suitable:

- Private offices requiring an ambient noise level of 35 dBL_{Aeq} can be located on the south west of the site
- Meeting/ Lecture rooms with an internal ambient noise level of 40 dBL_{Aeq} can be located on the south east part of the site.

Background noise levels have been measured at the northern and southern site boundaries. The results of these measurements are considered suitable to set noise emission limits from any plant associated with the new building at these locations.

APPENDIX 1
NOISE SURVEY DATA

Location	Time, hh:mm	Duration, mm:ss	Sound pressure level in one-third octave bands (Leq)																			
			50	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1k**	**1.25k**	**1.6k**	**2k**	**2.5k**	**3.15k**	**4k**	**5k**
ST1	03/03/2016 08:14	00:10:00	62	62	58	55	54	52	52	51	48	48	49	50	53	53	50	49	47	44	42	38	35
ST2	03/03/2016 08:28	00:10:00	66	66	63	61	56	56	56	55	54	52	53	53	54	55	53	53	51	49	46	43	40
ST3	03/03/2016 08:54	00:10:00	59	59	55	53	52	50	46	45	43	43	44	47	48	48	48	47	38	34	36	38	35
ST4	03/03/2016 08:41	00:10:00	63	64	59	57	55	52	52	51	48	47	47	50	53	54	52	51	48	44	40	38	33

Table A1: One-third Octave Band Sound Pressure Level, L_{eq}

Location	Time, hh:mm	Duration, mm:ss	Sound pressure level in one-third octave bands (L90)																			
			50	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1k**	**1.25k**	**1.6k**	**2k**	**2.5k**	**3.15k**	**4k**	**5k**
ST1	03/03/2016 16:57	00:10:00	54	52	51	50	48	45	43	41	40	38	39	40	43	43	40	37	33	30	28	26	21
ST2	03/03/2016 17:10	00:10:00	58	57	54	52	50	48	47	46	45	43	44	45	47	47	44	43	40	37	34	30	26
ST3	03/03/2016 16:43	00:10:00	52	50	49	48	46	43	41	39	37	35	38	41	44	44	40	37	32	27	24	20	16
ST4	03/03/2016 17:23	00:10:00	58	56	53	50	48	46	45	43	40	37	37	40	43	45	42	40	37	33	30	26	22

Table A2: One-third Octave Band Sound Pressure Level, L_{90}

Location	Time, hh:mm	Duration, mm:ss	Sound pressure level in one-third octave bands (Lmax)																			
			50	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1k**	**1.25k**	**1.6k**	**2k**	**2.5k**	**3.15k**	**4k**	**5k**
ST1	03/03/2016 08:14	00:10:00	77	76	74	66	64	65	71	72	61	64	64	65	67	67	64	63	63	60	57	57	51
ST2	03/03/2016 08:28	00:10:00	81	84	80	84	72	73	71	70	71	67	70	66	67	70	66	65	64	63	61	57	57
ST3	03/03/2016 08:54	00:10:00	73	70	65	66	70	70	58	57	56	56	54	54	56	66	73	70	52	52	58	62	57
ST4	03/03/2016 08:41	00:10:00	81	76	71	72	67	68	64	63	60	59	57	59	59	61	59	62	57	56	52	53	53

Table A3: One-third Octave Band Sound Pressure Level, L_{max}

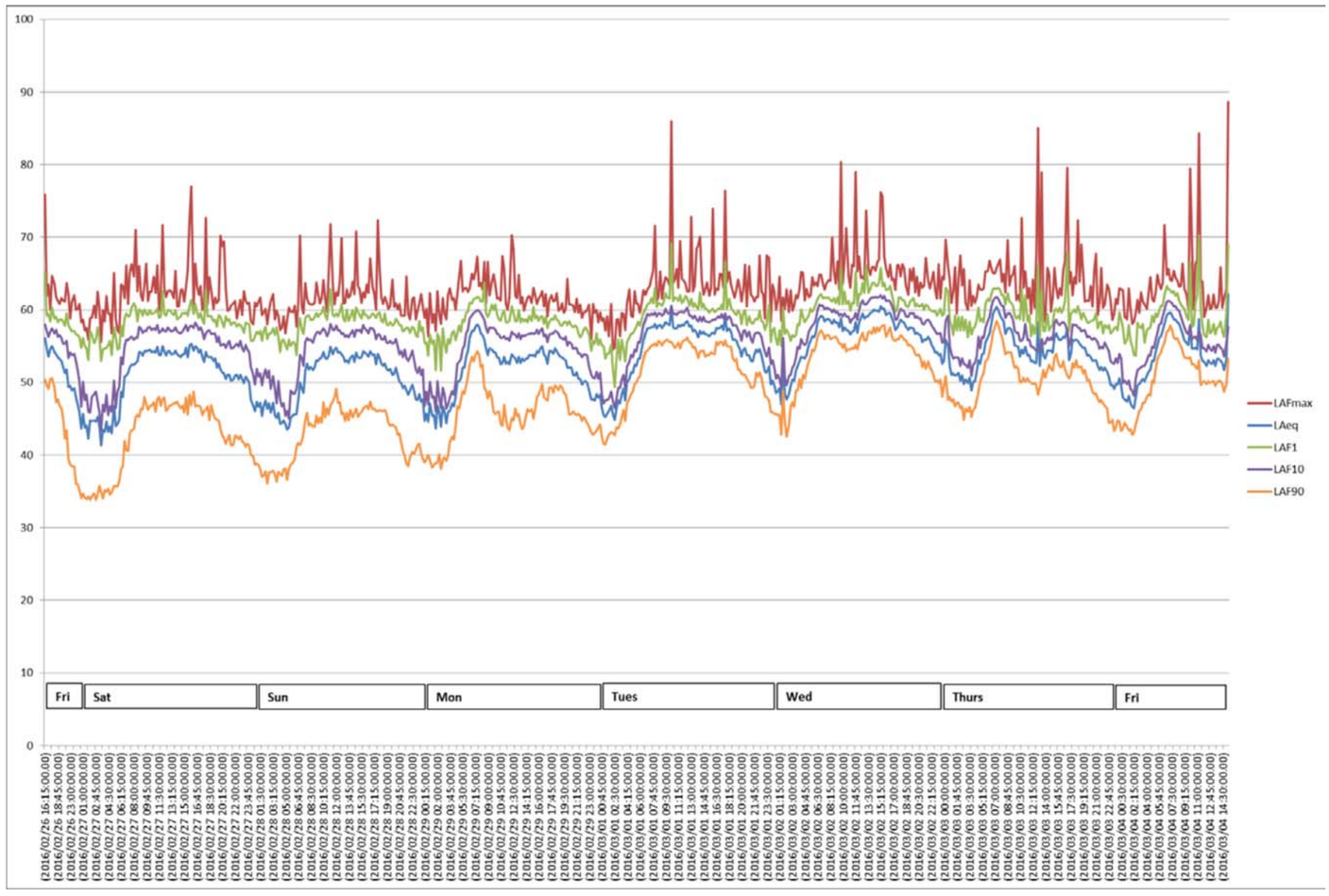


Figure 3 Time history for North logger

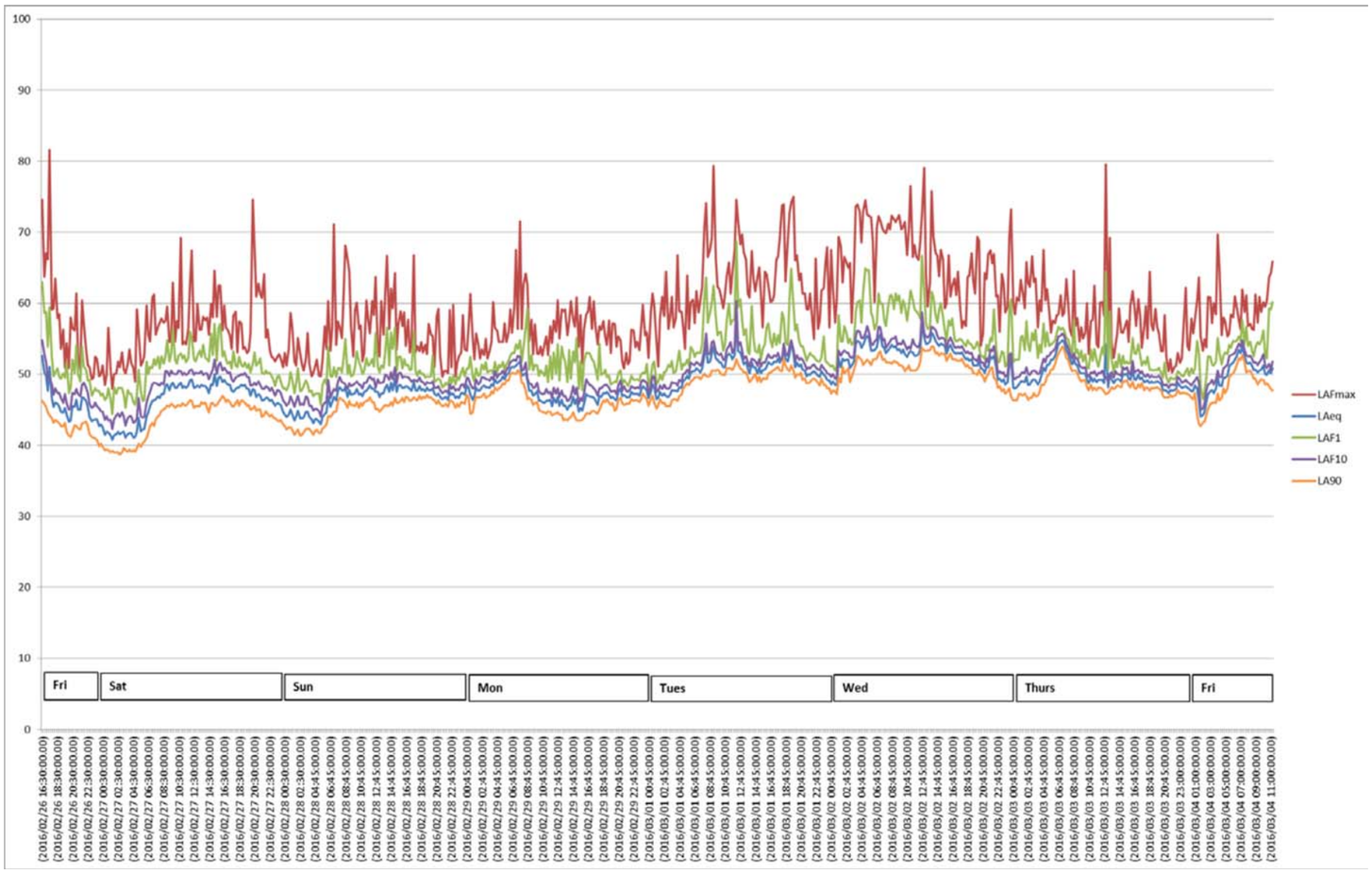


Figure 4 Time history for South logger

APPENDIX 2
ACOUSTIC TERMINOLOGY

A-WEIGHTED DECIBEL (dBA)

The unit generally used for measuring environmental, traffic or industrial noise is the A-weighted sound pressure level in decibels, denoted dB(A). An A-weighting network can be built into a sound level measuring instrument such that sound levels in dB(A) can be read directly from a meter. The weighting is based on the frequency response of the human ear and has been found to correlate well with human subjective reactions to various sounds. It is worth noting that an increase or decrease of approximately 10 dB corresponds to a subjective doubling or halving of the loudness of a noise, and a change of 2 to 3 dB is subjectively barely perceptible.

EQUIVALENT CONTINUOUS SOUND LEVEL (L_{eq})

Another index for assessment for overall noise exposure is the equivalent continuous sound level, L_{eq}. This is a notional steady level which would, over a given period of time, deliver the same sound energy as the actual time-varying sound over the same period. Hence fluctuating levels can be described in terms of a single figure level.

MAXIMUM NOISE LEVEL (L_{max})

The maximum noise level identified during a measurement period. Experimental data has shown that the human ear does not generally register the full loudness of transient sound events of less than 125 ms in duration. Fast time weighting has an exponential time constant of 125 ms which reflects the ear's response. The maximum level measured with fast time weighting is denoted as $L_{AMax,f}$. Slow time weighting (S) with an exponential time constant of 1s is used to allow more accurate estimation of the average sound level on a visual display.

Impulse (I) time weighting has a fast rise (35ms) and a slow decay and is intended to mimic the ear's response to impulsive sounds.

SOUND REDUCTION INDEX (R)

The sound reduction index (or transmission loss) of a building element is a measure of the loss of sound through the material, i.e. its attenuation properties. It is a property of the component, unlike the sound level difference which is affected by the common area between the rooms and the acoustic of the receiving room. The weighted sound reduction index, R_w, is a single figure description of sound reduction index characterising a range of frequencies, which is defined in BS EN ISO 717-1: 1997. The R_w is calculated from measurements in an acoustic laboratory. Sound insulation ratings derived from site (which are invariably lower than the laboratory figures) are referred to as the R'_w ratings.

STATISTICAL NOISE LEVELS

For levels of noise that vary widely with time, for example road traffic noise, it is necessary to employ an index which allows for this variation. The L_{10}, the level exceeded for ten per cent of the time period under consideration, has historically been adopted in the UK for the assessment of road traffic noise. The L_{90}, the level exceeded for ninety per cent of the time, has been adopted to represent the background noise level. The L_1, the level exceeded for one per cent of the time, is representative of the maximum levels recorded during the sample period. A weighted statistical noise levels are denoted L_{A10},dB L_{A90} etc. The reference time period (T) is normally included, e.g. dB $L_{A10,\ 5min}$ or dB $L_{A90,\ 8hr}$.

TYPICAL NOISE LEVELS

Some typical noise levels are given in the following table.

Noise Level dB(A)	Example
130	Threshold of pain
120	Jet aircraft take-off at 100 m
110	Chain saw at 1 m
100	Inside disco
90	Heavy lorries at 5 m
80	Kerbside of busy street
70	Loud radio (in typical domestic room)
60	Office or restaurant
50	Domestic fan heater at 1m
40	Living room
30	Ventilation Noise in Theatre
20	Remote countryside on still night
10	Sound insulated test chamber
0	Threshold of hearing

Appendix 12.6 Max Fordham noise survey for the Civil Engineering Building 2016

UNIVERSITY OF CAMBRIDGE

MAX FORDHAM

The Civil Engineering Building

Noise & Vibration Impact Assessment

Rev F

October 2016

Noise and Vibration Impact Assessment

Prepared by Max Fordham

Submitted as part of the planning application for the Civil Engineering Building

On the West Cambridge Site, Madingley Road, Cambridge

Version Rev F

Dated October 2016

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ISSUE HISTORY

Issue	Date	Description
*	30/02/2016	For Information
A	13/07/2016	For Information
B	09/09/2016	For Information
C	28/09/2016	For Information
D	30/09/2016	For Information
E	30/09/2016	For Information
F	07/10/2016	For Planning Submission

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1.0 INTRODUCTION

Max Fordham LLP have been appointed to provide acoustic design and advice for the new building on behalf of Grimshaw Architects.

An acoustic noise survey has been undertaken in order to establish the existing acoustic environment and baseline noise levels. A calculation of the airborne noise levels resulting from the proposed development has been prepared and an assessment of the significance of noise impact at the nearest noise sensitive receptors has been made. This report presents and summarises the results of this noise impact assessment.

Sound Space Vision, on behalf of Smith & Wallwork Ltd, have undertaken an assessment of the vibration impact from the proposed development and this vibration impact assessment is included in the appendices of this report.

2.0 RELEVANT STANDARDS AND GUIDANCE

2.1 National Planning Policy Framework

The NPPF sets out the Government's planning policies for England and how these are expected to be applied. Section 11 paragraph 123 of NPPF states that planning policies and decisions should aim to:

- Avoid noise from giving rise to significant adverse impacts on health and quality of life as a result of new development;
- Mitigate and reduce to a minimum other adverse impacts on health and quality of life arising from noise from new development, including through the use of conditions;
- Recognise that development will often create some noise and existing businesses wanting to develop in continuance of their business should not have unreasonable restrictions put upon them because of changes in nearby land uses since they were established;
- Identify and protect areas of tranquillity which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason;"

2.2 Noise Policy Statement for England

The Department for Environmental Food and Rural Affairs published the NPSE in 2010. This document is intended to apply to all forms of noise other than that which occurs in the workplace and includes environmental noise and neighbourhood noise in all forms.

The NPSE contains an explanatory notes which defines the NOEL, LOAEL and SOAEL terms which are used in the NPPF:

NOEL – No Observed Effect Level: This is the level below which no effect can be detected. In simple terms, below this level there is no detectable effect on health and quality of life due to the noise

LOAEL – Lowest Observed Adverse Effect Level: This is the level above which adverse effects on health and quality of life can be detected.

SOAEL – Significant Observed Adverse Effect Level: This is the level above which significant adverse effects on health and quality of life occur

2.3 National Planning Practice Guidance

The NPPG published in 2014 states that "noise needs to be considered when new developments may create additional noise and when new developments would be sensitive to the prevailing acoustic environment".

The NPPG provides advice on how to determine the impact of noise, including whether or not a significant adverse effect "is occurring or likely to occur" and whether or not a "good standard of amenity can be achieved".

2.4 Local Noise Policy

Cambridge Environmental Health have confirmed that the noise impact requirements, relating to *'mechanical and electrical building services and other sound of an industrial and/or commercial nature, in order to protect the quality of life / amenity of neighbouring premises'* are as follows:

> *"To satisfy any plant noise assessment or noise insulation condition, the rating level (in accordance with BS4142:2014) from all plant, equipment and vents etc (collectively) associated with this*

application should be less than or equal to the existing background level (L90) at the boundary of the premises subject to this application and having regard to noise sensitive premises."

Policy 4/13 "Pollution and Amenity" of the Cambridge City Council's Local Plan (July, 2006) states:

"Development will only be permitted which:

a. does not lead to significant adverse effects on health, the environment and amenity from pollution; or

b. which can minimise any significant adverse effects through the use of appropriate reduction or mitigation measures.

Proposals that are sensitive to pollution, and located close to existing pollution sources, will be permitted only where adequate pollution mitigation measures are provided as part of the development package."

3.0 BACKGROUND NOISE SURVEY

Two long term noise surveys have been undertaken by Max Fordham LLP in order to establish the existing background noise levels at the site of the proposed building.

A 48-hour noise survey was undertaken from the 22nd – 24th February 2016, during a period where the roads are busy (few people on holiday). A second, 140-hour, noise survey was undertaken at the same location from the 26th August to 1st September 2016, during a school and university holidays when the traffic is much lighter. This survey period incorporates weekdays and weekends. There was a bank holiday Monday during this measurement period which for the purposes of this survey is assumed to be similar to a weekend day.

It is expected that noise levels during the weekend will be similar both within and outside of summer holiday periods.

The chosen measurement location is considered to be representative of the noise levels experienced at the nearest residential property to the proposed development, at The Lawns of Clerk Maxwell Road.

3.1 Survey Procedure

For both surveys a sound level meter was set up to make consecutive 15 minute noise throughout the survey duration.

The microphone of the sound level meter was mounted on a tripod externally, approximately 1.5m from the ground (See Figure 1 and Figure 2). This position is considered to be free-field and representative of noise levels experienced at the nearest noise sensitive properties to the proposed development. A weather protection kit was used. The sound level meter was calibrated at the beginning and end of the survey period and no significant drift was observed.

The weather conditions throughout the survey in February were moderately cold with wind speeds typically below 4m/s and no precipitation. During the survey in August the weather conditions were warm (typically between 15 and 25 degrees Celsius) with wind speeds typically below 5m/s. There were 2 short periods of rainfall (approx. 40 mins) during the survey at around 4pm and 9pm 28th August 2016.

All weather data is obtained from Atomwide Weather Station in Cambridge, approximately 1km from the measurement location.

A microphone windshield was used during all measurements. The weather conditions are not considered to have affected the noise survey results in any significant way during either survey.

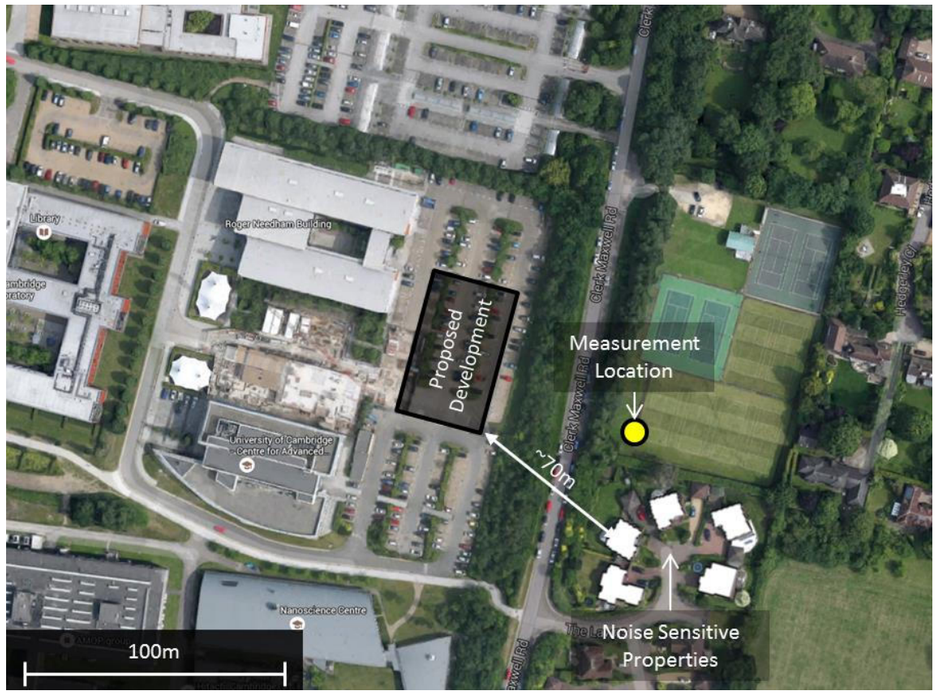


Figure 1 - Site Plan & Measurement Location



Figure 2 - Photo of 48-hour Survey

3.2 Survey Equipment

Table 1 and Table 2 below give details of the equipment used during the long term noise surveys and the dates are the relevant accredited calibration. Copies of calibration certificates are available upon request.

Item	Make	Type	Serial no.	Calibration Intervals	Last Calibrated	Next Due Calibration
Class 1 sound level meter	Norsonic	140	1405942	2 years	20/03/2014	20/03/2016
Microphone	Norsonic	1225	208215	2 years	20/03/2014	20/03/2016
Microphone preamplifier	Norsonic	1209	15804	2 years	20/03/2014	20/03/2016
Calibrator	Norsonic	1251	34059	1 year	11/04/2015	11/04/2016
A calibration check was undertaken using the sound pressure level calibrator producing 114.0 dB at an octave band centre frequency of 1000 Hz with reference to 2×10^{-5} N m^{-2} before and after the tests.						

Table 1 - 1st Survey Sound Level Meter and Calibrator Information

Item	Make	Type	Serial no.	Calibration Intervals	Last Calibrated	Next Due Calibration
Class 1 sound level meter	Norsonic	140	1405942	2 years	11/04/2016	11/04/2018
Microphone	Norsonic	1225	208215	2 years	11/04/2016	11/04/2018
Microphone preamplifier	Norsonic	1209	15804	2 years	11/04/2016	11/04/2018
Calibrator	Norsonic	1251	34059	1 year	11/04/2016	11/04/2017
A calibration check was undertaken using the sound pressure level calibrator producing 114.0 dB at an octave band centre frequency of 1000 Hz with reference to 2×10^{-5} N m^{-2} before and after the tests.						

Table 2 - 2nd Survey Sound Level Meter and Calibrator Information

3.3 Survey Results

The results of the noise surveys are presented graphically in Figure 3 and Figure 4 below. Table 3 gives a summary of the minimum background, "representative" background and logarithmic average values for day, evening and night time periods.

It is assumed that the differences in noise level between the two surveys is due to a reduced level of activity around in the local area during the second survey because it was during the summer holiday period. Values are separated further to show values for week days during busier seasons, week days outside busy seasons and weekends. In some respects the February survey results are likely to be more representative for the normal noise levels on site but to ensure acceptable noise levels the limits have been set on the more onerous survey.

