Metric Survey Specifications for Cultural Heritage

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Historic England

Contents of Metric Survey Specifications for Cultural Heritage

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Preface

The survey brief

The preparation of a brief for the supply of survey services based on the requirements of this specification should ensure the necessary communication between the information user (the client) and the information supplier (the surveyor) required for the successful application of metric survey.

Performance of metric survey in heritage documentation

In order to obtain metric survey fit for the purposes of heritage management it will be necessary to consider not only the metric performance of measured data but also the required quality of work needed to act as both a record and an archive of the cultural heritage. The conventions of selection and presentation of measured drawing in architecture constitute a visual language that requires careful consideration. This specification contains both descriptions and illustrations of the required standard.

Use of the specification

This document is a description of the services and standards required for the supply of various types of metric survey. Sections 1 and 2 describe the general terms and performance requirements common to all services. Sections 3, 4, 5, 6, and 7 contain standards specific to laser scanning, photogrammetric survey, measured building survey, topographic survey, and building information modelling (BIM), respectively while section 8 covers presentation and delivery. A brief based on the accompanying MS Word document *Metric Survey Specifications for Cultural Heritage - Project Brief Template* should be prepared in order to communicate the requirements of a particular project.

The use of any part of this specification without reference to the appropriate clauses of sections 1, 2 and 8 plus the appropriate service description from parts 3, 4, 5, 6, and 7 is likely to result in an unsatisfactory product. While it is hoped that this specification will be distributed widely and is available for anyone to use, its use is not a guarantee of the required results and it is recommended that, if in doubt, professional advice is sought.

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1.1 Introduction

The general conditions cover aspects of undertaking survey that are common to most metric survey activities carried out on historic sites. A separate project brief will contain the administrative and logistical aspects of a particular project plus reference to any variable clauses in the following sections.

1.1.1 Pertinent legislation

Contractors are to be aware of all current statutory requirements relevant to the contract for survey work. The contractor's attention is brought to:

- the Ancient Monuments and Archaeological Areas Act 1979
- the Planning (Listed Buildings and Conservation Areas) Act 1990
- the Construction (Design and Management) Regulations of 2015, introduced under the Health and Safety at Work Act 1974.

Copies of the above legislation can be obtained from The Stationery Office:
www.tsoshop.co.uk

Tel: 0333 202 5070

Where the survey work occurs in countries other than England, the law of that country will apply.

1.1.2 Client's guidance on matters concerning survey

Contractors are required to comply with the client's guidance on matters of safety and standards of work regarding the historic fabric.

1.2 The contract and other documentation

1.2.1 Contract

The contract will consist of the conditions noted in the project brief, this specification plus any attached documents or diagrams.

1.2.2 Method statement

In response to a request for a quotation or invitation to tender, a method and resource statement is to be provided by the contractor. As a minimum it must include:

- method proposed for providing survey control and the required detail
- number of and positions of staff to be employed on project, including project leader
- survey equipment, cameras etc to be used
- access equipment to be used
- lighting and electrical equipment to be used
- any proposed alternative survey methods and their performance
- the anticipated level of completion
- data retention and archiving arrangements
- delivery schedule.

1.2.3 Risk assessment

A risk assessment must also be supplied with the quotation or tender. Known hazards will be highlighted in the project brief.

1.2.4 Site visits

The contractor may wish to visit the site to verify the requirements of the project and facilitate the production of the quotation or tender, the method statement and the risk assessment. Where access to land not in the client's care is necessary, assistance will be provided to secure the appropriate way-leaves.

1.2.5 Calibration certificates

Copies of up-to-date calibration certificates for all relevant equipment are to be supplied with the quotation or tender.

1.3 Contractual details

1.3.1 Completion of survey

The client will seek agreement with the contractor on the extent of cover, within the acceptable limits of tolerance and method (i.e., establishing any areas that require an alternative survey technique or that cannot be covered). Where obstructions to survey exist, the client will seek agreement about the possible extent of completion.

1.3.2 Right of rejection

The client reserves the right to reject the application of any proposed survey technique or submitted survey product.

1.4 Health and safety

1.4.1 Contractor's responsibilities for safety

The following requirements are included here as a guide, and contractors must ensure that all relevant safety regulations associated with the provision of survey on behalf of the client are complied with during the contract period. The contractor's attention is brought to the need for best practice in matters of safety.

1.4.2 Health and safety requirements

The client's health and safety requirements will be found in the project brief.