BS4142:2014 states that the impact of noise should be assessed in comparison to the background noise level. However when obtaining the background noise level it is also noted that *"the objective is not simply to ascertain a lowest measured background sound level, but rather to quantify what is typical during particular time periods".*

The proposed method of obtaining "typical" background noise levels is to discount the highest 20% of values in order to ensure outlying erroneous values are discounted then take the median of the remaining values to be representative of the background level. Therefore the 40th percentile value of background noise levels is used as a "representative" background noise level.

Histograms of the background noise level for each day, evening and night period are shown in Appendix A – Background Noise Level Histograms.

Parameter	Time Period	Busy Week	Holiday Week	Weekend
$L_{A90,15min}$ Minimum	Day (8am – 6pm)	42	38	37
	Eve (6pm - 11pm)	42	39	37
	Night (11pm – 8am)	40	36	31
$L_{A90,15min}$ 40th Percentile	Day (8am – 6pm)	47	42	42
	Eve (6pm - 11pm)	47	42	41
	Night (11pm – 8am)	43	40	37
$L_{Aeq,T}$	Day (8am – 6pm)	51	47	48
	Eve (6pm - 11pm)	49	46	46
	Night (11pm – 8am)	49	48	44

Table 3 - Summary of Noise Survey Results

In order to allow an assessment for particular time periods the representative background noise levels for Saturday mornings (9am to 1pm) have also been calculated as:

- Minimum $L_{A90,15min\ (9am-1pm)}$ = 41dB
- 40th Percentile $L_{A90,15min\ (9am-1pm)}$ = 42dB
- $L_{Aeq,(9am\ -\ 1pm)}$ = 47dB

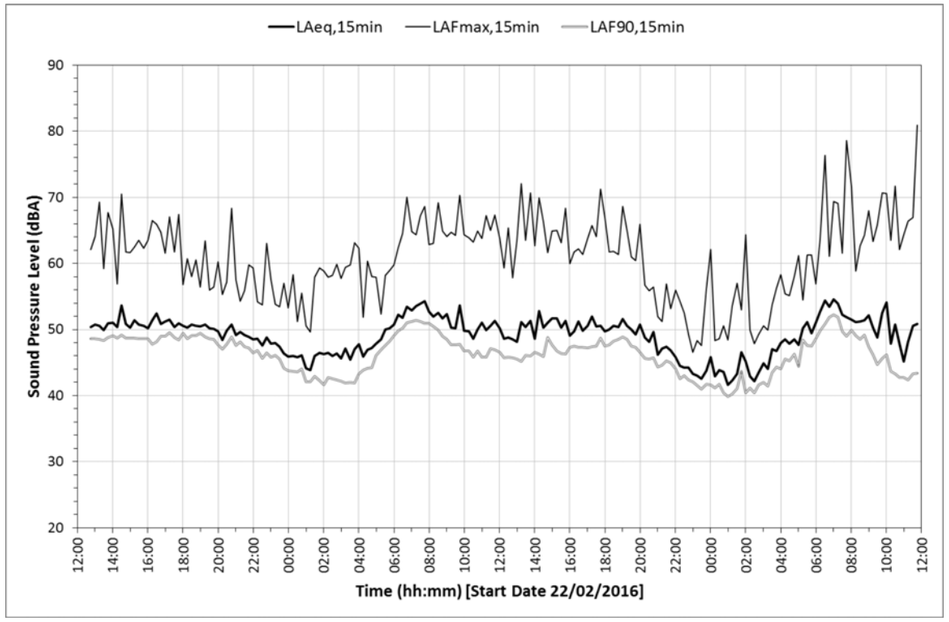


Figure 3- Summary of Survey Results (Feb Survey)

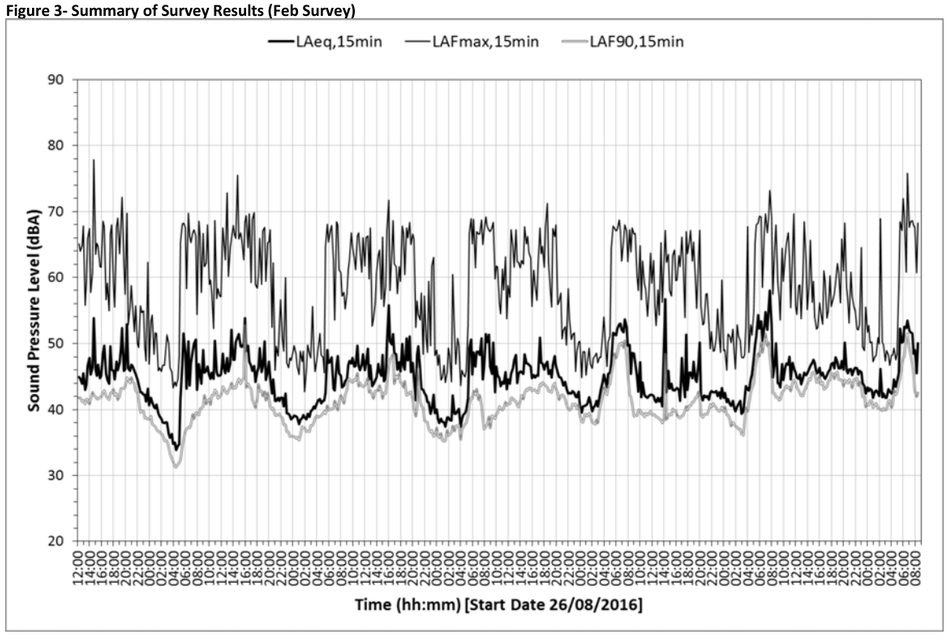


Figure 4 - Summary of Survey Results (Aug Survey)

4.0 TARGET NOISE LEVELS

There are two sources of noise which have been identified by the design team and Cambridge City Council as having a potential impact on nearby residents:

- Plant & Machinery Noise: Including both noise from fixed external plant and noise from machinery used within the structures lab.
- Delivery Access Road: Noise from vehicles on the access road, making deliveries to the structures lab.

4.1 Plant & Machinery

In order to avoid noise from the proposed site causing a noise impact on the nearby residential properties it is critical that noise from machinery and equipment is sufficiently attenuated. The usual method for rating and assessing industrial sound is set out in British Standard 4142:2014.

BS 4142 states that an estimate of the impact of the specific sound can be obtained by subtracting the background sound level from the rating level. The specific sound is the level of the new sound source (i.e. Concrete Mixer etc.) and the rating level is the specific sound level with penalties applied to account for certain characteristics of the sound.

It is then stated that:

- *A difference of around +10dB or more is likely to be an indication of a significant adverse impact.*
- *A difference of around +5dB is likely to be an indication of an adverse impact.*
- *Where the rating level does not exceed the background sound level, this is an indication of the specific sound source having a low impact.*

Cambridge Council have confirmed that an assessment should be made at the boundary of the proposed development and that the noise rating level should not exceed the background noise level as per the local authority noise policy described in Section 2.4.

4.2 Delivery Access Road

The delivery access road is a noise source which is associated with the development (rather than a public access road) and as such the local authority have requested that it should be assessed under the criteria of sound of an industrial/commercial nature as per BS 4142:2014

5.0 PLANT & MACHINERY NOISE LEVELS

5.1 Engineering Machinery Noise Levels

On 3rd February 2016 measurements were made of the equipment and machinery within the existing Cambridge University Engineering Department building on Trumpington Street, Cambridge.

The items of equipment measured were a concrete mixer, a concrete beam shaker and a jackhammer. See Figure 5 for photos of the items of machinery that were measured.



Figure 5 - Photos of Machinery

Measurements were taken at a distance far enough away from the item of machinery in order to ensure that the measurements were taken within the reverberant sound field of the room, rather than the direct sound field.

Table 4 and Figure 6 show the 1/3rd octave band reverberant sound pressure levels for each item of machinery measured.

It should be noted that the use of the jack hammer is only occasional, but is included in this assessment to demonstrate that the worst case is still acceptable.

Frequency (Hz)	Concrete Mixer	Beam Shaker	Jack Hammer
50	65.6	90.9	50.7
63	71.9	94.3	51.1
80	72.5	83.1	52.9
100	81.8	70.8	55.9
125	79.7	84	63.0
160	85.8	79.1	62.8
200	79.6	75.8	62.9
250	77.8	72.1	71.5
315	76.8	74.6	72.7
400	79.4	76.7	80.5
500	81.2	78.6	84.8
630	79.7	79.6	84.0
800	82.2	78.2	85.8
1000	84	78.3	82.6
1250	85.4	79.9	81.0
1600	87.7	79.8	82.2
2000	89.2	74.1	83.4
2500	87.5	72.3	81.2
3150	86.9	70.3	81.8
4000	88.2	67.5	83.9
5000	87.6	64.4	81.5
6300	84.3	61.1	85.7
8000	81.1	59.3	82.0
A-Weighted	**97.9**	**87.6**	**94.6**

Table 4 - Machinery Reverberant Sound Pressure Levels (dB)

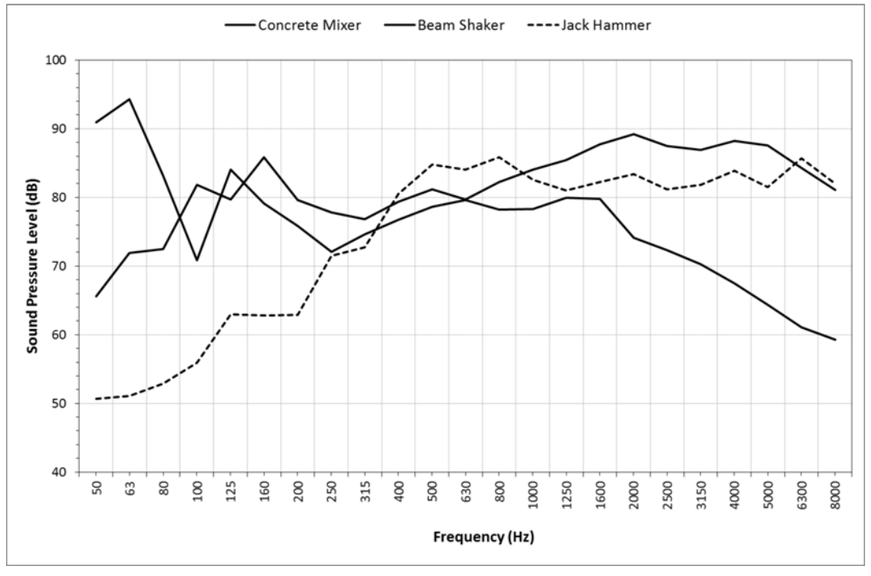


Figure 6 - Machinery Reverberant Sound Pressure Levels (dB)

5.2 Mechanical Plant Equipment Noise Levels

The complete extent and acoustic performance of mechanical plant is not finalised at this stage, however below is a summary of the main plant items that are expected to form part of a noise impact assessment:

- Ground floor internal plant room – Central heating & cooling plant
- Roof plant – Fume cupboard extract fan
- Local ventilation plant – A number of labs, offices and meetings contain local MVHR units and/or fan-coil units.

There are currently no emergency generators or large items of external plant equipment within the current proposals.

6.0 ACCESS ROAD NOISE LEVELS

British Standard 5228 Part 1: 2009 "Code of practice for noise and vibration on construction and open sites" has various information and guidelines on noise from plant, machinery and vehicles. Annex C of BS5228 provides "current sound level data on site equipment and site activities" and the relevant levels are reproduced below along with an average value which will be used for the assessment.

Table	Ref no.	Description	Power Rating [kW]	Weight [t]	Lmax at 10m [dB] in Frequency Octave Bands [Hz]								
					63	125	250	500	1k	2k	4k	8k	dBA
C.11	6	Lorry	343	29	92	82	76	78	77	76	74	68	83
C.11	16	Lorry	235	26	86	81	74	76	73	72	69	60	79
C.11	19	Lorry	201	26	87	76	73	81	79	75	68	62	83
C.11	20	Lorry	160	18	91	76	79	78	80	76	70	64	83
Average					**89**	**79**	**76**	**78**	**77**	**75**	**70**	**64**	**82**

Table 5 - BS5228-1 Lorry Lmax Levels

Noise levels of an idling vehicle (specifically a Dumper Truck in this case) can also be taken from Annex C of BS5228-1:2009 and are reproduced below:

Description	Leq at 10m [dB] in Frequency Octave Bands [Hz]								
	63	125	250	500	1k	2k	4k	8k	dBA
Idling Vehicle (BS5228-1 Table C.4 Ref 5)	73	64	55	55	60	56	50	43	63

Table 6 - BS5228-1 Idling Vehicle Leq

7.0 PROPOSED FAÇADE PERFORMANCE

The façade of the proposed building is approximately 78m from the façade of the nearest residential property and 60m from the garden boundary fence of the nearest residential property. The façade is specified to be constructed of the following elements:

Façade Element	Area (m^2)	Sound Reduction Rw (dB)	Transmission Coefficient, t	Area weighted transmission
Ventilation Opening	12	36	0.00025	0.0030
Glazing	28	41	0.00008	0.0022
Sliding Door	73	47	0.00002	0.0015
Solid Façade	82	47	0.00002	0.0016
Total	**195**	**43.7**	**0.00004**	**0.0083**
Formula	A	R	10^(-0.1 x R)	t x A

Table 7 - Proposed Façade Performance

Accounting for the area of the façade and external propagation over a distance of 60m there will be a weighted sound level difference between the internal reverberant noise level of the proposed building and the level at the garden boundary of the nearest residential property of 70dB.

Description	Formula	Reduction
Reverberant level to sound intensity in façade	10Log(4)	6dB
Sound reduction of facade	Refer to Table 7	43.7dB
Area source propagation to 2.9m	No attenuation from area source	0dB
Line source propagation to 6.4m	10Log(6.4/2.9)	3.5dB
Point source propagation to 60m	$10Log(60^2/6.4^2)$	19.5dB
Hemispherical propagation correction	-10Log(2)	-3dB
Total Attenuation		**70dB**

Table 8 - Facade Noise Propagation Calculation

8.0 ACCESS ROAD PROPERTIES

An assessment of the noise levels from deliveries using the proposed access road will be made at the nearest noise sensitive property which is approximately 78m from the engineering building façade and 57m from the access road (at its closest point). See Figure 8.

There is an earth mound between the engineering building and the nearest residents. At the area directly outside the structures lab, where deliveries are expected to be made, the mound is at a height of approximately 2m above ground level. Along the length of the access road, the height of the earth mound varies and a height of 1.5m above ground level is taken for the purposes of this assessment. Figure 7 shows the measured ground heights of the proposed service access road, the earth mound on the site boundary and the height of Clerk Maxwell road.

The height of the receptor point is taken as being at a first floor window, approximately 4.5m above ground level. It is understood that the ground height at the location of the sensitive receptor is approximately 1.4m lower than the reference ground height of the service road. Therefore the receptor is taken to be 3.1m.

Table 9 below summarises the distances and reference heights of the noise sensitive receptor locations.

Location Parameter	Residential Façade at 1st Floor	Residential Garden
Distance to engineering building	78m	60m
Distance to access road (closest point)	57m	47m
Assessment height	4.5m	1.5m
Assessment height relative to reference ground level	3.1m	0.1m

Table 9 - Location parameters of sensitive receptors

For the case of a vehicle moving along the access road, a correction is required to convert the Lmax value at 10m to an average (LAeq) value corresponding to the equivalent noise level of the vehicle moving along the access road. It is assumed that vehicles will travel at 20km/h along the access road. Equation F.6 from BS5228-1:2009 gives a method for calculating the equivalent continuous noise level from vehicles that pass along service roads at intervals. This equation will be used to assess the equivalent noise level at the nearest sensitive receptor. Calculation details are given in Section 9.4.

Additionally, it is assumed that vehicles will spend up to 10 minutes idling outside the engineering building. Vehicles will drive into the structures lab of the engineering building and the acoustic doors will be closed before any loading/unloading takes place. There will be no external loading or unloading of vehicles.

As per the methodology of BS4142, the specific sound source is to be evaluated over a reference time interval of 1 hour. It is currently assumed that there will be no more than 1 delivery vehicle within any 1 hour period.

The university have confirmed that there will be approximately 6 HGV (<30 tonne) deliveries per year and all other deliveries will be via light goods vehicles, typically small vans up to 3.5 tonnes.

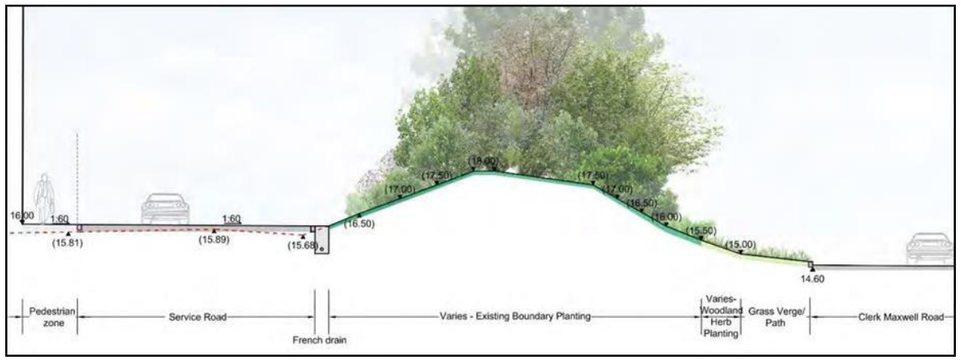


Figure 7 - Section showing relative ground heights

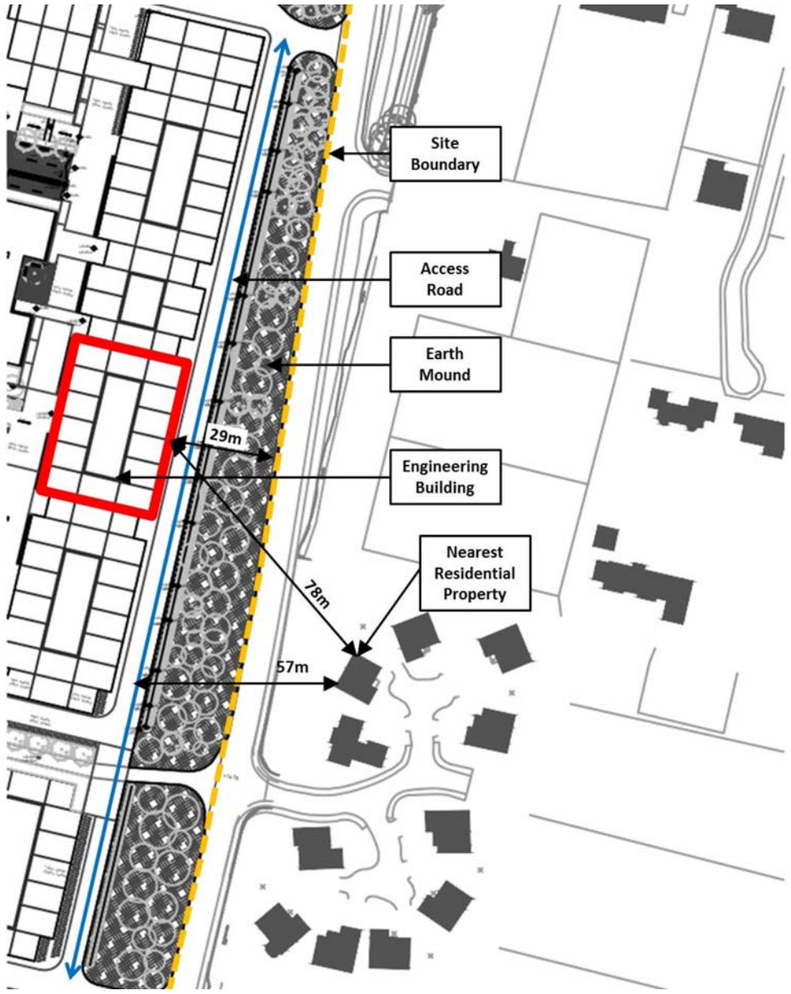


Figure 8 - Site Plan Showing Access Road

9.0 NOISE IMPACT ASSESSMENT

9.1 Engineering Machinery

All engineering machinery (concrete mixers, jack hammer, beam shaker etc.) will be operated internally within the proposed building only. Therefore, the composite façade sound reduction provides the primary means of mitigating any noise impact from this machinery.

The loudest piece of machinery measured was the concrete mixer with a reverberant sound pressure level of 97.9dBA. According to the method in Annex C of British Standard 4142:2014 there is no single 1/3rd octave band sound level that is sufficiently higher than its adjacent bands for the noise source to be considered tonal.

It is proposed that a 3dB penalty should be applied to account for the intermittent nature of the noise source and a further 3dB penalty applied to account for the impulsive nature of the noise source (This applies more to the jack hammer than the concrete mixer, but is applied as a worst case scenario).

Therefore, the noise rating level of the concrete mixer is 104dBA. Subtracting the sound level difference described in Section 7.0 of 70dB, the noise rating level at the garden boundary of the nearest residential property is expected to be 34dB. An assessment at the façade of the residential property would be marginally lower.

As per BS4142:2014, the noise rating level should be compared to the representative background noise level which has been measured to be 47dBA by taking the 40th percentile LA90,15min value.

This noise rating level is **13dBA below** the typical background noise level and easily achieves the target set out in Section 4.1 and is in accordance Cambridge Environmental Health noise impact criteria as detailed in Section 2.4 and 4.0. A summary of the noise rating level in comparison to background noise levels during various time periods is given in Table 10.

It can be seen that the noise rating level from machinery within the engineering building is below the typical background noise level at the boundary of the nearest residential property (garden boundary). However, it is not anticipated that any such machinery would normally be operated outside of the daytime period (8am to 6pm).

Time of Year / Week	Time Period	Typical Background Noise	Excess of Rating (34dBA) Over Background Sound Level
Busy Week	8am – 6pm	47 dBA	-13dBA
	6pm – 11pm	47 dBA	-13dBA
	11pm – 8am	43 dBA	-9dBA
Holiday Week	8am – 6pm	42 dBA	-8dBA
	6pm – 11pm	42 dBA	-8dBA
	11pm – 8am	40 dBA	-6dBA
Weekend	8am – 6pm	42 dBA	-8dBA
	6pm – 11pm	41 dBA	-7dBA
	11pm – 8am	37 dBA	-3dBA

Table 10 - Machinery Noise Impact Assesment

Uncertainty of the Assessment
The measurement of the background noise levels have been taken under repeatable conditions over an extended period of time (~190 hours) covering every day of the week, therefore it is expected that the uncertainty of the background noise level measurement will be very low.

Measurements of the machinery noise levels have been taken from the existing items that the University currently use and are understood to be the same items that will be used within the proposed building. However, the new structures lab is specified to have a much lower reverberation time than the existing building and so it is expected that the reverberant noise level within the structures lab may be up to 5dB less. Sound reduction data for the specified façade performance is taken from laboratory tests reports of the currently proposed products.

The excess of the rating level of the background sound level is -13dBA and so in this instance the uncertainty of the assessment does not have any significance to the outcome of the assessment.

9.2 Engineering Machinery Low Frequency Assessment

During discussions with Cambridge Environmental Services a query has been raised highlighting a concern as to whether low frequencies noise from the engineering machinery may result in a noise impact over above that identified by the A-weighted assessment.

This additional assessment has been included in order to present the anticipated low frequency noise levels at the nearest residents resulting from the use of engineering machinery.

The Beam Shaker was measured as having the highest reverberant sound pressure levels at 50Hz and 63Hz. These were 91dB and 94dB respectively as shown in Table 4. Applying the same characteristic penalties as discussed in Section 9.1 results in Noise Rating Levels of 97dB and 100dB at 50Hz and 63Hz respectively.

The frequency weighted sound reduction index of the façade is calculated to be 44dB in Section 7.0. At 50Hz and 63Hz this is expected to be 18dB with a resulting sound level difference between the internal reverberant noise level of the proposed building and the level at the garden boundary of the nearest residential property of 46dB.

Therefore, the noise rating level of the Beam Shaker at the garden boundary of the nearest residential property would be 51dB and 54dB at 50Hz and 63Hz respectively.

The measured 40th percentile daytime background noise level is 55dB and 54dB at 50hz and 60Hz respectively. Therefore, the low frequency component of the machinery noise level is not significantly above the measured background noise level and it is expected that there would be no adverse impact from low frequency noise.

It should also be noted that the anticipated low frequency noise level of the Beam Shaker at the garden boundary is at approximately the threshold of audibility.

9.3 Mechanical Plant Equipment

The complete extent and acoustic performance of mechanical plant is not finalised at this stage, however a description of the anticipated items of plant equipment are given in Section 5.2.

There are no large external items of plant or emergency generators within the current proposals. All mechanical ventilation units and fan coil units are located internally, local to each room. Therefore any noise impact can be mitigated by ensuring the appropriate selection of atmosphere side attenuators to each item of plant. There may be an externally located fume cupboard extract fan on the roof of the proposed building. If the sound power of this fan exceeds the noise limits then it will need to be mitigated with the use of screening or an acoustic enclosure.

Table 11 gives the total allowable sound power level from all items of plant in order to ensure that the typical background noise level is not exceeded. A margin of 3dBA has been given to allow for addition of engineering machinery noise levels and a distance of 60m has been assumed as the nearest noise sensitive receptor.

The allowable total plant sound power level has been calculated according to the following equation to account for distance propagation (no account of barrier effects have been taken to provide a worst case example).

Allowable Total Plant Sound Power = Limit at Garden Boundary – 10Log(2/(4πr²))

Time of Year / Week	Time Period	Typical Background Noise	Noise Rating Limit at Garden Boundary	Allowable Total Plant Sound Power
Busy Week	8am – 6pm	47 dBA	44dBA	88dBA
	6pm – 12pm	46 dBA	43 dBA	87dBA
	12pm – 8am	43 dBA	40 dBA	84dBA
Holiday Week	8am – 6pm	42 dBA	39 dBA	83dBA
	6pm – 12pm	42 dBA	39 dBA	83dBA
	12pm – 8am	40 dBA	37 dBA	81dBA
Weekend	8am – 6pm	42 dBA	39 dBA	83dBA
	6pm – 12pm	40 dBA	37 dBA	81dBA
	12pm – 8am	37 dBA	34 dBA	78dBA

Table 11 - Allowable Total Plant Sound Power Levels

9.4 Delivery Access Road

The noise level from a HGV vehicle moving along the delivery access road and idling outside the engineering building for 10 minutes has been assessed at both the garden boundary of the nearest residential building and the façade of the residential building at 1st floor level.

Table 12 and Table 14 give details of the LAeq,1hr calculation at the residential façade for a moving vehicle and an idling vehicle respectively. Table 16 combines the two LAeq,1hr levels to give a total noise level.

Table 13 and Table 15 give details of the LAeq,1hr calculation at the residential garden boundary for a moving vehicle and an idling vehicle respectively. Table 17 combines the two LAeq,1hr levels to give a total noise level.

	Residential Façade Level	63	125	250	500	1k	2k	4k	8k	dBA
a)	Lorry Lmax at 10m	89	79	76	78	77	75	70	64	82
	Values from BS5228-1 Table C.11. Refer to Table 5 for details									
b)	Lorry Sound Power, Lw	117	107	104	106	105	103	98	92	110
	Lw = Lmax at 10m – 10Log(2 / 4πr²), where r is distance (10m)									
c)	Correction to Leq,1hr	-46	-46	-46	-46	-46	-46	-46	-46	
	As per method in BS5228 equation F.6 : -33 + 10log(Q) – 10Log(v), where Q is vehicles per hour (1), v is average speed (20km/h)									
d)	Distance Attenuation	-18	-18	-18	-18	-18	-18	-18	-18	
	-10Log(r), where r is distance (57m)									
e)	Barrier Attenuation	-5	-5	-5	-5	-5	-6	-7	-9	
	Barrier attenuation as per the Maekawa method: -10log(3 + 20N), N = Δd(2/λ), path difference = 0.0045m									
f)	Reflection Correction	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
	Correction for reflection from façade of engineering building									
g)	Leq,1hr at Receptor	**51**	**41**	**38**	**40**	**38**	**36**	**30**	**22**	**43**
	Leq,1hr at receptor = b + c + d + e + f									

Table 12 - Calculation of LAeq,1hr levels at residential façade from moving vehicle

	Residential Garden Boundary	63	125	250	500	1k	2k	4k	8k	dBA
a)	Lorry Lmax at 10m	89	79	76	78	77	75	70	64	82
	Values from BS5228-1 Table C.11. Refer to Table 5 for details									
b)	Lorry Sound Power, Lw	117	107	104	106	105	103	98	92	110
	Lw = Lmax at 10m – 10Log(2 / 4πr²), where r is distance (10m)									
c)	Correction to Leq,1hr	-46	-46	-46	-46	-46	-46	-46	-46	
	As per method in BS5228 equation F.6 : -33 + 10log(Q) – 10Log(v), where Q is vehicles per hour (1), v is average speed (20km/h)									
d)	Distance Attenuation	-16	-16	-16	-16	-16	-16	-16	-16	
	-10Log(r), where r is distance (40m)									
e)	Barrier Attenuation	-5	-6	-7	-9	-11	-13	-16	-18	
	Barrier attenuation as per the Maekawa method: -10log(3 + 20N), N = Δd(2/λ), path difference = 0.0705m									
f)	Reflection Correction	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
	Correction for reflection from façade of engineering building									
g)	Leq,1hr at Receptor	**52**	**41**	**37**	**38**	**35**	**31**	**23**	**14**	**40**
	Leq,1hr at receptor = b + c + d + e + f									

Table 13 - Calculation of LAeq,1hr levels at residential garden boundary from moving vehicle

	Residential Façade Level	63	125	250	500	1k	2k	4k	8k	dBA
a)	Idling Leq at 10m	73	64	55	55	60	56	50	43	63
	Values from BS5228-1 Table C.4.									
b)	Correction to Leq,1hr	-8	-8	-8	-8	-8	-8	-8	-8	
	As per BS4142: 10Log(Ton / Tref), where Ton is on time (10 minutes) Tref is reference time (60 minutes)									
c)	Distance Attenuation	-18	-18	-18	-18	-18	-18	-18	-18	
	-20Log(r1/r2), where r1 is original distance (10m) and r2 is new distance (76m)									
d)	Barrier Attenuation	-5	-6	-6	-7	-9	-11	-13	-16	
	Barrier attenuation as per the Maekawa method: -10log(3 + 20N), N = Δd(2/λ), path difference = 0.0403m									
e)	Reflection Correction	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
	Correction for reflection from façade of engineering building:									
f)	Leq,1hr at Receptor	**45**	**36**	**26**	**25**	**28**	**22**	**14**	**4**	**31**
	Leq,1hr at receptor = a + b + c + d + e									

Table 14 - Calculation of LAeq,1hr levels at residential façade from idling vehicle

	Residential Garden Boundary	63	125	250	500	1k	2k	4k	8k	dBA
a)	Idling Leq at 10m	73	64	55	55	60	56	50	43	63
	Values from BS5228-1 Table C.4.									
b)	Correction to Leq,1hr	-8	-8	-8	-8	-8	-8	-8	-8	
	As per BS4142: 10Log(Ton / Tref), where Ton is on time (10 minutes) Tref is reference time (60 minutes)									
c)	Distance Attenuation	-15	-15	-15	-15	-15	-15	-15	-15	
	-20Log(r1/r2), where r1 is original distance (10m) and r2 is new distance (58m)									
d)	Barrier Attenuation	-6	-7	-8	-10	-12	-15	-18	-20	
	Barrier attenuation as per the Maekawa method: -10log(3 + 20N), N = Δd(2/λ), path difference = 0.1154m									
e)	Reflection Correction	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
	Correction for reflection from façade of engineering building: 10Log(2)									
f)	Leq,1hr at Receptor	**47**	**37**	**26**	**25**	**27**	**21**	**12**	**2**	**31**
	Leq,1hr at receptor = a + b + c + d + e									

Table 15 - Calculation of LAeq,1hr levels at residential garden boundary from idling vehicle

Residential Façade Level	63	125	250	500	1k	2k	4k	8k	dBA
Moving Vehicle Leq,1hr	51	41	38	40	38	36	30	22	43
Idling Vehicle Leq,1hr	45	36	26	25	28	22	14	4	31
Total Leq,1hr	52	42	38	40	39	36	30	22	**43**

Table 16 – Total LAeq,1hr level at residential façade

Residential Garden Boundary	63	125	250	500	1k	2k	4k	8k	dBA
Moving Vehicle Leq,1hr	52	41	37	38	35	31	23	14	**40**
Idling Vehicle Leq,1hr	47	37	26	25	27	21	12	2	**31**
Total Leq,1hr	53	43	38	38	36	31	23	14	**40**

Table 17 - Total LAeq,1hr level at residential garden boundary

It can be seen that the most onerous condition is at the façade of the residential building at 1st floor level. Although this assessment location is further away from the access road, it has a reduced barrier effect from the mound due to being assessed at 1st floor level. The noise level to be compared to the typical background noise level is LAeq,1hr = 43dB.

Time of Year / Week	Time Period	Typical Background Noise	Excess of Rating Over Background Sound Level
Busy Week	8am – 6pm	47	-4dBA
	6pm – 11pm	47	-4dBA
Holiday Week	8am – 6pm	42	1dBA
	6pm – 12pm	42	1dBA
Weekend	8am – 6pm	42	1dBA
	6pm – 12pm	41	2dBA
Saturdays	9am – 1pm	42	1dBA

Table 18 – Access Road Noise Impact Assessment

Table 18 gives a comparison of the vehicle noise level at the residential boundary to the typical background noise levels at various time periods. During holiday periods when ambient traffic noise is less

The university are proposing to limit delivery periods to Mon-Fri 8am to 6pm and Saturdays 9am to 1pm. These time periods are highlighted in Table 18. It can be seen that the vehicle noise level exceeds the typical background noise level by no more than 1dBA during holiday weekdays and Saturday mornings. This small exceedance is to be mitigated by minimising the number of such deliveries.

This assessment is based upon the worst case scenario of an articulated lorry (<30 tonne). All other deliveries to the building will be made by a small van and noise levels from such a vehicle are expected to be much lower (by at least 5dBA) and always less than the typical background noise level.

Guidance for assessing the impact of noise is given in Section 11 of BS4141:2014 and states that:

> *"The lower the rating level is relative to the measured background sound level, the less likely it is that the specific sound source will have an adverse impact or a significant adverse impact. Where the rating*

level does not exceed the background sound level, this is an indication of the specific sound source having a low impact, depending on the context"

Values of +5db and +10dB are suggested to be indications of an adverse or significant adverse impact, respectively, depending on the context.

In this case the assessment of impact needs to be modified due to context and the following factors should be considered:

Absolute Sound Level
BS4142 suggests that "where background sound levels and rating levels are low, absolute levels might be as, or more, relevant than the margin by which the rating level exceeds the background." The World Health Organisation (WHO) guidelines for community noise suggest that sound level at the façade of dwellings should not exceed 45dB LAeq so as to avoid sleep disturbance, with a 5dB increase during the day. The background noise level and vehicle noise level are both lower than this value giving an indication that the absolute sound levels are low and unlikely to cause disturbance.

Frequency of Noise Events
The university have advised that deliveries from HGV (articulated lorries) are likely to occur approximately only 6 times per year. This means that a HGV delivery event would happen on <2% of days within a year and only once within that day. Therefore these events can be considered to be very rare and less likely to have adverse effect than an equivalent noise source that is heard every day.

Character and Level of the Residual Sound Compared to the Specific Sound
BS4142 suggests that may be beneficial "to assess the degree to which the specific sound source is likely to be distinguishable and will represent incongruous sound by comparison to the acoustic environment that would occur in the absence of the specific sound."

Traffic noise is the major component of both the specific noise and the residual sound, it is also apparent that the specific noise source is less than the residual sound level. Therefore the specific sound source would be expected to be less distinguishable and not an incongruous sound.

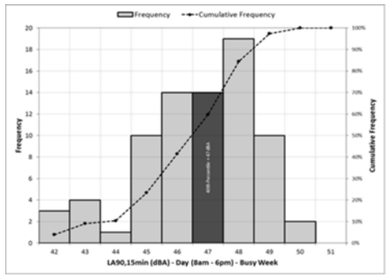
The university are taking reasonable steps to improve the situation for the nearest residents by providing an access road to take vehicles off, further away and screened from, Clerk Maxwell Road and providing an internal area to unload vehicles. In light off this and the contextual factors described above it is proposed that the noise level from deliveries is acceptable providing the following conditions which shall be written into the universities "Servicing and Operational Management Plan":

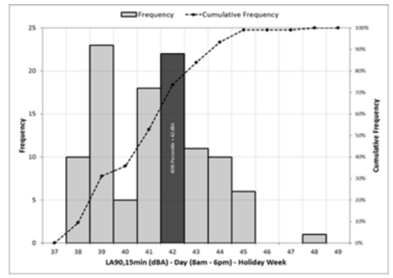
- Typically 1 delivery per day from a small van
- Approximately 6 HGV deliveries per year
- Weekday deliveries between 8am – 6pm
- Saturday deliveries between 9am – 1pm
- No deliveries on Sundays
- All unloading must be done inside the structures lab with acoustic doors closed
- A banksman shall be used when possible to avoid the need for reversing alarms

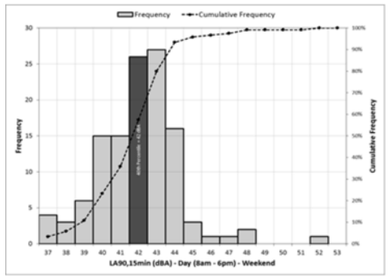
Uncertainty of the Assessment
The measurement of the background noise levels have been taken under repeatable conditions over an extended period of time (~190 hours) covering every day of the week, therefore it is expected that the uncertainty of the background noise level measurement will be very low.

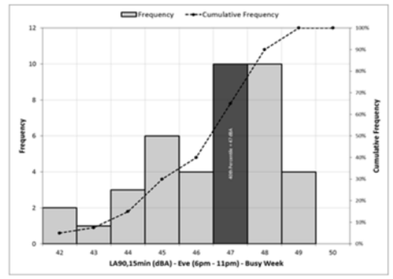
Measurements of the actual vehicles that will be using the service road is not possible at this stage and published sound levels of sub-30 tonne HGV Lorries are taken from BS5228 with an average of 4 values used. The range of values was 4dBA (+1dBA and -3dBA from the average).

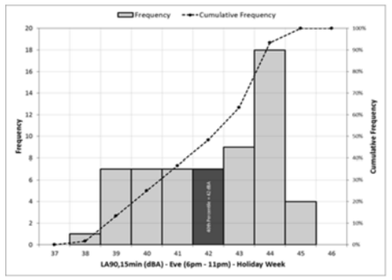
10.0 APPENDIX A – BACKGROUND NOISE LEVEL HISTOGRAMS

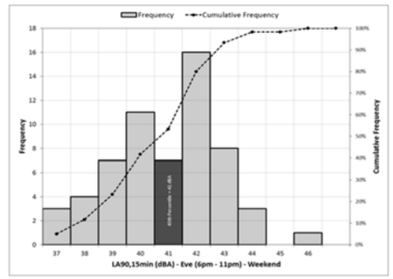


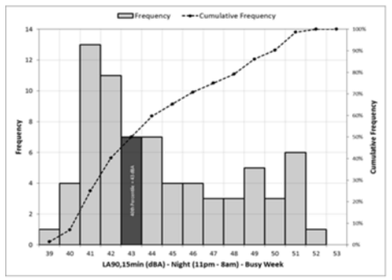


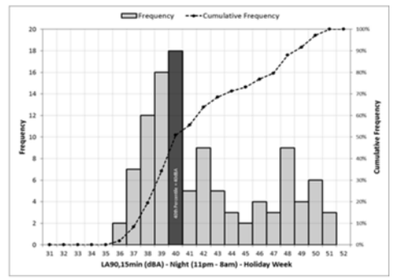


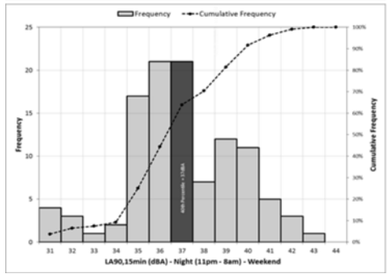












11.0 APPENDIX B – GLOSSARY OF ACOUSTIC TERMS

Sound Pressure Level, SPL or L_P (decibels, dB)

A measure of the instantaneous sound pressure at a point in space. The threshold of hearing occurs at approximately SPL=0 dB (which corresponds to a reference sound pressure of 20μPa).

LP(dB)=20.log10(Measured RMS Sound Pressure (Pa)/20μPa)

where RMS Sound Pressure is the Root-mean-square of the sound pressure at a point, relative to mean atmospheric pressure, over a time period defined by the sound level meter used.

A-Weighted Sound Pressure Level, L_A (dBA)

SPL values are weighted in a way that approximates the frequency response of the human ear and allows sound levels to be expressed as a single figure value.

Equivalent Continuous A-Weighted SPL, $L_{Aeq,T}$ (dBA)

Energy average of the A-weighted sound pressure level over a time period, T. The level of a notional continuous sound that would deliver the same A-weighted sound energy as the actual fluctuating sound over the course of the defined time period, T

Background Noise Level A-Weighted $L_{A90,T}$ (dBA)

A-weighted sound pressure level that is exceeded 90% of the time.

Maximum A-Weighted SPL, L_{AFMax} (dBA)

Maximum A-weighted sound pressure level measured with fast time weighting

Frequency, f (Hertz, Hz)

The rate of vibration of air molecules which transmit the sound measured in cycles per second or Hertz. The human ear is generally sensitive to sound in the range 20Hz – 20kHz.

smithandwallwork engineers

Cambridge University – New Civil Engineering Building at West Cambridge

Ground vibration planning statement

Simon Smith 7th October 2016 (rev 1)

Introduction

This brief report describes the vibration surveys carried out as part of the plans for the relocation of the main structures lab from Trumpington Street to the new Civil Engineering Building proposed at West Cambridge. It also describes vibration isolation measures proposed in the new building.

The report concludes with a review and assessment of the likely vibration dose values achieved at the site boundary in accordance with BS 6472-1:2008 *'Guide to evaluation of human exposure to vibration in buildings. Vibration sources other than blasting'*.

BS 6472 provides guidance on predicting human response to vibration in buildings over the frequency range 0.5 Hz to 80 Hz. Frequency weighting curves for human beings exposed to whole-body vibration are included, together with advice on measurement methods to be employed. Methods of assessing continuous, intermittent and impulsive vibration are presented.

BS 6472 describes how to determine the vibration dose value, VDV, from frequency-weighted vibration measurements. The vibration dose value is used to estimate the probability of adverse comment which might be expected from human beings experiencing vibration in buildings. Consideration is given to the time of day and use made of occupied space in buildings, whether residential, office or workshop.

It should be noted that the primary driver for in depth vibration surveys carried out to date has been to assess the impact of potential activities in the main structures lab on nearby lab equipment in the Graphene Centre, Nanoscience and indeed within the new Civil Engineering Building.

Surveys

Two vibration surveys have been carried out to date:

- At the existing structures lab facilities at Trumpington Street (to determine the level of likely vibration generating activities).
- At the proposed site to establish background levels of site vibration and to carry impact tests to mimic the likely levels of ground vibration (from the operation of the new structures lab).

New Civil Engineering Building

The new Civil Engineering Building will incorporate the main structures lab. The main strong floor and concrete lab are both designed to incorporate vibration isolation measures which will reduce

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the transmission of vibration within the new building as well to adjacent soil and hence building properties.

Assessment of Survey Results

The results of the surveys show that there is little to no impact on the sensitive lab equipment in the Graphene Centre and Nanoscience under daily activities that are envisaged within the new Civil Engineering Building.

When assessing the results of the surveys in relation to the residential properties (human exposure) in Clerk Maxwell Road (for which the survey was not originally intended) it is possible to use BS 6472-1:2008 to provide an assessment of ground vibration from the new Civil Engineering Building.

From the site vibration survey it can be seen that at the boundary to Clerk Maxwell Road we achieve VC-D which is equivalent to a velocity of 6.25×10^{-6} m/s (rms at one-third octave for frequencies 1-100Hz).

Referencing annex C4 of BS 6472 it can be seen that the vibration dose value can be derived using rms acceleration:

$$\mathrm{eVDV} = 1.4 \times a(t)_{\mathrm{r.m.s.}} \times t^{0.25}$$

From the survey results it can be seen that the dominant frequency is in the 20Hz range and as such the VC-D criteria relates to an acceleration of $0.0008 ms^{-2}$.

The weighting value that is applied to this rms acceleration varies according to the number of occurrences and duration of each vibration event. As we are dealing with envisaged activities and not actual insitu site measurements it would be prudent to assume a high magnitude of weighting and apply it to estimate a vibration dose value. In this instance a weighting value of 10 (ie 10 occurrences each 6 minute duration) will be taken which gives a vibration dose value of $0.008 ms^{-1.75}$.

As can be seen from table 1 of BS 6472 (extract below) this is within acceptable limits for both day and night activites.

Table 1 **Vibration dose value ranges which might result in various probabilities of adverse comment within residential buildings**

Place and time	Low probability of adverse comment $m \cdot s^{-1.75}$ 1)	Adverse comment possible $m \cdot s^{-1.75}$	Adverse comment probable $m \cdot s^{-1.75}$ 2)
Residential buildings 16 h day	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Residential buildings 8 h night	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8

Extract BS 6472-1:2008

CAMBRIDGE UNIVERSITY ENGINEERING DEPARTMENT

Vibration Transmission Survey

30 August 2016

Delivered by email to: Simon Smith, Smith & Wallwork Engineers

Sound Space Vision is the trading name for Sound Space Design Limited.

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2 EXECUTIVE SUMMARY

2.1 This report has been prepared under instruction from Smith & Wallwork Engineers, and is intended to form part of a strategy for planning the phase 1 building (Civil Engineering building) of Cambridge University Engineering Department's long term plans to relocate to the West Cambridge Site. The Civil Engineering Building will house the structures lab including the strong floor as well as other research activities.

2.2 The proposed site of the Civil Engineering Building lies close to the existing Electrical Engineering Division Building, which houses the Cambridge Graphene Centre, as well as the Nanoscience Centre. Both the Graphene Centre and the Nanoscience Centre employ test and manufacturing equipment and processes that are sensitive to disturbance from vibration.

2.3 The current structures lab is located within the Department of Engineering Building on Trumpington Street, Cambridge. A number of activities and equipment are in use that, when relocated to the new site, generate vibration levels that will propagate to the neighbouring Cambridge Graphene Centre and/or the Nanoscience Centre.

2.4 Vibration levels were measured in the current lab in February 2016 and documented in a Part 1 report [2] (Source Vibration Levels of Structures Lab Activities dated 9 March 2016) to provide source vibration level input for the design of the new Civil Engineering Building. Acceleration levels and frequency content were measured close to the machines used in the structures lab to characterize the vibration sources:

- whether the vibration levels generated will impact on the new building design (in terms of building occupants).
- whether the vibration levels generated will impact on the new building design (in terms of vibration sensitive equipment in the new Civil Engineering Building).
- the typical vibration generated by the machines and transmitted into the strong floor of the structures lab.
- the pattern of use of the machines and the worst case scenarios during normal use of the lab.

2.5 This Part 2 of the survey presents background level vibration survey results and documents the transmission of ground-borne vibration caused by known impact on the ground in the location of the new structures lab. The source was designed to approximate the impact of typical activities in the structures lab. The results are presented in two ways:

- transmission loss as a function of distance -- to enable calculation of transmission from different sources at different distances;
- direct measurement of vibration levels in the existing Graphene and Nanoscience Centres.

2.6 The background vibration levels measured in the Graphene Centre and Nanoscience Centre are lower than the minimum requirements. The results were obtained by averaging in time the vibration levels for the duration of the measurements.

2.7 The vibration level for the impacts peaked near the source in the 31.5 Hz frequency band, and this carries through transmission as the maximum frequency.

2.8 The vibration level decreases with distance from 5 dB/m at 5Hz to 8 dB/m 80Hz

2.9 Vibration received in the Graphene Centre in EBL and Electronics Lab was below the VC-E criteria for 98, 196, 392 Joule impact and below VC-D for 1,568 Joule impact.