1.4.3 Health and Safety at Work Act 1974

Under this Act employers have responsibilities to their employees and those affected by their work (e.g., members of the public and staff on the site). Further information on this can be obtained from:

Health and Safety Executive: www.hse.gov.uk

Publications may be ordered from HSE Books: books.hse.gov.uk/hse/public/home.jsf

Tel: 0333 202 5070

1.4.4 Access equipment

Access equipment supplied or used by contractors or their agents must conform to the current safety standards. The contractor's attention is drawn to:

- Work at Height Regulations 2005 SI 2005/735 The Stationery Office 2005, ISBN 0 71762976 7. https://www.legislation.gov.uk/uksi/2005/735/contents/made

- Lifting Operations and Lifting Equipment Regulations 1998. Found in Safe Use of Lifting Equipment, available from HSE Books, ISBN 0 7176 1628 2. https://www.hse.gov.uk/work-equipment-machinery/loler.htm
- Provision and Use of Work Equipment Regulations 1998. Found in Safe Use of Work Equipment, available from HSE Books, ISBN 0 7176 1626 6. https://www.hse.gov.uk/work-equipment-machinery/puwer.htm

Full details, certification and nominated safety contacts on proposed access equipment, where relevant, are to be included in the method statement.

1.4.5 Electrical equipment

Where applicable, electrical equipment (the use of domestic/battery-operated equipment is not included) must meet the requirements of the Electricity at Work Regulations 1989. Found in the Memorandum of Guidance on the Electricity at Work Regulations 1989, available from HSE Books, ISBN 0 7176 1602 9.
https://www.legislation.gov.uk/uksi/1989/635/contents/made

1.5 Damage to site and fabric

There is a range of penalties and powers of prosecution under the provisions of the Ancient Monuments and Archaeological Areas Act 1979 and the Planning (Listed Buildings and Conservation Areas) Act 1990 should unauthorised work be carried out or damage be caused to the building or monument.

1.5.1 Use of ground marks

The use of nails, permanent survey marks, etc is subject to approval of the mark and its location. The insertion of any mark may require scheduled monument consent (SMC) and must not be done without the permission of the client and/or landowner.

1.5.2 Use of surface-mounted targets

Surface-mounted targets, such as for photographic or laser scanning control, must be no larger than 200mm by 200mm and must only be fixed with an approved adhesive that will allow removal without damage to the surface.

1.6 Survey material supplied

1.6.1 Copyright

The copyright of all materials generated as part of the contract is to be transferred to the client unless stated otherwise in the project brief.

1.6.2 Retention of survey documentation

On request the contractor shall make available to the client all materials used for the compilation of the required survey. This material must be retained by the contractor for a minimum of seven years. As a minimum this material will include: field notes and/or diagrams generated while on site; the raw and processed data used for the final computation of control; and a working digital copy of the metric survey data that forms each survey drawing or model (including formatted 2-D and ‘raw’ 3-D data files). If during this period the contractor wishes to change the format of this data archive, they are to seek the client’s permission.

Section 2
General performance and control of metric survey

2.1 General performance requirements

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2.1 General performance requirements

Metric survey techniques are required to deliver data that can be verifiably repeated. There are three aspects to the required performance of metric survey data. These are:

- measurement performance
- feature selection performance
- presentation performance.

This specification is intended for the generation of base survey data, located accurately in its true 3-D position, to which specific thematic input or attributes can be added if required.

2.1.1 Measurement performance

Measurement performance may be considered in terms of both accuracy and precision.

Definition of accuracy

Accuracy describes the closeness between measurements and their true values. The closer a measurement is to its true value, the more accurate it is.

Definition of precision

In surveying, precision is taken to describe the consistency with which a measurement or set of measurements can be repeated.

Repeatability of capture method

Data capture must be by a method that can be repeated, to the appropriate order of precision, by the use of similar equipment and suitably qualified personnel. Therefore, the proposed method must be fully and clearly described in the method statement.

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Further information

For further information on measurement performance see the Historic England publication *Traversing the Past - The total station theodolite in archaeological landscape survey* 2016 Product Code: HEAG062 https://historicengland.org.uk/images-books/publications/traversingthepast/

2.1.2 Scale tolerance and point density

The precision of a survey is to be commensurate with the intended scale of presentation within the tolerances tabulated below. It is expected that surveyed data will allow repetition of a given measurement as presented on a plotted drawing within the following maximum tolerances when checked from the nearest control point.

Precision

Required maximum tolerance for precision of detail

scale	*acceptable precision (1 sigma)*
1:10	+/- 5mm
1:20	+/- 6mm
1:50	+/- 15mm
1:100	+/- 30mm
1:200	+/- 60mm
1:500	+/- 150mm

Point density/rate of capture

Required distribution of measured points

scale	*point cloud*	*digitising**	*field survey†*
1:10	≤1mm	1–15mm (max 0.25m)	2–30mm (max 0.5m)
1:20	≤2.5mm	2.5–30mm (max 0.5m)	5–60mm (max 1m)
1:50	≤5mm	5–50mm (max 1m)	10–100mm (max 2m)
1:100	≤15mm	15–100mm (max 1.5m)	20–200mm (max 3m)
1:200	≤30mm	30–300mm (max 2.5m)	50–600mm (max 5m)
1:500	≤75mm	75–750mm (max 5m)	0.1–1.5m (max 10m)

* From photogrammetric model, laser scan point cloud or ortho-image.
† For example by total station theodolite (TST) or global navigation satellite system (GNSS).