2.10 Vibration received in the Graphene Centre in SEM room was above the VC-E criteria for 98, 196 Joule impact and above VC-D for 392 and 1,568 Joule impact.

2.11 Vibration received in the Nanoscience Centre TEM room (Module 1) was below the VC-C criteria for 784 and 1,568 Joule impact. Vibration levels for lower impact energy could not be measured since the impulsive signal was below the background levels.

2.12 Vibration received in the Nanoscience Centre SEM room was below the VC-C criteria for 784 Joule impact and above VC-C criteria for 1,568 Joule impact. Vibration levels for lower impact energy could not be measured since the impulsive signal was below the background levels.

2.13 Vibration received in the Nanoscience Centre EBL room was below the VC-C criteria for 784 and 1,568 Joule impact. Vibration levels for lower impact energy could not be measured since the impulsive signal was below the background levels.

2.14 The highest vibration velocity of 18.5 um/s , over 3.12 um/s (VC-E), was received in the Graphene Centre room housing the Scanning Electron Microscope (SEM) for the highest impact energy of 1,568 Joule. However, this did not disturb the use of the SEM, which is mounted on an isolation table.

2.15 The highest velocity of 12.3 um/s measured on the floor of the Nanoscience Centre TEM Module 1 room was attenuated by the isolation joint in the slab surrounding the sensitive equipment. A similar machine is already installed in the room next to the measured one and lies on a similar isolation system. The machine was running during tests and it did not experience any disturbance. It is believed that the internal isolation system of the machine is robust enough to attenuate such vibration levels.

2.16 This survey report is concerned with the operation of the new Civil Engineering Building and does not extend in scope cover the construction of the new building and the vibration likely to be generated during the build process.

3 REFERENCE DOCUMENTS

1. H. Amick, M. Gendreau, T. Busch, and C. Gordon, “Evolving criteria for research facilities: vibration,” *Proceedings of SPIE Conference 5933: Buildings for Nanoscale Research and Beyond*, San Diego, CA, 31 Jul 2005 to 1 Aug 2005
2. Sound Space Vision, “Source Vibration Levels of Structures Lab Activities*”, Part 1 Report,* 9 Mar 2016
3. Trethewey, Martin W. "Structural impact testing force spectra." *Proceedings of SPIE, the International Society for Optical Engineering. Vol. 3089. Society of Photo-Optical Instrumentation Engineers,* 1997.

4 INTRODUCTION

4.1 This report has been prepared under instruction from Smith & Wallwork Engineers, and is intended to form part of a strategy for planning the phase 1 building (Civil Engineering Building) of Cambridge University Engineering Department’s long term plans to relocate to the West Cambridge site. The Civil Engineering Building will house the structures lab including the strong floor as well as other activities.

4.2 In a previous report (Part 1) [2] measurements of vibration velocity were made on the floor of the existing structures lab at Trumpington Street for use as input into a transmission model.

4.3 In this survey (Part 2) impulse response measurements were made to survey the vibration transmission characteristics of the ground on the proposed site of the new Civil Engineering Building and to inform predictions of the impact of the new building on sensitive equipment and activities in the Graphene Centre (Electrical Engineering Division Building) and the Nanoscience Centre.

4.4 The sensitive equipment includes Scanning Electron Microscope (SEM), Tunnelling Electron Microscope (TEM) and Electron-beam Lithography system (EBL). The high precision of these machines requires very low ambient vibration, defined in terms of a group of vibration criteria VC-A to VC-E. These are not concerned with human response to vibration but with machine tolerance. The specifications for these machines range from VC-C to VC-E (Figure 4.1).

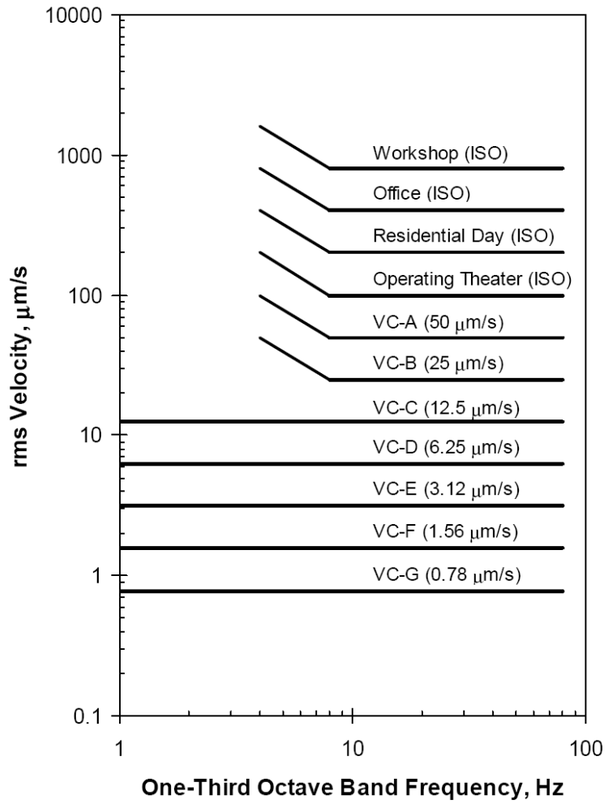


Figure 4.1 – Generic vibration criterion (VC) curves for vibration-sensitive equipment.

4.5 The VC criteria are defined in terms of RMS vibration velocity. As such, they are most relevant and most often used in relation to continuous signals, not short impulses. Our test signal is an impulse, typically about 0.5 seconds in duration. RMS velocity is calculated in 1/3 octave bands from a 2-second window of acceleration signal and compared to the VC criteria.

4.6 This report includes the methodology and results of the measurements, but not all the details of the signal processing.

5 BACKGROUND VIBRATION

5.1 The site was visited on 20/08/2016 by Fabrizio D'Amelio to measure background floor vibration in the Graphene Centre and the Nanoscience Centre.

5.2 Tests were made using a Dytran 3191A1 single axis accelerometer and Benstone Impaq Elite signal analyser. The combination had an analogue bandwidth from 1 to 500 Hz.

5.3 Unless stated otherwise, the accelerometer was mounted on a bespoke 3-point support plate, with the axis oriented vertically. The measurements were taken in one position close to the

mountings of the machines (approx. 20 cm) and the same positions were subsequently used for later impact tests.

5.4 Sample rate 1000 Hz. Integration from acceleration to velocity spectrum was stored each 1.6s, with frequency resolution 0.625 Hz.

5.5 30 minutes continuous samples were recorded in the Graphene Centre for EBL and SEM machines, giving 2184 short time FFT spectra each. The sensor was placed near the mountings of the machines on the concrete plinth that will support the EBL machine and on the finishes of the SEM floor. The concrete plinth is cast monolithic with the main building raft foundation.

5.6 Continuous samples 20 minutes long were recorded in the Nanoscience Centre for three different machines, namely, EBL (Bay 1), TEM (module 1). Measurements were made both on the isolation block that circumscribes the machines and outside the isolation block, giving 1456 short time FFT spectra each. A 10 minutes measurement, 728 short time FFT spectra, was conducted instead at the SEM machine both on the isolated block and on the main non isolated floor. In all cases, the accelerometers were placed on the floor finishes.

5.7 RMS velocity at each 1/3 octave band was averaged over the duration of the measurement.

5.8 The results obtained are plotted against VC-E curve which is the maximum allowed vibration level of the structure containing the machines under analysis [1]. The Electronics Lab has a VC-C requirement. To the best of our knowledge, VC-E threshold is applied to the machines measured in the Nanoscience Centre.

5.9 Figure 5.1 shows the positions of the sensors in the Graphene Centre, while, Figure 5.2 shows the position of the sensors in the Nanoscience Centre.

5.10 Figure 5.3 to 5.6 show the background levels measured in the Graphene and Nanoscience centres.

5.11 Figure 5.7 to 5.10 show additional short term (60s Graphene Centre, 16s Nanoscience Centre) background measurements made on 26/07/2016, the same day of impact tests. These measurements show very similar results at the Graphene Centre but slightly differ at the Nanoscience Centre. In the latter case, a higher background noise was experienced on the drop test day. The numerous machines and building services in the building might have affected the short term measurement.

5.12 Figure 5.11 to 5.13 show the time trace of the background noise in both the Graphene Centre and the Nanoscience Centre. The module in frequency of velocity is shown in time and no particular patterns can be detected during the time of measurements.

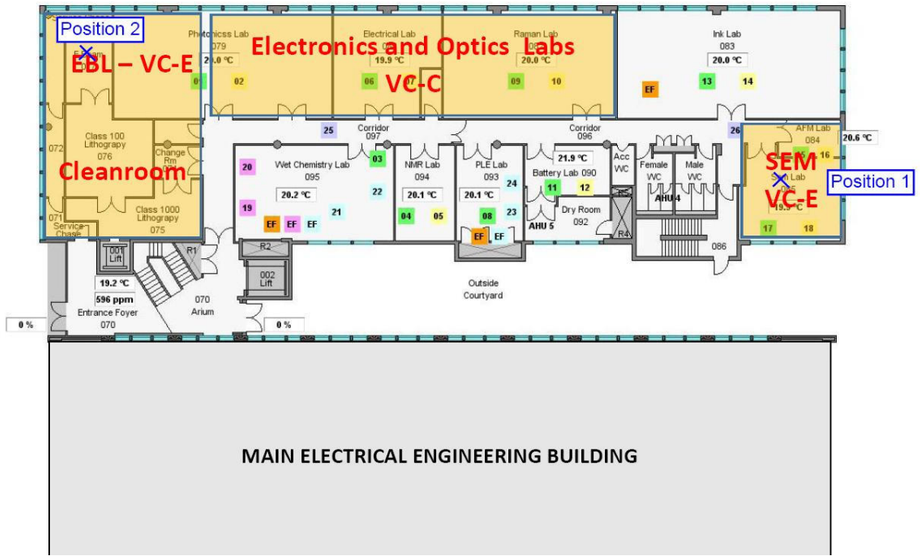


Figure 5.1 – Mark-up of measurement positions in Graphene Centre plan.

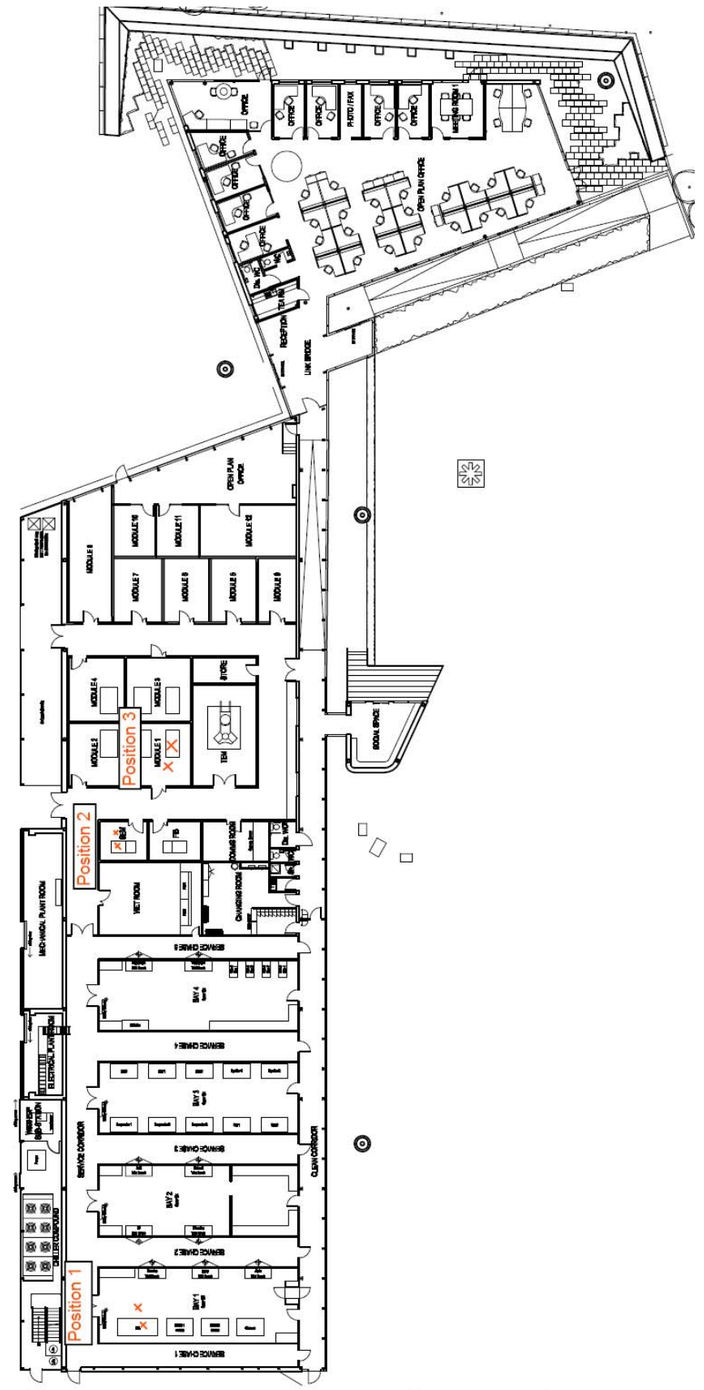


Figure 5.2 – Mark-up of measurement positions in Nanoscience Centre plan.

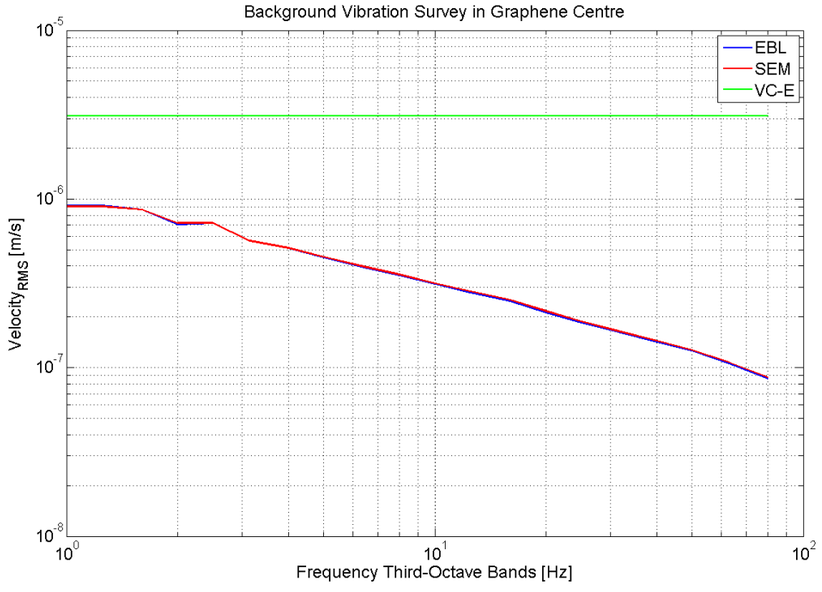


Figure 5.3 – Long term background vibration levels measured in the Graphene Centre.

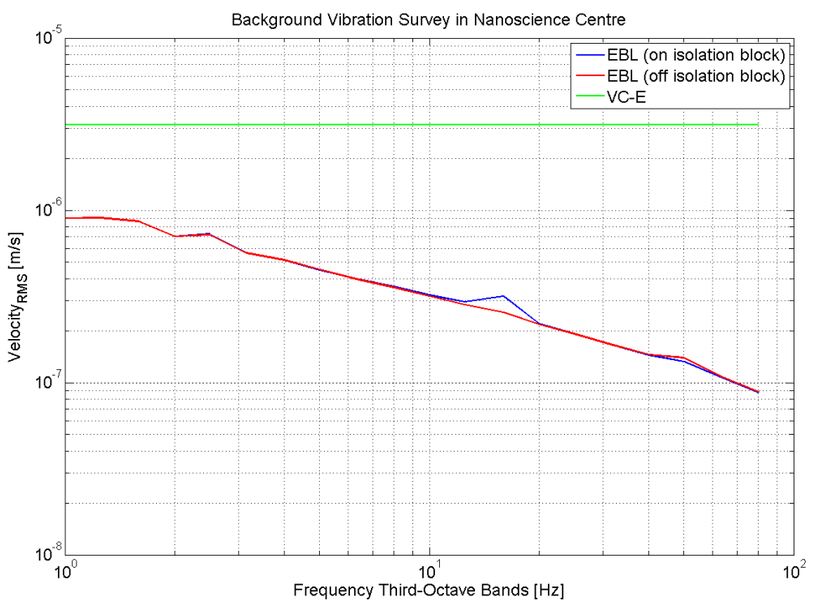


Figure 5.4 – Long term background vibration levels measured at EBL in the Nanoscience Centre.

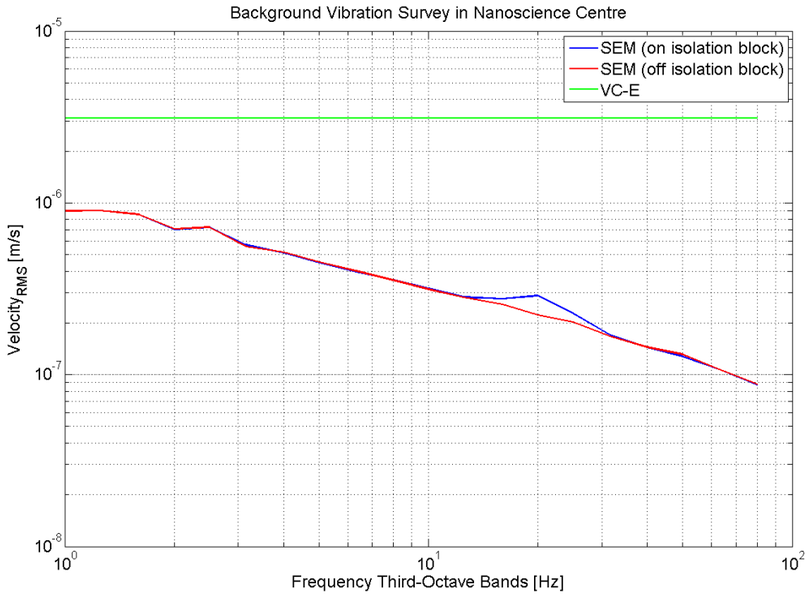


Figure 5.5 – Long term background vibration levels measured at SEM in the Nanoscience Centre.

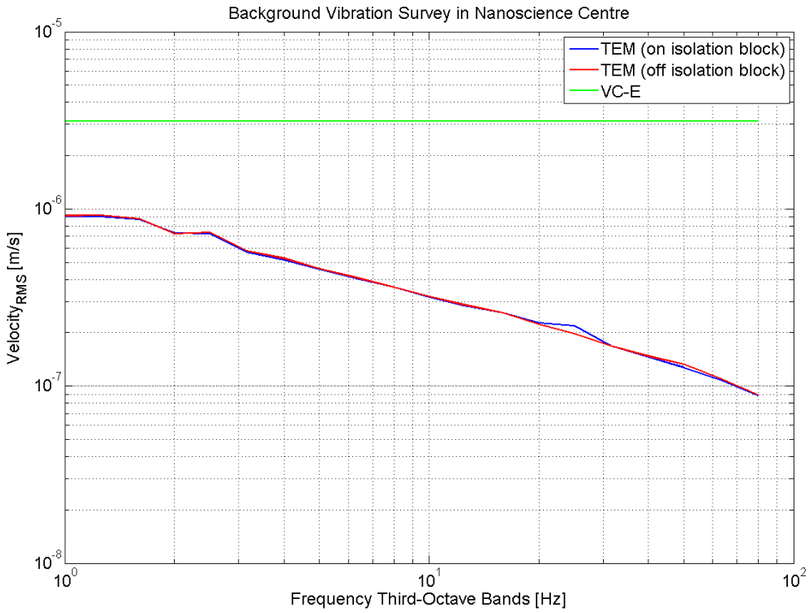


Figure 5.6 – Long term background vibration levels measured at TEM (Module 1) in the Nanoscience Centre

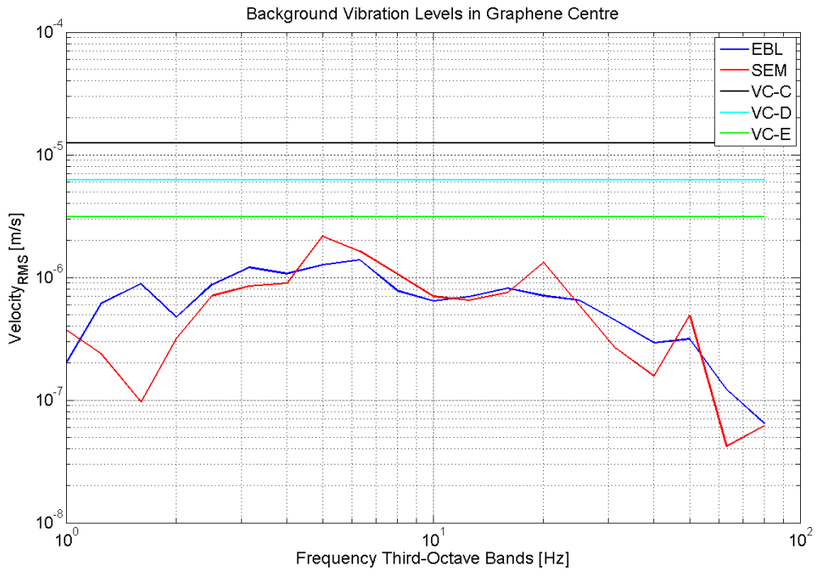


Figure 5.7 – Short term background vibration levels measured in the Graphene Centre.

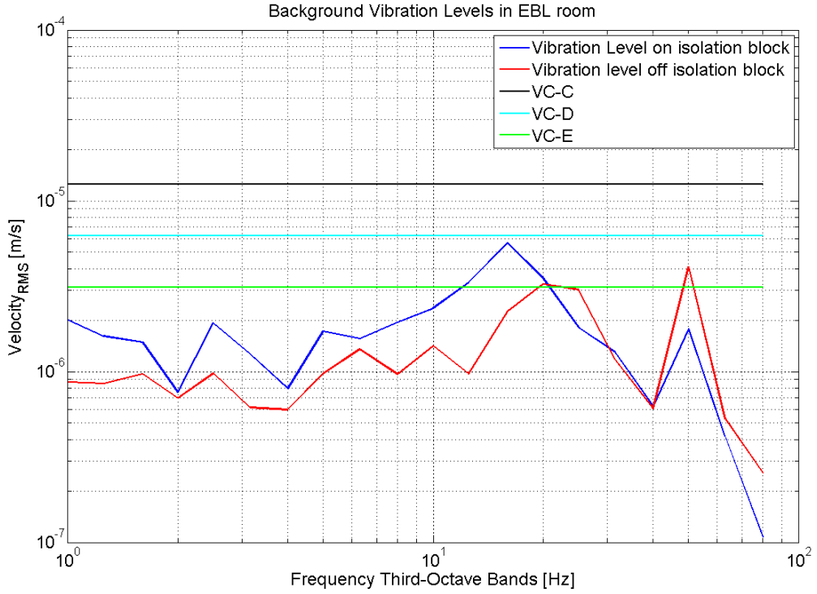


Figure 5.8 – Short term background vibration levels measured at EBL machine in the Nanoscience Centre. More isolation takes effect above 30Hz.

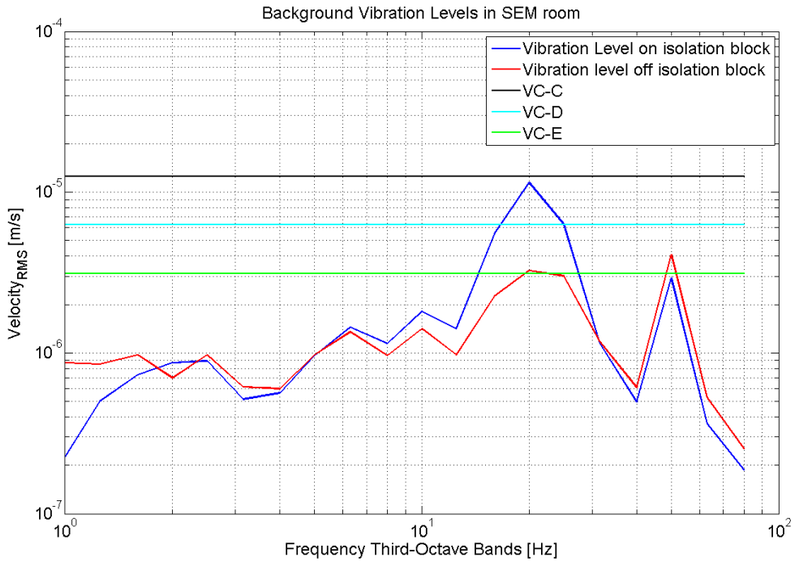


Figure 5.9 – Short term background vibration levels measured at SEM machine in the Nanoscience Centre. More isolation takes effect above 30Hz.

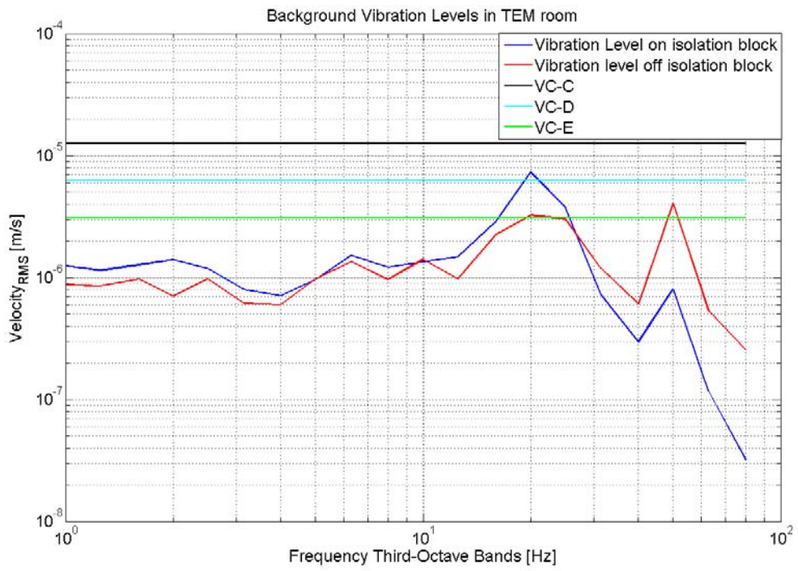


Figure 5.10 – Short term background vibration levels measured at TEM machine in the Nanoscience Centre. More isolation takes effect above 30Hz.

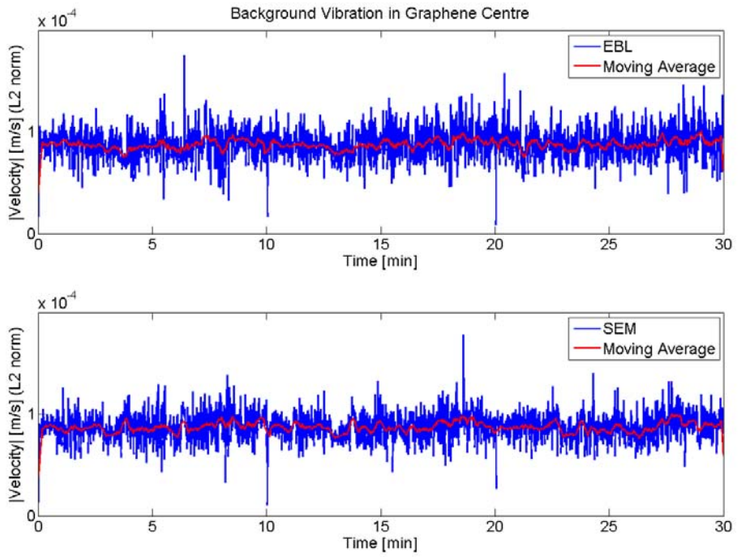


Figure 5.11 – Time trace of background velocity frequency module in the Graphene Centre. It is calculated as the square root of the velocity energy of each FFT spectrum. The red line is a 10 points moving average with each point representing a time window (Hanning) of 1.6s with 50% overlap.

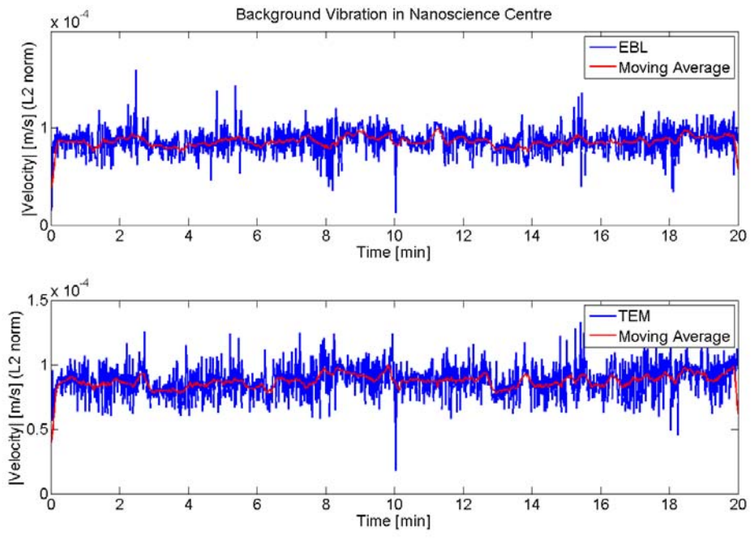


Figure 5.12 - Time trace of background velocity frequency module at EBL and TEM (module 1) in the Nanoscience Centre. It is calculated as the square root of the velocity energy of each FFT spectrum. The red line is a 10 points moving average with each point representing a time window (Hanning) of 1.6s with 50% overlap.

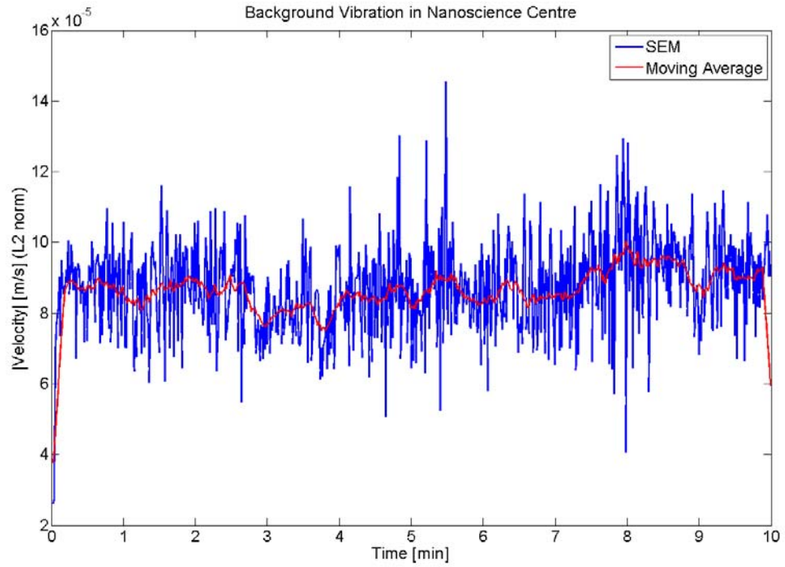


Figure 5.13 – Time trace of background velocity frequency module at SEM in the Nanoscience Centre. It is calculated as the square root of the velocity energy of each FFT spectrum. The red line is a 10 points moving average with each point representing a time window (Hanning) of 1.6s with 50% overlap.

6 THE IMPACT SOURCE

6.1 An impact source was developed to approximate the energy impulse on the ground of the activities in the future structures lab at West Cambridge. An impulsive source provides signal over a wide frequency range [3], from which transmission of ground-borne vibration can be predicted for other sources with specific frequency characteristics.

6.2 The site for the impact source test was located on the existing car park to the rear of the Graphene Centre approximately 30m from the face of the Graphene Centre. The location was chosen to represent the proposed location of the structures lab in the new building. The presence of buried surface water attenuation tanks (single size aggregate engineered fill) meant that the impact source location was located at the southern extreme of the proposed structures lab.

6.3 In Figure 6.2 the position of the impact source equipment is marked on aerial photo.

6.4 A concrete block 1m x 1m x 1m was cast on the ground to approximate coupling of activity into the ground . A 1m deep pit was excavated and the block cast onto the clay base layer, with no soil contact to the side of the block.

6.5 A 200kg cylindrical steel weight was lifted with a drilling rig and dropped onto the concrete block from different heights ranging from 50mm to 800mm. The diesel motor of the lifting rig was shut down during the drop to avoid imparting vibration.

6.6 In order to bias the vibration spectrum toward low frequencies and to protect the concrete against significant deterioration over multiple drops, neoprene mats of varying thicknesses 6mm to 24mm were placed on top of the slab.

6.7 Preliminary trials with mat thicknesses of 6, 12, 18, 24mm over the different drop heights indicated that the 24mm mat would create sufficient energy up to 80 Hz, the limit of the defined VC criteria. Data are presented here for the source with 24mm pad. Some additional measurements were made with thinner pads and no pads.

6.8 The impulse source energy at the top of the block is calculated from the potential energy PE = m g h. The energy imparted by the block into the ground is modified by the slab-ground interface.

Mass (kg)	200
Drop Height (mm)	Energy (Joules)
50	98
100	196
200	392
400	784
800	1,568

Table 6.1 – Potential Energy values for different drop tests.

6.9 The 98 Joule impact source is expected to represent a daily activity within the structures lab, for example gantry crane operation which levels have been measured in [2]. The two processes can be compared in terms of frequency content of the excitation produced or in terms of impact energy.

6.10 For the Gantry Crane movement, a maximum value of about 30 um/s is found in the range 4 - 5 Hz. A similar spectrum value is produced by the Glulam Split and Beam Casting Shaker (no load) but only in the low frequency range 3-7 Hz for the 98 and 196 Joule drop. Higher velocity values are found in the other frequencies of the field drop tests.

6.11 In terms of impact energy the 98 Joule drop represents a forklift driving over the construction joint. A 1000kg load was taken as example and 1cm height of drops.

6.12 The 1,568 Joule impact source is expected to represent the worst case scenario when the full loaded crane accidentally drops a 2000kg weight from a 100mm height. A similar energy can be produced by dropping a 200kg weight from 800mm.

6.13 The remaining cases were calculated to have a drop progression and address possible minor rare events.



Figure 6.1 – Impact test equipment.

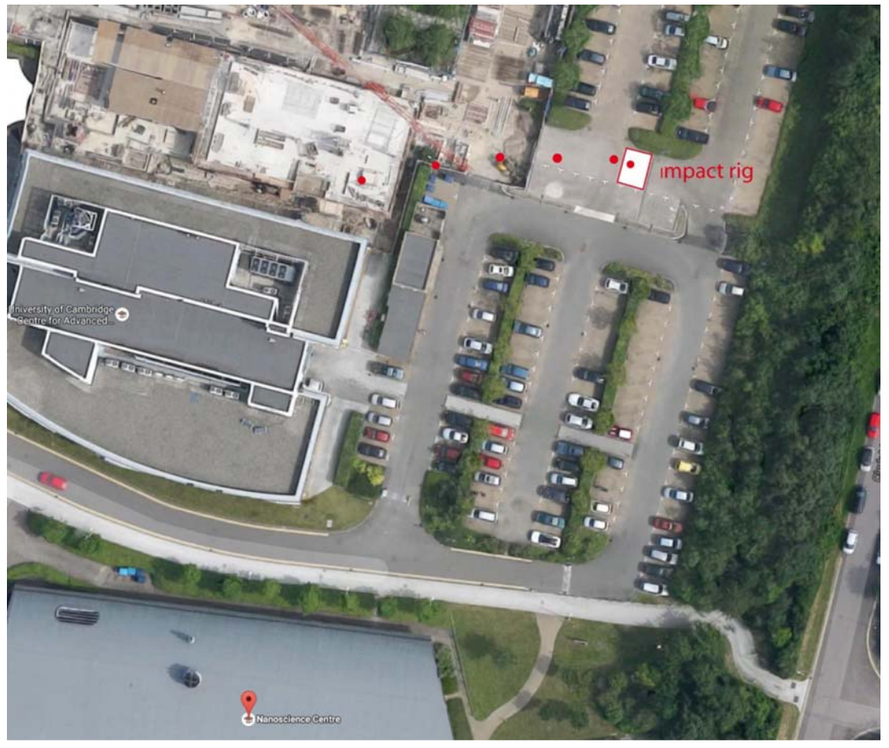


Figure 6.2 – Impact test equipment mark-up of aerial photo.

7 IMPULSE MEASUREMENTS

7.1 The site was visited on 25/08/2016 and 26/08/2016 by Bob Essert and Fabrizio D'Amelio. Dr. James Talbot (Cambridge University Engineering Department) was on site with his measurement kit. In collaboration with Dr. James Talbot, measurements were made of impulses propagating through the ground to the adjacent buildings.

7.2 The site for the impact tests equipment was in the existing car park to the rear of the Graphene Centre. Traffic was kept away from the immediate area during the measurements, and in any case was very light. No measurement was made when there was vehicle movement visible within the immediate vicinity.

7.3 The weather was fine, temperature 20-25C.

7.4 The impulses have been generated with the system described in section 6. As can be seen in Table 7.5 to Table 7.7 , different drop heights were chosen for different tests to reproduce typical activities and extraordinary events in the proposed new site of the structures lab.

7.5 Unless stated otherwise, results are reported for drops using the 24mm neoprene mat. No double hits of the steel bar were evident, validating the choice of using neoprene mats to dampen the impact on the concrete block.

7.6 Three different measurement sessions were conducted throughout the two days. Tests and measurements to estimate the behaviour of vibration propagation in the ground were conducted on 25/08/2016. The same day, measurements at EBL, SEM, Electronics Lab in the Graphene Centre were made. On 26/08/2016, the measurement kit was installed at the Nanoscience Centre.

7.7 Vibration propagation tests were made using 5 number Dytran 3191A1 high sensitivity single axis accelerometers and 1 single axis low-sensitivity accelerometer. The low sensitivity accelerometer was positioned on the concrete block to capture the acceleration at the source. Sensitivity of accelerometers is showed in Table 7.2. Dytran accelerometers A1, A2, A3, A4 were set on bespoke 3-point mounting plates on the tarmac ground at various distances from the source. Distances of the sensors from the source are showed in Table 7.1.

7.8 Measurements at the Graphene Centre were made using 3 Dytran 3191A1 single axis accelerometer set on their 3-point mounting plates on the floor next to the mountings of the sensitive equipment. Positions of sensors in the building are showed in Figure 7.1 and Table 7.3.

7.9 Measurements at the Nanoscience Centre were made using 4 Dytran 3191A1 single axis accelerometers set on their 3-point mounting plates on the floor. The structural isolation systems used in the Nanoscience Centre differ from the ones used in the Graphene Centre, and consists of a concrete block isolated from the main concrete slab of the building. Therefore, it was possible to measure the vibration levels on and off the isolation block to estimate the level of isolation achieved by the system. The positions of sensors in the building are showed in Figure 7.2 and in Table 7.4.

7.10 A National Instruments cDAQ model 9184 and laptop computer were used to acquire signals from the 6 accelerometers.

7.11 Sampling frequency was set to 2048 Hz, giving a max measurable signal frequency of 1024 Hz.

7.12 Duration of the measured impulse was between 0.5 to 1s depending on distance. A time window of 2s was used to extract the impulsive signal from each channel of the recording.

7.13 Unless stated otherwise, frequency analysis has been done in third-octave bands from 1 to 80 Hz, in line with the threshold specifications given in [1].

7.14 RMS velocity at each 1/3 octave band was calculated over the 2-second duration of the measurement.

7.15 A complete list of drop tests and measurements is showed in Table 7.5 to 7.7 for each measurement session.

Sensor	Distance from source [m]
A1	2
A2	10
A3	18
A4	32
A5	SEM Lab
Source	On concrete block

Table 7.1 – Positions of accelerometers from impact source.

Model:	Dytran	3191A1
Serial Number	Sensitivity	Unit
A1	10082	mV/g
A2	9958.9	mV/g
A3	9919.8	mV/g
A4	9859.7	mV/g
A5	10119	mV/g
Source	100.8	mV/g

Table 7.2 – Sensitivity of accelerometers

Sensor	Room
A1	EBL
A2	Electronics Lab
A5	SEM

Table 7.3 – Position of accelerometers in the Graphene Centre.

Sensor	Room
A1	SEM (on isolation block)
A2	SEM (outside isolation block)
A3	TEM - Module 1 (on isolation block)
A4	EBL (on isolation block)

Table 7.4 – Positions of accelerometers in the Nanoscience Centre.

File	Drop Height [mm]	Neoprene pad thickness [mm]
UKCRIC4	50	24
UKCRIC5	50	24
UKCRIC6	50	24
UKCRIC7	100	24
UKCRIC8	100	24
UKCRIC9	100	24
UKCRIC10	200	24
UKCRIC11	200	24
UKCRIC12	200	24
UKCRIC13	200	24
UKCRIC14	200	24
UKCRIC15	200	24
UKCRIC16	800	24
UKCRIC17	800	24
UKCRIC18	800	24
UKCRIC19	50	6
UKCRIC20	50	0

Table 7.5 – Measurements of vibration propagation in the ground.

File	Drop Height [mm]	Neoprene pad thickness [mm]
UKCRIC21	50	0
UKCRIC22	50	0
UKCRIC23	50	6
UKCRIC24	50	24
UKCRIC25	100	24
UKCRIC26	200	24
UKCRIC27	400	24
UKCRIC28	800	24

Table 7.6 – Measurements of vibration levels in the Graphene Centre.

File	Drop Height [mm]	Neoprene pad thickness [mm]
UKCRIC29	0	0
UKCRIC30	50	0
UKCRIC31	50	6
UKCRIC32	50	24
UKCRIC33	100	24
UKCRIC34	200	24
UKCRIC35	400	24
UKCRIC36	800	24
UKCRIC37	50	0
UKCRIC38	100	0
UKCRIC39	200	0
UKCRIC40	400	0
UKCRIC41	800	0

Table 7.7 – Measurements of vibration levels in the Nanoscience Centre

Measurements taken with Dytran 3191A1 (A1, A2, A5, A8).
A1 - EBL (on plinth)
A2 - Electrical Lab (on faraday cage beneath finishes)
A5 - SEM

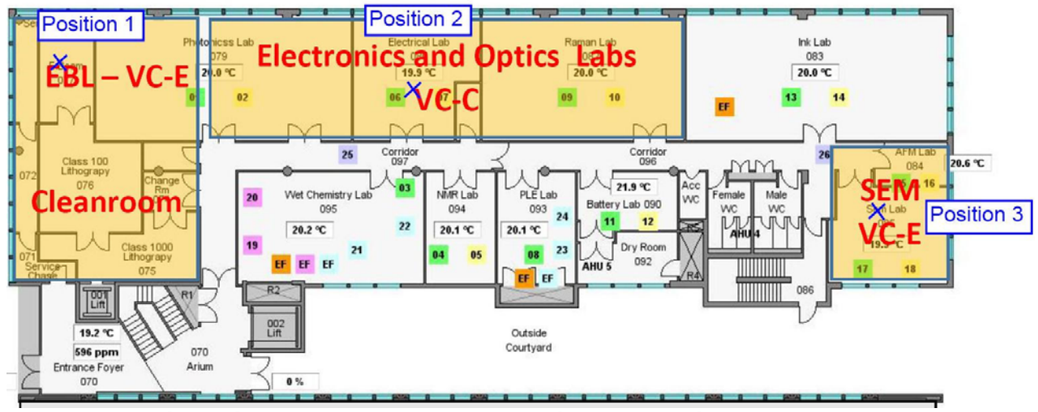


Figure 7.1 – Mark-up of measurement positions in Graphene Centre plan.

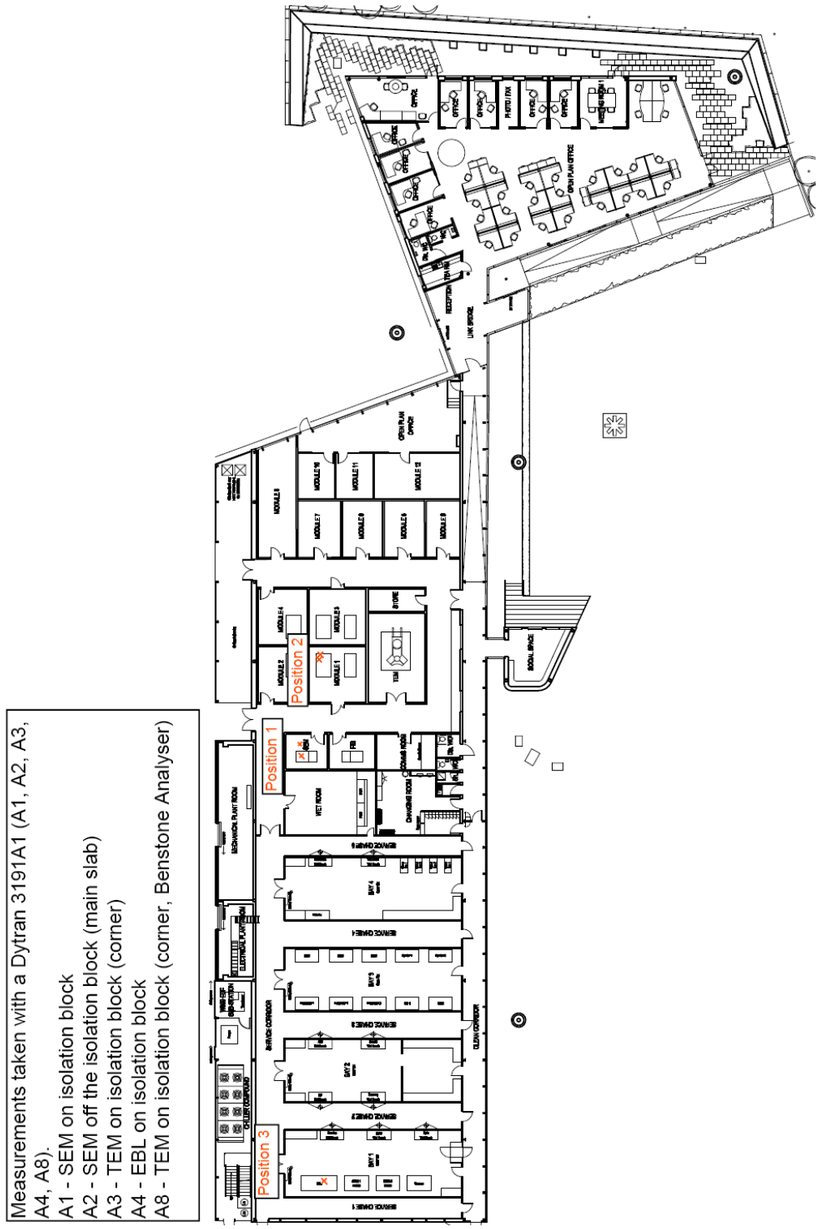


Figure 7.2 – Mark-up of measurement positions in the Nanoscience Centre plan.

8 OBSERVED DISTURBANCE AT MACHINE

8.1 An additional set of tests was carried out on 26/07/2016 in the Graphene Centre as well as in the Nanoscience Centre. The purpose of this set of drop tests was to test empirically if any disturbance could be noticed from the operator during normal use of the machines.

8.2 The machines used for these tests were the SEM in the Graphene Centre and the TEM in the Nanoscience Centre. The SEM machine in the Graphene Centre was operated by the lab manager Dr. Flavia Tomarchio.

8.3 In Table 8.1 and 8.2 tests parameters and notes of the results are presented.

Drop Height [mm]	Thickness of Neoprene pads [mm]	Observation at SEM	Comment
50	0	No detection	-
100	24	Minor detection	SEM operator stated that a minor disturbance was just visible but it was probably not correlated with the weight drop since happened seconds later the drop. The operator stated that the interference would not impact the operation of the machine.
200	24	No detection	-
400	24	No detection	-
800	24	Minor detection	A minor disturbance was just visible but it was probably not correlated with the weight drop since happened seconds later the drop. The operator stated that the interference would not affect the operation of the machine.

Table 8.1 – Drop tests with SEM machine in operation in the Graphene Centre.

Drop Height [mm]	Thickness of Neoprene pads [mm]	Observation at TEM	Comment
50	0	No interference	-
100	0	No interference	-
200	0	No interference	-
400	0	No interference	-
800	0	No interference	-

Table 8.2 – Drop tests with TEM machine in operation in the Nanoscience Centre.

9 RESULTS

9.1 The results of the measurements taken during the three sessions will be shown in this section starting from the vibration propagation measurements and then following with the Graphene Centre data and the Nanoscience Centre.