In both cases where lines appear straight or detail is sparse the interval may be increased up to the maximum shown in brackets.

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Further information

Scale tolerance can be specified in terms of standard deviation (sigma) or root mean square error (rmse). Standard deviation is based on the assumption that random errors will have a normal distribution around the mean. One standard deviation means there is about a 68 per cent probability that all measurements will have errors not greater than the mean value. For more information on this subject see *Measured surveys of land, buildings and utilities*, RICS guidance note, 3rd edition (2014) ISBN 978 1 78321 064 0 https://www.rics.org/uk/upholding-professional-standards/sector-standards/land/measured-surveys-of-land-buildings-and-utilities/

2.1.3 Completeness of survey

The detail and precision with which survey data is collected must be commensurate with the required scale across the entirety of the survey, whatever the method or methods employed.

Survey coverage, with regard to both the extent of the survey and the completion required within that extent, is to be determined by the needs of the project. Elevations and sectional elevations shall be complete to full height unless otherwise specified. Any requirement for field completion of obscured areas by another method will be by agreement between the contractor and the client.

2.2 Control of survey

2.2.1 General requirements

The control for all survey projects must be reliable, repeatable and capable of generating positions within the required tolerances. The method and equipment used to establish survey control networks is at the discretion of the contractor; however, the proposed methods and equipment must be detailed in the method statement. The contractor is to establish a hierarchical network of coordinated and levelled permanent, semi-permanent and temporary survey stations to control the survey and to provide references for future surveying and engineering works.

All coordinate and level values generated must be expressed in metres to three decimal places and presented in the order of easting (X), northing (Y) and height (Z).

2.2.2 Hierarchy of control

The primary survey control network is to consist of permanently and semi-permanently marked stations and should, wherever practical, wholly enclose the detail survey area. If possible, the distance between primary stations should not be less than 100 metres and not more than 300 metres. Additional secondary control networks consisting of semi-permanent control stations are to be established from primary control such that the spacing between adjacent primary and secondary control stations is not less than 50 metres and not more

than 300 metres. Tertiary control networks and spur stations required for mapping purposes may be established from secondary control stations at the contractor's discretion.

Survey control stations or targets are to be named using the following format *???, where * is the type prefix and ??? is a three-digit numerical value to identify the individual target. For example, 'P001' is the first primary station.

Type	Prefix	Description
Primary	P	Primary control is the highest order most secure control on the site, for example the highest accuracy GNSS baseline present or the local site datum.
Secondary	S	Secondary control is established via observations to the primary control, for example a traverse based on a primary baseline.
Tertiary	T	Tertiary control is established via observations to the secondary control for example a sub-traverse or spur station based on a secondary baseline.
Photogrammetric Target	PH	Targets coordinated for the purpose of controlling photogrammetry, for example butterfly targets.
Laser Scanning Target	LS	Targets coordinated for the purpose of controlling laser scanning, for example chequer boards or tilt and turn targets.
Aerial Mapping Target	A	Targets coordinated for the purpose of controlling drone based aerial mapping, for example chequer boards.

2.2.3 New control network

Survey grid

Where the establishment of a new control network is required it is to be related to Ordnance Survey National Grid (OSGB36) and/or a local plane grid derived from OSGB36. The network must be derived from GNSS observations related to the Ordnance Survey National GNSS Network Active Stations and transformed to OSGB36 using Ordnance Survey National Grid Transformation OSTN15®.

A local grid origin is to be established in such a way as to ensure that the Eastings will not match the Northing values anywhere on the site and that all values will be positive. The origin used should ensure that local grid coordinates will not be confused with National Grid values.

Where it is not possible/required to relate the local grid to Ordnance Survey National Grid, a local grid will be established such that the orientation is either as close to Ordnance Survey National Grid north as is practicable or parallel to the principal axis of the historic building or monument being surveyed.

Level datum

The level datum to be used is Ordnance Datum Newlyn (ODN) derived by GNSS observations related to the Ordnance Survey National GNSS Network Active Stations and transformed to ODN using Ordnance Survey National Geoid Model OSGM15®.

A local arbitrary datum may be required to be used on occasions, where this is the case full details of the site benchmark are to be included with the permanent survey mark witness diagrams.