9.2 For each measurement three main parameters are considered, drop height and its relative impact energy, thickness of neoprene mats and distance from the impact source. In order to have a better view on the relationships between these parameters and the velocity values, plots over frequency and distance are presented in this section.

9.3 Figure 9.2 shows the spectrum of the impulsive vibration signal produced by dropping the 200kg steel bar on a concrete block from different heights with 24mm neoprene pad. RMS velocity over frequency in third-octave bands is shown. The distance of the accelerometer considered in this case is 10m from the impact source.

Attenuation with distance

9.4 Figure 9.3 shows the attenuation of vibration propagation in the ground. The accelerometers were placed as in Table 7.1. The results are plotted for the 50mm drop and 200mm drop to illustrate the propagation dependency on impact energy. There is little dependence on the initial energy.

9.5 Figure 9.4 characterizes the attenuation in frequency with respect to distance from the impact source.

9.6 Figure 9.5 shows the calculated transfer function of the soil on which the concrete block rests. The results are presented at different distances from the impact source. The propagation behaviour is dependent on distance and soil homogeneity. The frequency range showed is clipped at 250 Hz since the signal to noise ratio was deemed too low at higher frequencies.

Graphene Centre

9.7 The data obtained at the Graphene Centre are presented in three different figures, one for each machine. RMS velocity is plotted in third-octave frequency bands. VC criteria are also shown.

9.8 Figure 9.6 shows the levels obtained in the EBL room. The accelerometer was placed on the concrete plinth that will support the machine. The concrete plinth is cast monolithic with the main building raft foundation.

9.9 Figure 9.7 shows the vibration levels obtained in the Electronics Lab for different weight drops. The accelerometer was placed with floor finish cut outs and as such assumed to be placed on the concrete raft slab although this could not be confirmed on site (details of the floating "Faraday" floor were not clear).

9.10 Figure 9.8 shows the vibration levels obtained in the SEM room for different weight drops. The accelerometer was place on the floor finish which was a lino floor assumed to be bonded to a concrete screed finish. The relationship between floor finish and the underlying concrete raft foundation is not known.

Nanoscience Centre

9.11 Vibration levels have been similarly measured in the Nanoscience Centre. The measured rooms are EBL (Bay 1), SEM and Module 1 which will house a TEM machine. Only the 400mm and 800mm drop tests were measurable since the signal to noise ratio was deemed too low for lower impact energies.

9.12 Figure 9.9 shows the vibration levels obtained in the EBL room. The accelerometer was placed on the floor finish and on the isolation block.

9.13 Figure 9.10 shows the vibration levels obtained in the SEM room. The accelerometer was placed on the floor finish and on the isolation block.

9.14 Figure 9.11 shows the vibration levels obtained in the TEM room (Module 1). The accelerometer was placed on the floor finish and on the isolation block.

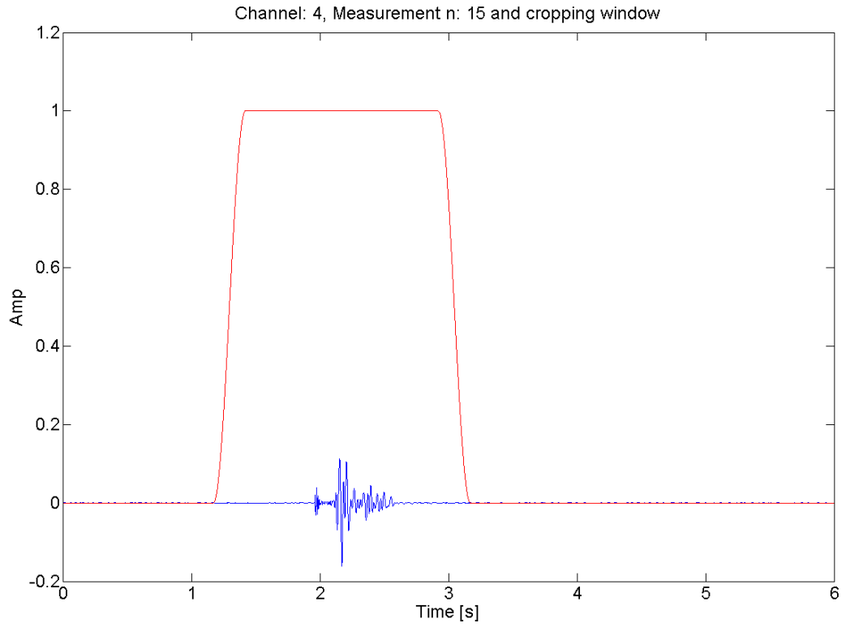


Figure 9.1 – An example of acceleration signal captured at one sensor (32m) cropped in time with a 2s Tukey (raised cosine) window around the impulse. Measurement number 15 is a 800mm drop test with 24mm thickness of neoprene pad.

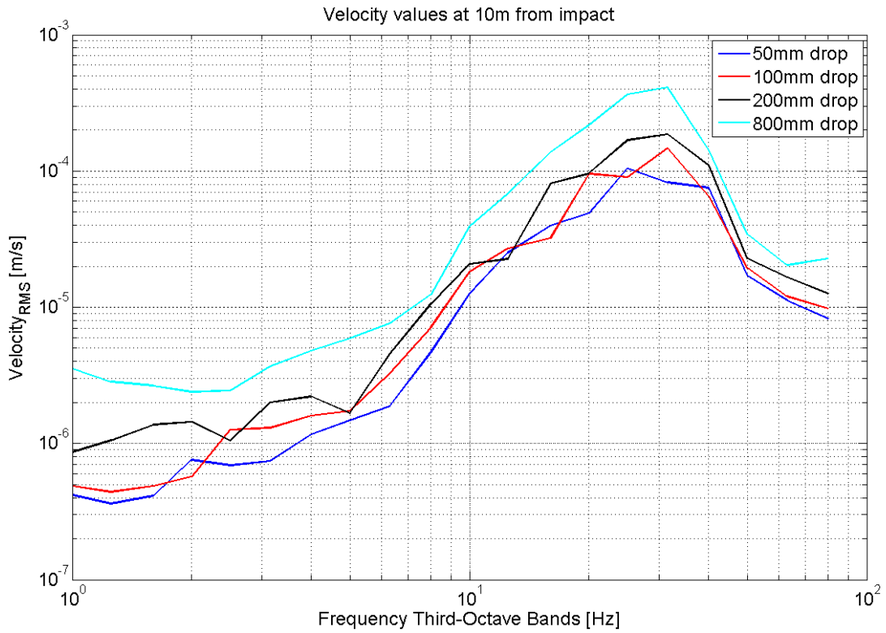


Figure 9.2 – RMS Velocity over frequency in third-octave bands measured at 10 m from the impact source. Different curves resulting from various drop heights are displayed over frequency. Neoprene thickness is 24 mm for all measurements.

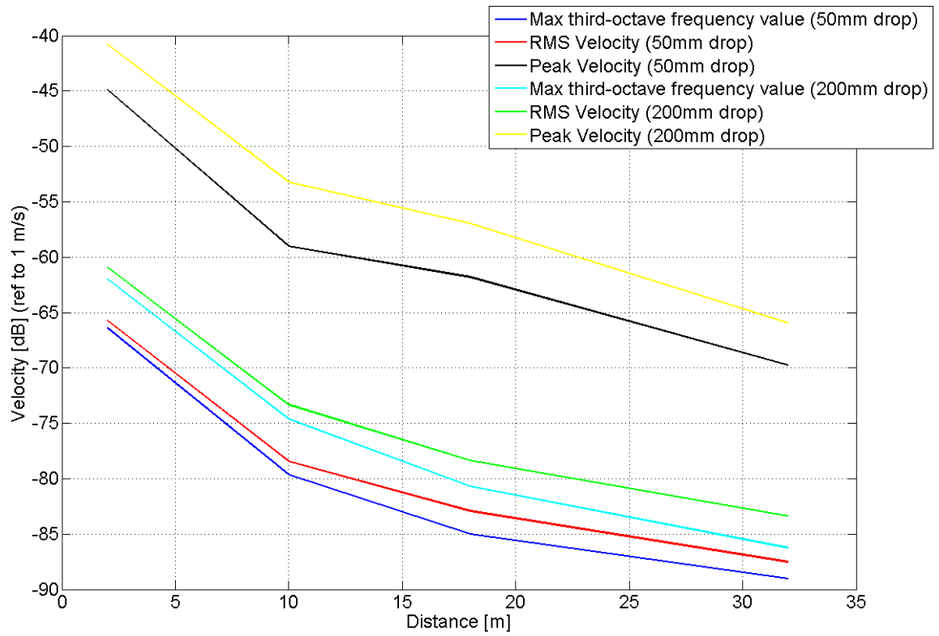


Figure 9.3 – Velocity in dB (ref to 1 m/s) over distance from impact source. The values are sampled at 2m, 10m, 18m, 32m. The curves showed are obtained by taking the max value of RMS velocity over the frequency range at each accelerometer, the peak value of the velocity signal in the time domain and the RMS velocity values in the time domain.

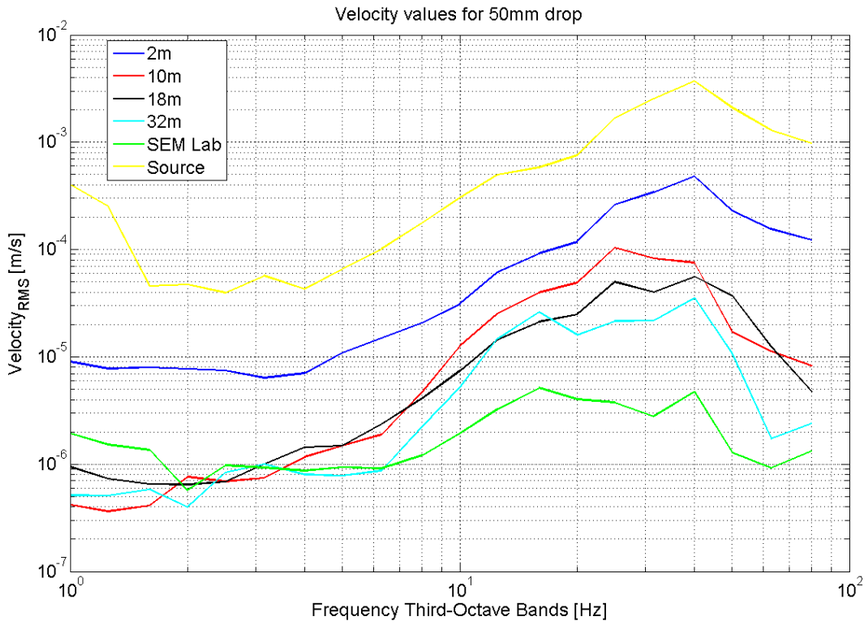


Figure 9.4 – RMS velocity in third-octave bands measured at several distances from the impact source.

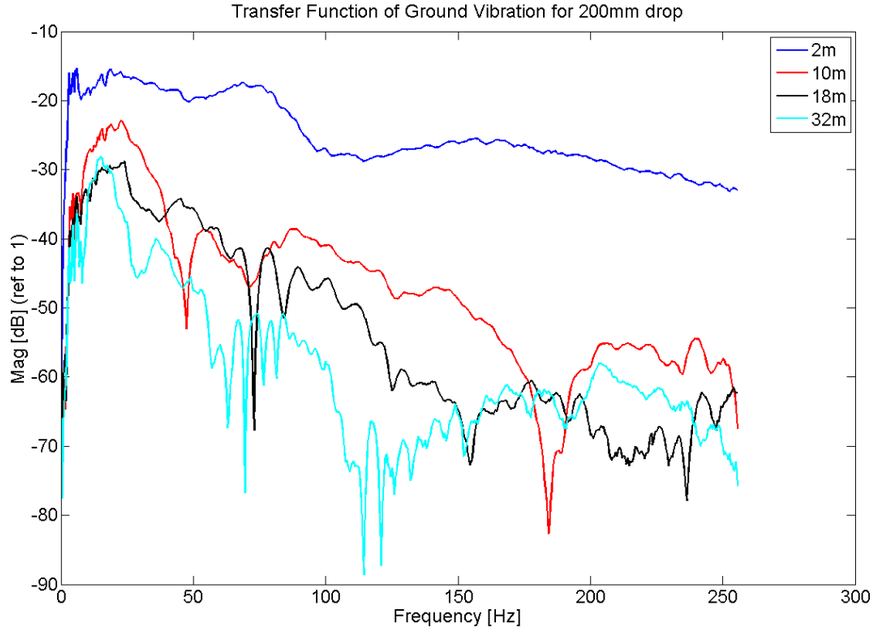


Figure 9.5 – Transfer function of soil at several distances from impact source calculated as $H_i(w) = Y_i(w)/X(w)$, where X(w) is the source signal (in frequency) measured on top of the concrete block and $Y_i(w)$ is the signal captured by one accelerometer placed at a certain distance from the source.

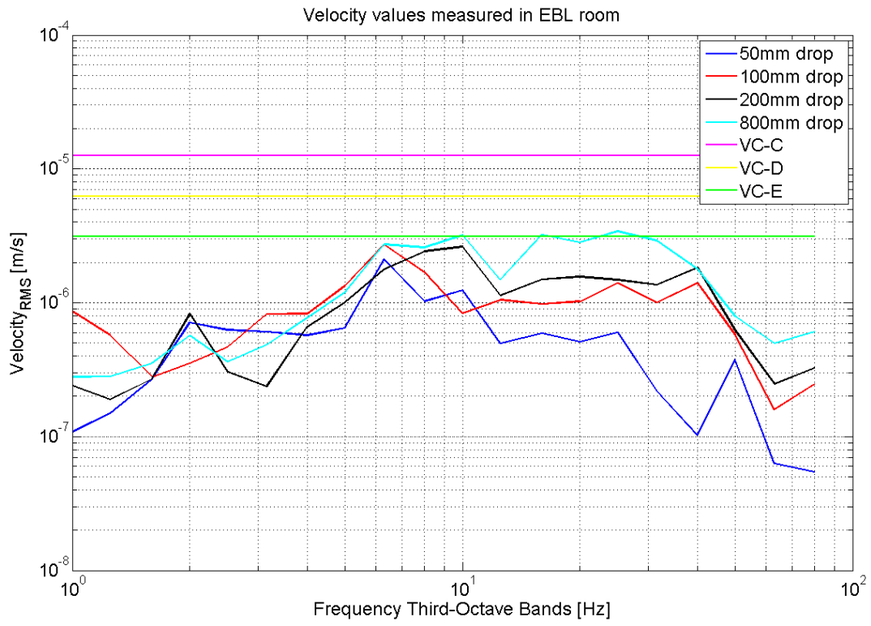


Figure 9.6 – Vibration levels measured on the plinth of the EBL room in the Graphene Centre.

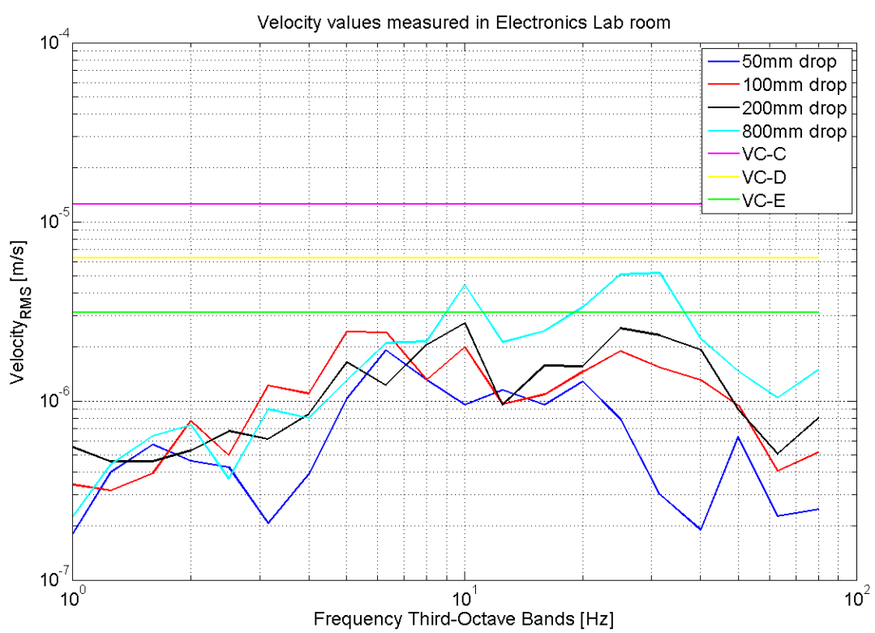


Figure 9.7 – Vibration levels measured in the Electronics Lab of the Graphene Centre.

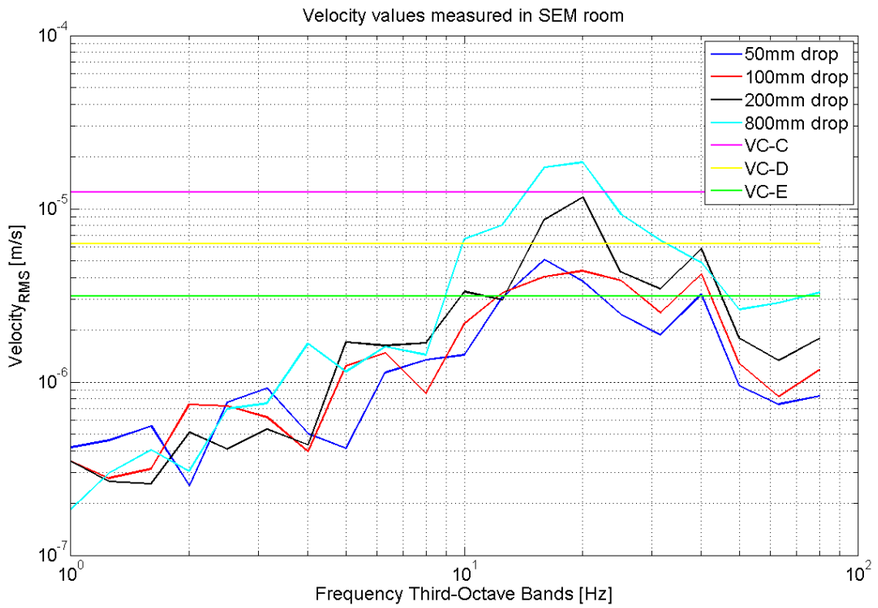


Figure 9.8 - Vibration levels measured in the SEM room of the Graphene Centre.

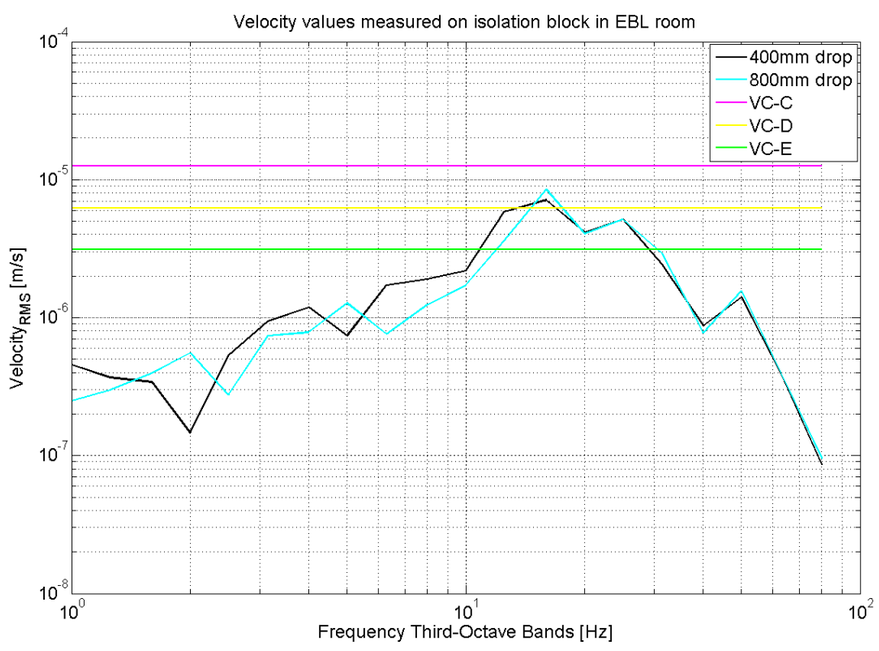


Figure 9.9 – Vibration levels measured in the EBL room of the Nanoscience Centre. The sensor was placed on the isolated concrete block. Impact source drops less than 400mm were not detected.

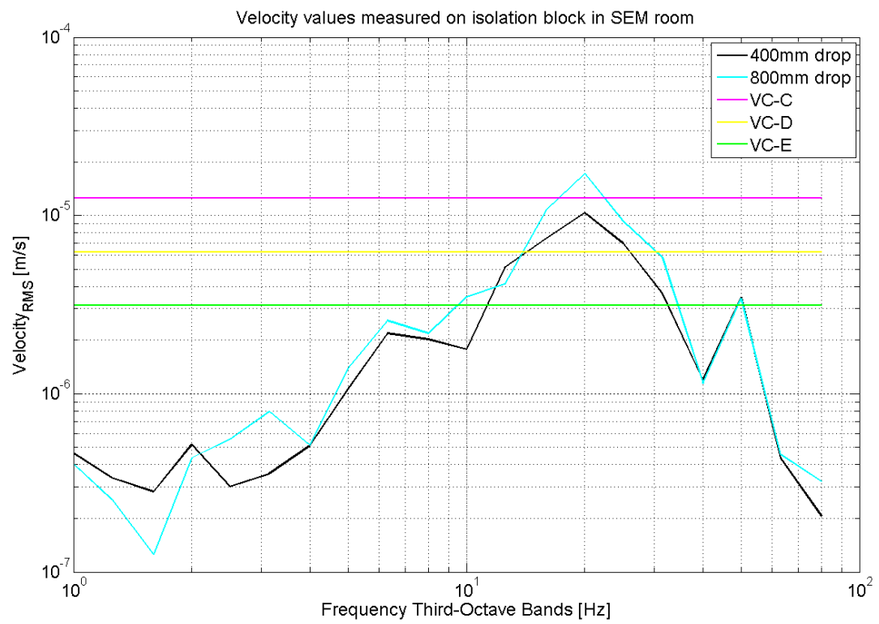


Figure 9.10 – Vibration levels measured in the SEM room of the Nanoscience Centre. The sensor was mounted on the isolation block of the machine. Impact source drops less than 400mm were not detected.

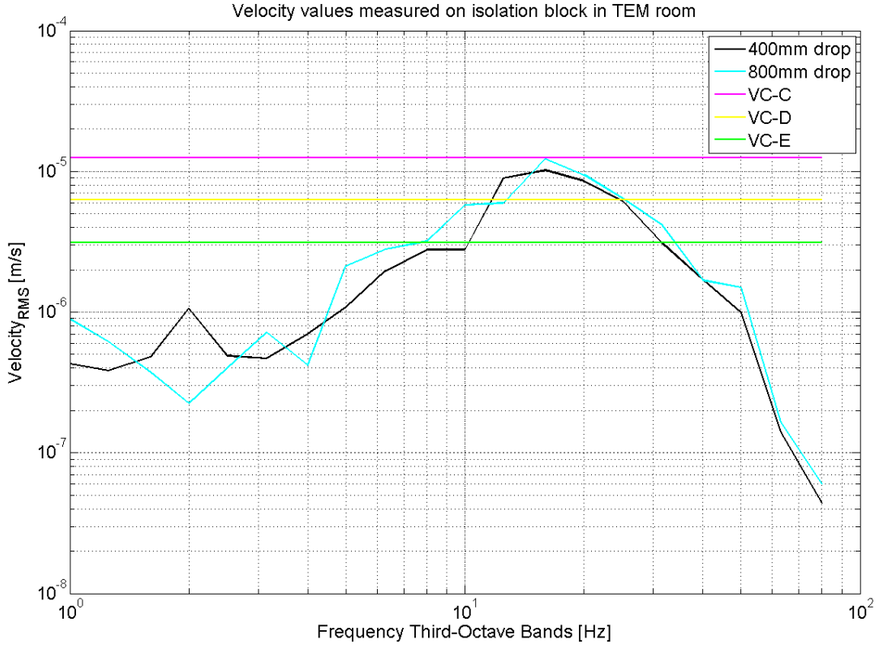


Figure 9.11 – Vibration levels measured in the TEM room (Module 1) of the Nanoscience Centre. The sensor was mounted on the isolation block of the machine. Impact source drops less than 400mm were not detected.

10 ANALYSIS

10.1 At the Graphene Centre, the most prominent frequencies measured at each drop test are found to be in the range 10 – 30 Hz. These frequencies are also the greatest in energy at the source, as it can be seen in Figure 9.4.

10.2 The 98 Joule source (50mm drop) is likely to occur several times a week in the concrete lab and even if it exceeds the VC-E threshold set out for the SEM machine, the internal isolation system that supports the machine appears to perform well enough to permit a normal use of the machine without major disturbances.

10.3 Impacts in the SEM room were above VC-E at 20 Hz for all input energies, and above VC-D for the upper 3 energies (which are unlikely to occur in the new building). Despite this, the operator of the SEM stated that the vibration impulses in the SEM room had no significant detrimental effect on the use of the machine, even at the highest energies.

10.4 The 98 Joule source (50mm drop) is attenuated enough as it propagates to the EBL and Electronic Labs to be below VC thresholds. Therefore, the machines installed in these two rooms with a vibration requirement of VC-E should not experience any disruptions given by vibration generated at the proposed new site of the Civil Engineering Building.

10.5 The structures lab of the Civil Engineering Building will be 30m by 60m and the strong floor will be on elastomeric pads. The concrete lab will sit on a floating reinforced concrete slab that sits on the raft. The final building is a dynamically complex system with different masses and dampening materials, and the real performance will depend on resonances at certain frequencies and complex propagation into the ground. The floor of the concrete lab will be a floating reinforced concrete slab supported on resilient bearings on the raft slab, and this will damp the vibration levels arriving at the building foundations. In addition, the new building will be coupled with the surrounding ground, resulting in an increased stiffness and damping by the ground itself. Also, vibration propagation in the ground will differ in attenuation with distance and directivity from the that of 1m^3 concrete cube used in tests.

10.6 The impact tests were on balance conservative. The 1m^3 concrete cube used in the tests models the foundations of the new Civil Engineering Building, but it does not include the isolation systems in effect before the building foundations.

10.7 The 196 Joule source (100mm drop) is likely to occur less often, probably once a month, since it can be related to the spectrum produced by the Glulam Split or a Beam Casting Shaker. The machine is not regularly used in the lab. It has to be noted that the frequency content of the two signals, drop test and Glulam Split/Beam Casting Shaker is different and lower in general but they could be compared in the range 4-8 Hz.

10.8 The 1,568 Joule source (800mm drop) is not likely to occur or just in rare events (probably once a year) like accidental weight drops from about 100mm of the loaded crane (2000kg).

10.9 Impacts in the Graphene Centre EBL room and Electronics Lab were below VC-E for all energies except the highest, which is unlikely ever to occur.

10.10 The Electronics Lab will be subjected to a major refurbishment in the future, Thus, the results shown in Figure 9.7 are only valid for the measured point. The surface on which the accelerometer is placed could influence the results due to resonances of the floor finishes.

10.11 The magnitude of the ground transfer function (Figure 9.5) is independent of the impulse energy (drop height), at least in this range. The plot shows how frequencies are attenuated differently as the vibration wave propagates further from the source. A 10 dB (ref. to 1) difference between 5 and 80 Hz is found at 2m from the source but a 15 dB difference is found at 32 meters in the same frequency range, indicating a greater attenuation with distance for higher frequencies. A decay rate of 5-6 dB per doubling distance is found at 5 Hz whereas a decay rate of 8-10 dB per doubling distance is found at 80 Hz.

10.12 For this source geometry, vibration velocity increases at 5 dB / doubling of input energy. Adjustments for larger slabs should be made during design.

10.13 Beyond 10m the overall vibration level falls off at about 6 dB per doubling of distance.

10.14 Impacts were not measurable in any of the Nanoscience building locations for impacts less than 784 Joules (400mm drop). In these cases, the impulsive signal given by the weight drop was not distinguishable from the background noise.

10.15 The long term average background noise in the measured positions in both Nanoscience Centre and Graphene Centre does not exceed the vibration criteria of the machines (Figure 5.3 to 5.6). Short term events found in the Nanoscience Centre (Figure 5.8 to 5.10) can exceed VC-

E in a narrow band around 20 Hz, which could be due to resonance of the resilient block support.

10.16 Given the significant short term background vibration in the Nanoscience Centre (in some cases above VC-E) and the fact that interference of drop tests with TEM machine was not detected, it is apparent that the specialist/internal isolation systems for the equipment play a significant role in achieving the successful working levels. We expect this will continue to be the case after the new building is completed and occupied.

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CAMBRIDGE UNIVERSITY ENGINEERING DEPARTMENT

Source Vibration Levels of Structures Lab Activities

Revision 1: 9th March 2016

Delivered by email to: Simon Smith, Smith & Wallwork Engineers
cc: Bob Essert, SSV

Sound Space Vision is the trading name for Sound Space Design Limited.

1 EXECUTIVE SUMMARY

1.1 This report has been prepared under instruction from Smith & Wallwork Engineers, and is intended to form part of a strategy for planning the relocation of the Structures Research lab and the Civil Engineering Group to a new building on the West Cambridge Site.

1.2 The proposed site options include plots close to the existing Centre for Advanced Photonics and Electronics, which houses the Cambridge Graphene Centre, as well as the Nanoscience Centre. Both the Graphene Centre and the Nanoscience Centre employ test and manufacturing equipment and processes that are sensitive to disturbance from vibration.

1.3 The current Structures Research Lab is located within the Department of Engineering building on Trumpington Street, Cambridge. A number of activities and equipment are in use that, when relocated to the new site, raise some concerns about vibration levels that may propagate to the neighbouring Cambridge Graphene Centre and/or the Nanoscience Centre.

1.4 The vibration survey was also carried out to provide source vibration level input for the design of the new UKCRIC building, in particular to inform (with Part 2 of the study):

- whether the vibration levels generated will impact on the new building design (in terms of building occupants).
- whether the vibration levels generated will impact on the new building design (in terms of vibration sensitive equipment in the new UKCRIC building).

1.5 This report presents data measure at the Department of Engineering for a selected range of activities. From this data, engineering design values for source vibration levels will be derived, for use in vibration propagation evaluations at later stages in the siting decisions and designs of the relocated laboratory.

1.6 This document must be read in conjunction with the associated set of A3 figures, showing measured data.

1.7 This version of the report is Revision 1. It replaces the original issued on 24 February 2016.

2 REFERENCE DOCUMENTS

2.1 STANDARDS

1. H. Amick, M. Gendreau, T. Busch, and C. Gordon, “Evolving criteria for research facilities: vibration,” *Proceedings of SPIE Conference 5933: Buildings for Nanoscale Research and Beyond*, San Diego, CA, 31 Jul 2005 to 1 Aug 2005

2.2 A3 FIGURES

2. 2193-R01-F01: Calibration Check
3. 2193-R01-F02: Concrete Mixer – Data Overview
4. 2193-R01-F03: Concrete Mixer – Dry Load – Engineering Data Summary
5. 2193-R01-F04: Beam Casting Shaker - Data Overview
6. 2193-R01-F05: Beam Casting Shaker - Engineering Data Summary
7. 2193-R01-F06: Shaker Table - Mid Height - Data Overview
8. 2193-R01-F07: Shaker Table - Mid Height - Engineering Data Summary
9. 2193-R01-F08: Handheld Breaker - Data Overview
10. 2193-R01-F09: Handheld Breaker (Concrete) – Engineering Data Summary
11. 2193-R01-F10: Handheld Breaker (Steel) – Engineering Data Summary
12. 2193-R01-F11: Fork Lift Drop - Data Overview
13. 2193-R01-F12: Fork Lift Drop - Engineering Data Summary
14. 2193-R01-F13: Gantry Crane - Data Overview
15. 2193-R01-F14: Gantry Crane - Engineering Data Summary
16. 2193-R01-F15: Glulam Split - Data Overview
17. 2193-R01-F16: Glulam Split - Engineering Data Summary
18. 2193-R01-F17: Background Vibration Levels

3 INTRODUCTION

3.1 Through discussion with the Structures Lab Manager, the following types of activities associated with the Lab were identified as potential sources of vibration disturbance:

- Mixing and vibrating of concrete for casting of test samples
- Breaking of concrete samples using hand-held ‘jack hammers’ (sometimes referred to as ‘Kango hammers’)
- Dropping and moving of loads from fork-lift trucks
- Movements of the overhead gantry crane
- Dynamic load/cyclical load test rig
- Stress testing to breaking of structural beam samples

3.2 For each Category, a number of specific operation were identified for testing:

- Concrete Mixing
- Concrete Beam Casting – Vibrator (used to release air pockets before setting)
- Concrete Sample Casting – Shaker Table
- Handheld Breaker – breaking of concrete sample laid on floor
- Fork-lift Truck – drop-placement of load onto bearers
- Gantry Crane – vibration due to movements
- Beam splitting (stress testing to breaking) – impulse source at failure point.
- Note that the dynamic load/cyclical load test rig was not able to be operated on the day of the tests.

4 SURVEY METHOD

4.1 The Lab was visited on 3 February 2016 by Bob Essert, Evan Green and Paul Malpas of Sound Space Vision.

4.2 Tests were made using a 356B18 PCB tri-axial accelerometer (Serial No. 07241002) and Benstone Impaq Elite, 4 channel dynamic signal analyser.

4.3 Unless stated otherwise, the accelerometer was fixed to the floor, with Channel 3 (Z Axis) oriented vertically (ie in the 'foot-head' mode). In general, the Channel 1 (X Axis) was orientated towards the equipment under test, and might be thought of as the 'Front-Back' mode. Channel 2 (Y Axis) may then be thought of as the 'Left-Right' mode.

4.4 A Rion VE-10 accelerometer calibration check source was used to confirm the sensitivity settings of the test equipment. See the A3 figure in Reference 2.

4.5 Tests were made of activities and test cases (conditions) as listed in Table 1. In each case, time trace data was recorded in each of the X, Y and Z axes simultaneously, of RMS vibration velocity, using a sample period of 0.4s and frequency resolution of 2.5Hz.

File	Time	Activity/ Equipment	Test location	Case/ Condition	Anticipated Usage
calib	10:00	Calibration		10mm/s rms	
Mixing1	10:14	Concrete Mixer	100mm from base plate edge.	Dry	Concrete lab (mixing, shaking) used approx.. once per fortnight. Mixing run up to 5 mins per batch
Mixing2	10:15	Concrete Mixer	100mm from base plate edge.	Dry	
Mixing3	10:16	Concrete Mixer	100mm from base plate edge.	Added water	
CastingEmpty	10:21	Beam Vibrator	100mm from foot edge at motor end, on same slab	Empty	Casting or table shaker runs for up to 1 minute, twice per sample
Casting1	10:24	Beam Vibrator	100mm from foot edge at motor end, on same slab	Half full	
Casting2	10:34	Beam Vibrator	100mm from foot edge at motor end, on same slab	Full	
ShakingEmpty	10:39	Shaker Table - mid height	100mm from base plate edge.	Empty	
Shaker1	10:41	Shaker Table - mid height	100mm from base plate edge.	Half full	
Shaker2	10:45	Shaker Table - mid height	100mm from base plate edge.	Full	
Kango1	11:13	Kango hammer	250mm from concrete beam rested on floor of structures lab	Concrete beam	Breaking tool used as required to dispose of samples. Perhaps 2-3 times per year, per periods up to 1 hour each
Kango2	11:14	Kango hammer	250mm from concrete beam rested on floor of structures lab	Concrete beam	
Kango-Steel	11:15	Kango hammer	500mm from steel plate rested on floor of structures lab	onto 10mm steel plate	
Fork1	11:48	Fork Lift drop 1	500mm from bearers	example 1	Fork lift movements may be regular – eg once per month. However, 'drop' events may be les regular, and each drop represents a vibration event of less than 1 second
Fork2	11:48	Fork Lift drop 2	500mm from bearers	example 2	
Fork3	11:53	Fork Lift drop 3	500mm from bearers	example 3	
Gantry3	12:15	Gantry crane	Floor at mezzanine	Crane to mezzanine floor	Gantry crane used whenever needed. However, most running induces levels only close to background, with occasional low level peaks above that
0005(1)	14:57	Glulam splitting tests 2	100mm from beam support	Sample breaks	This is a very infrequent activity. In any case, the actual vibration event occurs only at the point of failure, for less than 1s.

Table 1: Vibration Source - Activities and conditions/cases tested

5 ANALYSIS

5.1 The vibration record files were analysed using the Benstone Novian software, v2.1.8.1, supplied on the website (www.benstone.com).

5.2 Analysis was made for each of the Activities listed in Table 1.

5.3 For each Activity, the files for each relevant case were opened and examined for each axis (X, Y, Z) individually.

5.4 Except where stated otherwise, each measurement record uses a 2.5Hz frequency resolution and 400 lines FFT, resulting in 0.4s sample lengths and analysis up to 1000Hz.

5.5 In the associated A3 figures, for each Activity, two types of Results sheets are presented:

- Data Overview
- Engineering Data Summary

5.6 For each case and axis, the time traces were viewed as intensity maps, for example as seen in 2193-R01-F01 (Reference 2). In the intensity map, frequency bins are shown across the graph x-axis, with time (or sample count) progressing up the graph y-axis. Colour intensity forms the graph data or z-axis, allowing the event to be viewed in a time and frequency spectrogram.

5.7 'Waterfall' 3 dimension plots (not typically shown here) were also used to help identify the character and timing of any trends, transients or events within each recording analysed.

5.8 Through inspection, it was established if mode (X, Y, Z), case or both were critical elements in identifying the dominant characteristic(s) of the measured activity. Where helpful, 'slices' of the intensity maps were extracted as either a spectrum for a particular sample count/time, or a time slice for a particular frequency bin. These were used as visual indications of the character and timing of each activity measured, such as comparing the trends between the modes (X, Y, Z) and the cases investigated.

5.9 The 'Data Overview' sheets record the intensity map spectrograms (time/frequency, colour as amplitude), along with any helpful spectral or time slices, as well as essential observations, which are expanded on in the sections below.

5.10 During the analysis, the FFT frequency bin data were combined and distributed between the relevant One Third Octave frequency bands from 2.5Hz to 1000Hz. The 'Engineering Data Summary' sheets then record two graphs of third octave vibration level (rms):

- RMS velocity amplitude, averaged over typical running of the activity, or over a period encapsulating the event or transient conditions identified
- Maximum values over the entire measurement, for each FFT frequency bin independently, these maxima combined into Third Octaves summed values as above.

5.11 The Time Averaged Vibration Level data is plotted against a range of VC (Vibration Criteria) curves used to assess or specify vibration levels affecting sensitive equipment (Reference1). These are not fully relevant to compare with measurement data taken at source, except to indicate the orders of magnitude of attenuation that may be required over the full propagation from source to the sensitive equipment siting in the neighbouring building.

6 DATA & OBSERVATIONS

6.1 Concrete Mixing

The accelerometer was placed on the concrete floor of the concrete mixing lab, around 100mm from the base plate edge of the mixer.



Figure 1: Concrete Mixer under test

The concrete mixer was loaded by the technician, first with the dry mix and then with the liquid added. Two subsequent measurements were made during the dry mix part of the process, with a third after the liquid components had been added.

File	Time	Activity/Equipment	Test location	Case/Condition
Mixing1	10:14	Concrete Mixer	100mm from base plate edge.	Case 1: Dry Mix 1
Mixing2	10:15	Concrete Mixer	100mm from base plate edge.	Case 2: Dry Mix 2
Mixing3	10:16	Concrete Mixer	100mm from base plate edge.	Case 3: Wet Mix

Table 2: Analysis Cases - Concrete Mixer

See Figure 2193-R01-F02 (Reference 3) for an overview of the analysed cases.

It was noted that:

- As expected, vibration energy measured was broadband in nature (non-harmonic)
- No significant distinction was noted between the three Cases, including the Wet Mix

Case 2 (Dry Mix 2) has been analysed in third octave bands – see 2193-R01-F03 (Reference 4). It is noted that:

- Z-Axis vibration levels dominate, at around 10-20dB higher than the X and Y axes.
- Time-averaged vibration levels in the Z-Axis measured around 0.04 to 1.0 mm/s rms per third octave band, over the range measured up to the 400Hz band.

6.2 Beam Casting Shaker

The accelerometer was placed on the concrete floor of the concrete mixing lab (same slab section), around 100mm from the base foot of the shaker, at the motor end.



Figure 2: Beam Casting Shaker under test

The Shaker was first run up and down unloaded, ie without any concrete in the beam casting trough (Case 1).

Concrete was loaded by the Technician up to half depth (as is common to do so) and the shaker run up, sustained, and run down again (Case 2).

Concrete was loaded by the Technician up to full depth and the shaker run up, sustained, and run down again (Case 3).

File	Time	Activity/Equipment	Test location	Case/Condition
CastingEmpty	10:21	Beam Vibrator	100mm from foot edge at motor end, on same slab	Case 1: Unloaded
Casting1	10:24	Beam Vibrator	100mm from foot edge at motor end, on same slab	Case 2: Half filled
Casting2	10:34	Beam Vibrator	100mm from foot edge at motor end, on same slab	Case 3: Full

Table 3: Analysis Cases – Beam Casting Shaker

See Figure 2193-R01-F04 (Reference 5) for an overview of the analysed cases.

It was noted that:

- As expected, vibration energy measured was harmonic in nature, with energy value peaks easily observed at what appear to be discrete excitation frequencies (eg of the various rotating elements) and harmonics of these. The frequencies of excitation (and of corresponding harmonics) rise in value with running up and drop again with running down. These can be seen clearly in the spectrograms.
- Being rotational, the principal excitations run through all frequencies upwards from '0Hz'.
- Analysis has concentrated on the dominant Z-Axis excitation.

- In Case 1 (unloaded), the strongest harmonic rises up to 105Hz, measuring 10-14dB (ref 1 mm/s rms).
- In Case 2 (half load), the fundamental rises up to 70Hz, measuring 10-12dB (ref 1 mm/s rms), and sustains at that level and frequency for around 20-30 seconds before running down.
- In Case 3 (full load), the fundamental rises up to 50-60Hz, measuring 8-10dB (ref 1 mm/s rms), and sustains at that level and frequency for around 20-30 seconds before running down.

Case 1 (unloaded) has been analysed in third octave bands – see 2193-R01-F05 (Reference 6). It is noted that:

- Z-Axis vibration levels dominate, at around 10-20dB higher than the X and Y axes.
- Time-averaged vibration levels in the Z-Axis measured around 0.2 to 2.0 mm/s rms per third octave band, over the range measured up to the 250Hz band, dropping away quickly at higher bands.

6.3 Shaker Table – Mid Height

The accelerometer was placed on the concrete floor of the concrete mixing lab (same slab section), at 100mm from the base plate of the shaker table. The shaker table was mounted on vibration elastomeric isolation mounts onto the concrete slab.



Figure 3: Shaker Table under test

The Shaker was first run up and down unloaded, ie without any concrete in the block casting trough (Case 1).

Concrete was loaded by the Technician up to half depth (as is common to do so) and the shaker run up, sustained, and run down again (Case 2).

Concrete was loaded by the Technician up to full depth and the shaker run up, sustained, and run down again (Case 3).

File	Time	Activity/Equipment	Test location	Case/Condition
ShakingEmpty	10:39	Shaker Table - mid height	100mm from base plate edge.	Case 1: Unloaded
Shaker1	10:41	Shaker Table - mid height	100mm from base plate edge.	Case 2: Half filled
Shaker2	10:45	Shaker Table - mid height	100mm from base plate edge.	Case 3: Full

Table 4: Analysis Cases – Beam Casting Shaker

See Figure 2193-R01-F06 (Reference 7) for an overview of the analysed cases.

It was noted that:

- As expected, vibration energy measured was harmonic in nature, with energy value easily observed at what appear to be discrete excitation frequencies (eg of the various rotating elements) and harmonics of these. The frequencies of excitation (and of corresponding harmonics) rise in value with running up and drop again with running down. These can be seen clearly in the spectrograms.
- Being rotational, the principal excitations run through all frequencies upwards from '0Hz'. The rise is swift, over 2-3 seconds, with the run-down taking 4-6s.

- Analysis has concentrated on the dominant Z-Axis excitation.
- In Case 1 (unloaded), the strongest harmonic rises quickly to 50Hz, measuring around 0dB (ref 1 mm/s rms), and sustains at that level and frequency for around 10 seconds before running down.
- In Case 2 (half load), the fundamental rises also to 50Hz, measuring -2dB (ref 1 mm/s rms), and sustains at that level and frequency for around 20-25 seconds before running down.
- In Case 3 (full load), the fundamental rises also to 50Hz, measuring -3.5dB (ref 1 mm/s rms), and sustains at that level and frequency for around 40 seconds before running down.

Case 1 (unloaded) has been analysed in third octave bands – see 2193-R01-F07 (Reference 8). It is noted that:

- Z-Axis vibration levels dominate, at around 10-20dB higher than the X and Y axes.
- Time-averaged vibration levels in the Z-Axis measured around 0.05 mm/s rms per third octave band below 50Hz, peaking at 0.7mm/s rms in the 50Hz band, dropping quickly at higher bands.
- In the X and Y axes, time-averaged vibration levels were measured around 0.02 mm/s rms at 12.5Hz and above, rising to 0.05 mm/s rms at 4.0 Hz and below.

6.4 Handheld Breaker

The accelerometer was placed on the concrete floor of the main Structures lab (same slab section), approximately 250mm from the impact point on a concrete sample, and around 500mm from a steel plate, both used in the tests.



Figure 4: Handheld Breker test

The Breaker was first used on the concrete sample laid directly on the lab floor (Case 1), which was then repeated for Case 2. The Technician stood on the sample during the breaking action in each test.

For Case 3, the Breaker was applied to a 10mm steel plate laid directly on the lab floor.

File	Time	Activity/Equipment	Test location	Case/Condition
Kango1	11:13	Kango hammer	250mm from concrete beam rested on floor of structures lab	Case 1: Concrete beam
Kango2	11:14	Kango hammer	250mm from concrete beam rested on floor of structures lab	Case 2: Concrete beam
Kango-Steel	11:15	Kango hammer	500mm from steel plate rested on floor of structures lab	Case 3: onto 10mm steel plate

Table 5: Analysis Cases – Beam Casting Shaker

See Figure 2193-R01-F08 (Reference 9) for an overview of the analysed cases.

It was noted that:

- As expected, vibration energy measured was percussive in nature
- Onto the concrete sample, the z-axis vibration levels dominated by 25-60dB
- Onto the steel plate, the x-axis and y-axis vibration levels are higher than the z-axis levels by around 0-15dB.

Case 1 (concrete) has been analysed in third octave bands – see 2193-R01-F09 (Reference 10). It is noted that:

- Z-Axis vibration levels dominate, at around 25-60dB higher than the X and Y axes, being highest at low frequencies and dropping consistently with rising frequency band.
- Excitation is non-resonant, with the frequency content linked to the impact repetition rate. Note that the measurement is very close to a small impact site, unlike other tests relating to larger rotating equipment where the source size is considerably larger and excitation is by rotation. For the Breaker, this has resulted in high apparent 'source' values.

Case 3 (steel) has been analysed in third octave bands – see 2193-R01-F10 (Reference 11). It is noted that:

- X-Axis and Y-Axis vibration levels dominate, at around 20dB higher than the Z-Axis, being highest at low frequencies and dropping consistently with rising frequency band.
- Excitation is non-resonant, with the frequency content most likely to be linked to the impact repetition rate. Note that the measurement is very close to a small impact site, unlike other tests relating to larger rotating equipment where the source size is considerably larger and excitation is by rotation. For the Breaker, this has resulted in high apparent 'source' values.

Compared to the concrete breaking case, the impacts onto the steel plate exhibit around 10-15dB lower levels in the Z-Axis. This energy in the steel case appears to have been transferred laterally to the X and Y-Axes, which exhibit considerably higher vibration velocity levels.

6.5 Fork Lift Drop

The accelerometer was placed on the concrete floor of the main Structures lab (same slab section), around 500mm from the one of two wooden bearers.



Figure 5: Fork Lift Drop test

A load of around 750kg was 'dropped' by releasing the pneumatic lift on forks from a height of around 700mm. This was repeated over 3 examples.

File	Time	Activity/Equipment	Test location	Case/Condition
Fork1	11:48	Fork Lift drop 1	500mm from bearers	Case 1: example 1
Fork2	11:48	Fork Lift drop 2	500mm from bearers	Case 2: example 2
Fork3	11:53	Fork Lift drop 3	500mm from bearers	Case 3: example 3

Table 6: Analysis Cases – Beam Casting Shaker

See Figure 2193-R01-F11 (Reference 12) for an overview of the analysed cases.

It was noted that:

- Within each recording, the 'event' of the impact is more easily identifiable in the Z-axis trace (as shown), whereas the energy in all 3 axes is similar. If anything, levels are slightly higher in the X-Axis.

Case 1 has been analysed in third octave bands – see 2193-R01-F12 (Reference 13). It is noted that:

- Excitation is non-resonant, with low energy levels rising to 0.08mm/s rms below 8.0Hz.
- Above 50Hz, levels drop quickly below 0.01mm/s rms.
- No particular axis appears to dominate the values.

6.6 Gantry Crane

The accelerometer was placed on the mezzanine floor overlooking the main Structures lab, around 2.5m from a structural steel column supporting the beam on which the Gantry Crane runs.



Figure 6: Fork Lift Drop test

Measurements were made while the crane was operated through its range.

See Figure 2193-R01-F13 (Reference 14) for an overview of the analysed data.

It was noted that:

- Levels were not significantly greater in any one axis.
- Levels are generally only slightly above the measured background values (see 2193-R01-F17, Reference 18), with occasional short time-base exceptions.

Case 1 has been analysed in third octave bands – see 2193-R01-F14 (Reference 15).

6.7 Glulam Split

The accelerometer was placed on the main Structures Lab floor, around 100mm from one of the supports bearing a span of glulam beam. The beam was stress tested under a mid-span load, until a break occurred. Vibration testing captured the moment the break occurred, allowing the impulsive force into the floor to be registered.

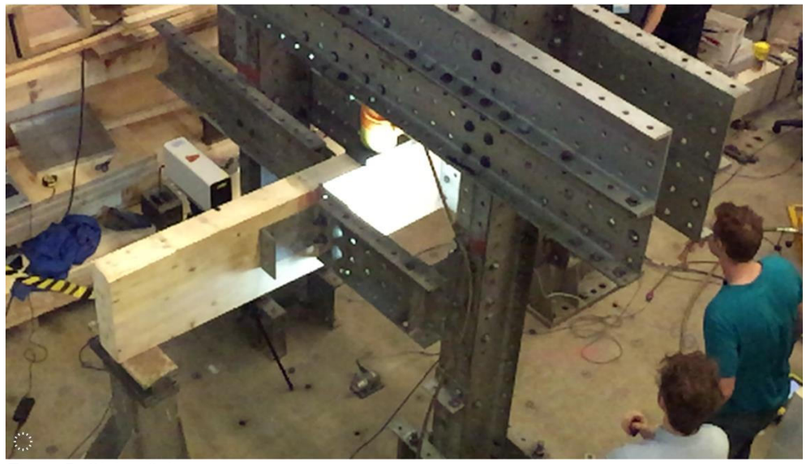


Figure 7: Glulam Split test

See Figure 2193-R01-F15 (Reference 16) for an overview of the analysed data.

It was noted that:

- The split event was easily identifiable in all axes, with no axis dominating the levels measured.

The break event has been analysed in third octave bands – see 2193-R01-F16 (Reference 17).

- The significant energy of the event occurs above 100Hz, peaking around 315-500Hz at less than 0.1mm/s rms in all axes.

6.8 Background Levels

Background spectra were measured on the main Structures Lab floor and on the Mezzanine Floor, for comparison with relevant measurement data.

See 2193-R01-F17 (Reference 18)

7 CONCLUSIONS

7.1 Vibration Velocity Levels have been measured close to typical activities at the CUED Structures Lab, for activities identified as being potential sources of vibration energy from rotational or impact input.

7.2 Levels were measured as 0.4s samples and FFT analysed into corresponding 2.5Hz bins. These were combined and divided to form time-averaged energy values in third octaves from 2.5Hz to 1000Hz.

7.3 In each event, the 'typical worst case' vibration event within the activity type was identified within the time traces, and spectral energy-averaged data is presented for those periods. Maxima data is also presented for each test analysed, as part of the context for characterising the vibration source levels to take forward into propagation analysis.

7.4 Background vibration levels are also given, as context.

7.5 The Levels reported can be investigated to identify:

- critical activities (in the context of expected frequency of occurrence and period of use)
- characteristic levels to apply, along with propagation analysis, to evaluating net vibration levels in sensitive spaces.

7.6 It is expected that propagation analysis will occur at the next stage, including site measurements and other techniques. As this analysis is expected to be necessarily circumspect to some extent, due to the multiple mechanisms occurring in geotechnical and structural vibration transfer functions, the data here should be used to understand a characteristic range of vibration levels and spectral content to apply at source.

Measurements of the geological transfer function between buildings on the new site will be obtained in the next stage of work.

It is envisioned that the floor of the future civil/structural lab will be a heavy slab of similar thickness to the slab in the existing building. Structural dynamics modelling can be adjusted for differences in boundary conditions.

Vibration levels in the new building and other surrounding sensitive buildings can be projected from these source levels, propagation functions and transfer within buildings by the design team.

SOUND SPACE VISION
bob.essert@soundspacevision.com

Appendix 12.7 Calibration certificates

Campbell Associates Ltd
5b Chelmsford Road Industrial Estate
GREAT DUNMOW, CM6 1HD, England
www.campbell-associates.co.uk
info@campbell-associates.co.uk
Phone 01371 871030 Facsimile 01371879106

CALIBRATION UKAS Laboratory 0789

Certificate number: U15237 (Supplement)

Certificate of Calibration and Conformance

Test object:	**Sound Calibrator**
Manufacturer:	**Brüel and Kjær**
Type:	**4231**
Serial no:	**2619374**
Customer:	Brett Consulting Limited
Address:	Imperium, Imperial Way, Reading, Berkshire. RG2 0TD.
Contact Person:	Adam Bamford - Assistant Engineer
Order No:	Contract: 22042

Measurement Results:	Level	Level Stability	Frequency	Frequency Stability	Distortion
1:	94.05 dB	0.06 dB	999.98 Hz	0.00 %	0.33 %
2:	94.05 dB	0.06 dB	999.97 Hz	0.00 %	0.33 %
3:	94.05 dB	0.06 dB	999.97 Hz	0.00 %	0.33 %
Result (Average):	**94.05 dB**	**0.06 dB**	**999.97 Hz**	**0.00 %**	**0.33 %**
Expanded Uncertainty:	0.10 dB	0.02 dB	1.00 Hz	0.01 %	0.10 %
Degree of Freedom:	>100	>100	>100	>100	>100
Coverage Factor:	2.00	2.00	2.00	2.00	2.00

The stated level is relative to 20µPa. The level is traceable to National Standards.
The stated level is valid at reference conditions. The following correction factors have been applied during the measurement: Pressure: 0.00008 dB/kPa Temperature: 0.0015 dB/°C Relative humidity: 0.001 dB/%RH Load volume : 0.0003 dB/mm3
The reported expanded uncertainty of measurements is based on a standard uncertainty multiplied by the coverage factor of k=2, providing a level of confidence of approximately 95%. Where the degrees of freedom are insufficient to maintain this confidence level, the coverage factor is increased to maintain this confidence level. The uncertainty has been determined in accordance with UKAS requirements.
Records: K:\C A\Calibration\Nor-1504\Nor-1018 CalCal\2014\BNK4231v1_2619374_M1.nmf

Environmental conditions:	Pressure:	Temperature:	Relative humidity:
Reference conditions:	101.325 kPa	23.0 °C	50 %RH
Measurement conditions:	99.079 ± 0.042 kPa	23.4 ± 0.2 °C	46.1 ± 1.4 %RH

Date received for calibration:	13/01/2014
Date of calibration:	15/01/2014
Date of issue:	17/10/2016
Engineer	

Supervisor

Palanivel Marappan B.Eng(Hons), M.Sc

Darren Batten TechIOA

This certificate is issued in accordance with the laboratory accreditation requirements of the United Kingdom Accreditation Service. It provides traceablity of measurement to recognised national standards, and to the units of measurement realised at the National Physical Laboratory or other recognised national standards laboratories. This certificate may not be reproduced other than in full without the prior written approval of the issuing laboratory.

Template PE v2.6

Certificate number: U15237

Preconditioning
The equipment was preconditioned for more than 4 hours in the specified calibration environment.

Measurements
The calibrator has been tested as described in the following annexes to BS EN IEC60942:2003 Sound Calibrators; B3.4 for sound pressure level, B3.5 for frequency, B3.6 for total distortion and A4.4 for short term stability of the pressure level.

Method
Calibration has been performed as set out in the current version of CA Technical procedure TP01

Instruments and program
A complete list of equipment, hardware and software that has been used in this calibration is available from the calibration laboratory on request.

Traceability
The measured values are traceable to the following laboratories:
Sound Pressure Level: National Physical Laboratory, United Kingdom
Voltage: National Physical Laboratory, United Kingdom
Frequency: National Physical Laboratory, United Kingdom
Ambient Pressure: National Physical Laboratory, United Kingdom
Temperature & Relative Humidity: National Physical Laboratory, United Kingdom

Comment
Plus 20dB spot check = 114.07dB. Note this is not UKAS data
Supplement to original calibration certificate. Certificate re-issued at customer request.

Statement of conformance
As public evidence was available[1], from a testing organisation responsible for approving the results of pattern evaluation tests, to demonstrate that the model of sound calibrator fully conformed to the requirements for pattern evaluation described in annex A of BS EN IEC 60942:2003, the sound calibrator tested is considered to conform to all the class 1 requirements of that BS EN IEC 60942:2003.

[1] This evidence is held on file at the calibration laboratory.

Notes:
The sound pressure level generated by the calibrator in its ½ inch configuration was measured five times and averaged by a WS2P working standard microphone for class 1 or 2 devices or a LS2P reference microphone for class 0 or LS devices as specified in the International Standard BS EN 61094-4. The results of three replications and the mean of the measurements obtained are given in the measurement results table of this certificate. The frequency and distortion were measured in a similar manner. The figures in **BOLD** are the final results; a small correction factor may need to be added to the sound pressure level quoted here if the device is used to calibrate a sound level meter that is fitted with a free field response microphone. See manufacturer's handbooks for full details of this and other corrections that may be applicable.

Measurements performed by
Campbell Associates

Sonitus House, 5b Chelmsford Road Industrial Estate, Great Dunmow, GB-CM6 1HD
Tel (+44) 01371 871030 Fax (+44) 01371 879106
email calibration@campbell-associates.co.uk

MEASUREMENT SYSTEMS

CERTIFICATE OF CONFORMANCE

Date of Issue	**12 September 2014**
Customer	**Brett Consulting Limited**
Certificate Number	**CONF091416**

	Manufacturer	**Type**	**Serial Number**
Acoustic Calibrator	Rion	NC-74	34746691

This is to certify that the instrument was tested and calibrated at the Manufacturer's factory according to their specification and that the product satisfied all the relevant requirements of the following Standards:

IEC 60942:2003 Class 1 (Electroacoustics - Sound Calibrators)

The instrument also received a functional check by ANV Measurement Systems prior to despatch in the UK, in accordance with our standard procedures.

Signed. Amrat C. Patel Position.Laboratory Manager. Date.12 September 2014.

Amrat C Patel

BEAUFORT COURT, 17 ROEBUCK WAY, MILTON KEYNES, MK5 8HL
☎ 01908 642846 🖷 01908 642814
✉ info@noise-and-vibration.co.uk 💻 www.noise-and-vibration.co.uk

ACOUSTICS NOISE AND VIBRATION LIMITED. REGISTERED IN ENGLAND NO. 3549028. REGISTERED OFFICE AS ABOVE.

MEASUREMENT SYSTEMS

CERTIFICATE OF CONFORMANCE

Date of Issue	**12 September 2014**
Customer	**Brett Consulting Limited**
Certificate Number	**CONF091417**

	Manufacturer	**Type**	**Serial Number**
Acoustic Calibrator	Rion	NC-74	34746693

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Signed. Amrat C. Patel Position.Laboratory Manager. Date.12 September 2014.

Amrat C Patel

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MEASUREMENT SYSTEMS

CERTIFICATE OF CONFORMANCE

Date of Issue	**31 July 2014**
Customer	**Brett Consulting Limited**
Certificate Number	**CONF071420**

	Manufacturer	**Type**	**Serial Number**
Sound Level Meter	Rion	NL-52	00542902
Preamplifier	Rion	NH-25	42930
Microphone	Rion	UC-59	06479

This is to certify that the instrument was tested and calibrated at the Manufacturer's factory according to their specification and that the product satisfied all the relevant requirements of the following Standards:

IEC 61672-1:2002 Class 1.

The instrument also received a functional check by ANV Measurement Systems prior to despatch in the UK, in accordance with our standard procedures.

Signed. Amrat C Patel Position.Laboratory Manager... Date.31st July 2014.

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MEASUREMENT SYSTEMS

CERTIFICATE OF CONFORMANCE

Date of Issue	**31 July 2014**
Customer	**Brett Consulting Limited**
Certificate Number	**CONF071421**

	Manufacturer	**Type**	**Serial Number**
Sound Level Meter	Rion	NL-52	00542903
Preamplifier	Rion	NH-25	42931
Microphone	Rion	UC-59	06480

This is to certify that the instrument was tested and calibrated at the Manufacturer's factory according to their specification and that the product satisfied all the relevant requirements of the following Standards:

IEC 61672-1:2002 Class 1.

The instrument also received a functional check by ANV Measurement Systems prior to despatch in the UK, in accordance with our standard procedures.

Signed.Amrat c Patel Position.Laboratory Manager...Date.31st July 2014.

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MEASUREMENT SYSTEMS

CERTIFICATE OF CONFORMANCE

Date of Issue	**31 July 2014**
Customer	**Brett Consulting Limited**
Certificate Number	**CONF071419**

	Manufacturer	**Type**	**Serial Number**
Sound Level Meter	Rion	NL-52	00542901
Preamplifier	Rion	NH-25	42929
Microphone	Rion	UC-59	06478

This is to certify that the instrument was tested and calibrated at the Manufacturer's factory according to their specification and that the product satisfied all the relevant requirements of the following Standards:

IEC 61672-1:2002 Class 1.

The instrument also received a functional check by ANV Measurement Systems prior to despatch in the UK, in accordance with our standard procedures.

Signed. Amrat C. Patel Position.Laboratory Manager...Date.31st July 2014.

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ACOUSTICS NOISE AND VIBRATION LIMITED. REGISTERED IN ENGLAND NO. 3549028. REGISTERED OFFICE AS ABOVE.

Campbell Associates Ltd
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www.campbell-associates.co.uk
Phone 01371 871030 Facsimile 01371879106

CALIBRATION UKAS Laboratory 0789

Certificate of Calibration

Certificate number: U15173

Test object:	**Sound Level Meter, Type 1 (Precision)**
Manufacturer:	**Brüel and Kjær**
Type:	**2250**
Serial no:	**2626231**
Customer:	**Brett Consulting Limited**
Address:	**10 Queen Square, Bristol. BS1 4NT.**
Contact Person:	**Zoe Richardson.**

Method :
Calibration has been performed as set out in CA Technical Procedures TP01 & 02 as appropriate. The following items have been calibrated as set out in BS 7580 Part 1:1997

	Producer:	Type:	Serial No:	Certificate number
Microphone	Brüel & Kjær	4189	2621209	15172
Calibrator*	Brüel and Kjær	4231	2619373	U15171
Preamplifier	Brüel & Kjær	ZC0032	8125	Included

Additional items that also have been submitted for verification

Wind shield	None
Attenuator	None
Extension cable	None

These items have been taken into account wherever appropriate.

	Pressure:	Temperature:	Relative humidity:
Environmental conditions:			
Reference conditions:	101.325 kPa	23.0 °C	50 %RH
Measurement conditions:	100.844 kPa	24.2 °C	46.1 %RH

Date received : 20/12/2013
Date of calibration: 08/01/2014
Date of issue: 08/01/2014

Engineer

Michael Tickner

Supervisor

Darren Batten Tech IOA

This certificate is issued in accordance with the laboratory accreditation requirements of the United Kingdom Accreditation Service. It provides traceability of measurement to recognized national standards, and to the units of measurement realized at the National Physical Laboratory or other recognized national standards laboratories. This certificate may not be reproduced other than in full, except with the prior written approval of the issuing laboratory.

* The calibrator was complete with any required coupler for the microphone specified

Calibration Certificate
UKAS Laboratory Number 0789

Certificate No.: U15173

Method
From markings on the sound level meter or by reference to the manufacturer's published literature it has been determined that the instrument submitted for verification was originally manufactured to BS EN 60651 and or BS EN 60804. The reference range, reference sound pressure level, primary indicator range, secondary indicator range, pulse range, linearity range and display range as specified by the manufacturer were used for the verification. The sound level meter was set to A weighting and adjusted to read correctly in response to the associated sound calibrator the reading was derived from the calibrator calibration certificate and manufacturer's instruction manuals. A measurement of the self noise of the sound level meter was then made using a dummy microphone having a capacitance of ±20% of the associated microphones self capacitance. The sound level meter was then tested, and its overall sensitivity adjusted, in accordance with Section 5 of BS 7580:Part 1:1997. The acoustic calibration at 1 kHz specified in sub-clause 5.6.1 of the standard was performed by application of a reference sound calibrator, whilst the tests at 125 Hz and 8k Hz (sub-clause 5.6.2) were performed by the electrostatic actuator method. At the end of the test, the associated sound calibrator was reapplied to the sound level meter and the meter reading was recorded and is noted below in the statements section.

Traceability :
The following measured values are traceable to the National Physical Laboratory, United Kingdom.
Sound Pressure Level, Voltage, Frequency, Barometric Pressure, Temperature & Relative Humidity

Measurement Results:

Calibration of sound level meter - BS7580 #5.4	Passed
Noise test - BS 7580 #5.5.2	Passed
Level Linearity Test - BS 7580, #5.5.3	Passed
Frequency weightings: A Network - BS 7580 #5.5.4	Passed
Frequency weightings: C Network - BS 7580 #5.5.4	Passed
Frequency weightings: Z Network - BS 7580 #5.5.4	Passed
Time weightings F and S - BS7580 #5.5.5	Passed
Peak response - BS7580 #5.5.6	Passed
RMS accuracy - BS7580 #5.5.7	Passed
Time weighting I - BS7580 #5.5.8	Passed
Integrating Test : Time averaging - BS7580 #5.5.9	Passed
Integrating Test : Pulse range - BS7580 #5.5.10	Passed
Integrating Test : Sound exposure level - BS7580 #5.5.11	Passed
Overload SPL Test - BS 7580 #5.5.12	Passed
Overload Leq Test - BS 7580 #5.5.12	Passed
Acoustic tests - BS 7580 #5.4 and 5.6	Passed
Summation of acoustic tests - BS 7580 #5.5.4	Passed

Statements
The sound level meter in the configuration tested conforms to the requirements of BS 7580 Part 1.
The self-generated noise recorded in the test specified in § 5.5.2 was: 12.9 (Below MSD)dB(A), 15.0 (Below MSD)dB(C) and 25.4dB(Z).
The final response obtained using the associated calibrator was (§5.6.3): 93.9dB(A)
This reading should be used henceforth to set up the sound level meter for field use.
A stricter test than that specified in paragraphs 5.5.6 of BS7580:1997 has been used by verifying that the 10 ms reference pulse is also correct. The level uncertainty of the Laboratory's 1 kHz sound calibrator used during this verification is ± 0.1 dB.
The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

The sound level meter in the configuration tested was found to comply with BS 7580:1997 part 1 for a type 1 device. The associated calibrator has been corrected for barometric pressure at the time of calibration in accordance with the relevant manufacturer's instructions

Appendix 12.8 Multi storey car park noise calculations

31500 - West Cambridge Proposed Carpark Assessment

Receptor The Lawns off Clark Maxwell Road

Car Park	Event	Number of Events	SEL	Average Distance to Receptor (m)	Distance Correction	Location Correction	Corrected SEL	Calculated Sound Level at Receptor (LAeq,1hour)
AM Peak	Car Pass-by and Park	266	74	130	-16	3	61	49
	Engine Starting and Car Pulling Away	52	77	130	-16	3	64	45
	Calculated Sound Level at Receptor (LAeq,1hour)	51						
	Existing Residual Sound Level at Receptor (LAeq,1hour)	51						
	Cumulative Ambient Sound Level at Receptor (LAeq,1hour)	54						
	Difference	3						

Car Park	Event	Number of Events	SEL	Average Distance to Receptor (m)	Distance Correction	Location Correction	Corrected SEL	Calculated Sound Level at Receptor (LAeq,1hour)
PM Peak	Car Pass-by	48	74	130	-16	3	61	42
	Engine Starting and Car Pulling Away	139	77	130	-16	3	64	49
	Calculated Sound Level at Receptor (LAeq,1hour)	50						
	Existing Residual Sound Level at Receptor (LAeq,1hour)	49						
	Cumulative Ambient Sound Level at Receptor (LAeq,1hour)	53						
	Difference	4						

31500 - West Cambridge Proposed Carpark Assessment

Receptor 53 Madingley

Car Park	Event	Number of Events	SEL	Average Distance to Receptor (m)	Distance Correction	Location Correction	Corrected SEL	Calculated Sound Level at Receptor (LAeq,1hour)
AM Peak	Car Pass-by and Park	266	74	50	-12	3	65	53
	Engine Starting and Car Pulling Away	52	77	50	-12	3	68	49
	Calculated Sound Level at Receptor (LAeq,1hour)	55						
	Existing Residual Sound Level at Receptor (LAeq,1hour)	57						
	Cumulative Ambient Sound Level at Receptor (LAeq,1hour)	59						
	Difference	2						

Car Park	Event	Number of Events	SEL	Average Distance to Receptor (m)	Distance Correction	Location Correction	Corrected SEL	Calculated Sound Level at Receptor (LAeq,1hour)
PM Peak	Car Pass-by	48	74	50	-12	3	65	46
	Engine Starting and Car Pulling Away	139	77	50	-12	3	68	54
	Calculated Sound Level at Receptor (LAeq,1hour)	54						
	Existing Residual Sound Level at Receptor (LAeq,1hour)	57						
	Cumulative Ambient Sound Level at Receptor (LAeq,1hour)	59						
	Difference	2						

Appendix 12.9 Access route noise calculations

BS4142 Assessment Weekday Daytime

	Seconds
Assessment Period	3600

BS4142 Assessment Delivery Noise - Delivery Period	Lorry Arriving	Lorry Door Slam	Opening Lorry Shutter	Removing Support Bars	Moving Roll Cages Inside Lorry	Unloading cages	Wheeling roll cages off into store	Wheeling empty cages from inside store to outside	Loading empty roll cages onto lorry	Securing Support Bars	Closing lorry shutter	Door Slam	Lorry starting	Reversing Alarm	Lorry driving away
Sound Exposure Level (SEL)	68	83	76	88	93	94	97	92	95	88	76	83	89	94	68
Source Measurement Distance	1	1	1	4	3	1	1	4	1	4	1	1	1	1	1
Number of Events	1	1	1	1	14	14	14	14	14	3	1	1	1	1	1
Average Distance to Receptor (m)	20	70	70	70	70	70	70	70	70	70	70	70	70	70	20
Distance Loss	-26	-37	-37	-25	-27	-37	-37	-25	-37	-25	-37	-37	-37	-37	-26
Reflections	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acoustic Feature Correction	0	3	0	0	0	0	0	0	0	0	0	3	0	6	0
Acoustic Screening	0	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	0	0
Rating Level)dB Laeq,1hour)	**6**	**8**	**-2**	**22**	**37**	**28**	**31**	**38**	**29**	**27**	**-2**	**8**	**11**	**27**	**6**
Combined Rating Level (dB Laeq, 1hour)	**42**														
Background Noise Level	**47**														
Comparison	**-5**														



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