2.2.4 Existing control network

Where a previously defined site control network exists, the necessary information will be supplied by the client to enable the re-occupation of permanently marked points. This will include a full listing of 3-D coordinates and witness diagrams. During re-occupation and re-observation, the contractor is to:

- locate each marked point, by setting out from local detail or coordinates if necessary
- visually check for disturbance and undertake such observations as are necessary to confirm their integrity
- revise witness diagrams as necessary and record date of inspection.

Where discrepancies are found, the client is to be contacted to agree any necessary variations.

2.2.5 Vertical control using sprit levelling

Required accuracy/misclosures

Where a high standard of accuracy is required one primary control station is to be fixed in level and the remainder derived by spirit levelling. When using a level to observe survey control the level run must always close internally either in a loop or by double levelling. Where a lower standard of accuracy is specified then GNSS or traverse derived level values may be accepted.

Spirit level run misclosures are to be assessed by using Clark's Formula of:

- for level runs less than 1km: $E = 0.005 \sqrt{N}$ (where N = number of set ups) or
- for level runs greater than 1km: $E = 0.012 \sqrt{D}$ (where D = traverse length in kilometres).

When using digital levels, maximum misclosure should be approximately half the above values. If not, it is likely that a gross error has been made and further checks should be carried out.

Control observations and measurements

Closed levelling circuits from the required site datum point shall connect survey control stations and the resultant relative heights are to be used to determine absolute level value.

2.2.6 Horizontal and vertical control using traversing

Required accuracy/misclosures

Control networks are to have a linear accuracy of better than 1/20000 prior to any adjustment being made.

The maximum distance error between adjacent permanent survey control stations must not exceed 5mm ± 5 parts in 1000000 or 10mm, whichever is the greater.

Vertical differences in height between adjacent stations, when measured in the forward traverse direction, shall agree to better than ± 20 mm when compared with the vertical difference in height, when measured in the reverse traverse direction, or when checked by spirit levelling methods.

Control observations and measurements

The contractor is to undertake and record survey observations and measurements sufficient to enable the reduction and computation of co-ordinates to the required accuracy standards.

Each new control network must start and finish with observations to control stations of a higher network order.

A minimum of three rounds of observations and measurements are to be taken on each face of the instrument to ensure that unambiguous data is collected, and that redundant data can be excluded without compromising the validity of the computations.

All horizontal control observations are to be made to prisms optically or laser plumbed above the survey control mark.

Distances between adjacent survey control stations must be measured in both directions in order to eliminate centring errors.

Sufficient observations and measurements to enable computation of absolute level values for each secondary and tertiary survey station are to be taken while ensuring that unambiguous data is collected, and that redundant data can be excluded without compromising the validity of the computations.

Adjustments carried out to the observed network, including type and method of adjustment used and the results of transformations, are to be detailed in the final survey report.

2.2.7 Horizontal and vertical control using GNSS

Except where otherwise defined in the project brief, all horizontal and vertical control is to be related to the Ordnance Survey National GNSS Network as described in section 2.2.3. For guidance on good practice refer to RICS Guidelines for the Use of GNSS in Land Surveying and Mapping, 2nd edition (2010) ISBN 978 1 84219 607 6 https://www.rics.org/uk/upholding-professional-standards/sector-standards/land/guidelines-for-the-use-of-gnss-in-land-surveying-and-mapping/

General GNSS observation requirements

One of three orders of GNSS observation are to be used depending on the accuracy requirements and the nature of the project. In general, this will be the third order unless otherwise stated in the project brief.

Observation times and sources of control are detailed below:

Order	Observation Period	Source control
First	Minimum 4 hours static	Minimum 4 OS active stations
Second	Minimum 20 minutes static	Minimum 2 second order stations
Third	As described below for network RTK	Network RTK

For all GNSS observations, dual frequency, survey grade GNSS receivers are to be used. For network real time kinematic (RTK) observations, receivers should receive signals from the GPS and GLONASS constellations as a minimum.

Should it be required by the project brief, the contractor will submit a detailed plan, as part of the method statement, for all GNSS control network observations for approval prior to commencement of any work. This plan is to detail the approximate locations of control stations, a network diagram and the proposed schedule of occupation, including duration and observation periods.

GNSS control stations that are intended to measure height are to be located with a substantially clear view of the sky and not close to buildings or other structures that may introduce multipath effects. A minimum of five satellites must be observed for the full observation period, with a minimum elevation mask of 13°. Geometric dilution of precision (GDOP) values must not exceed 5 for the entirety of the observation period.

GNSS baselines are to be computed using National Geodetic Survey (NGS) antenna models. Baselines should be computed using post-processed, in preference to broadcast, ephemeris.

Baselines are to be post-processed and adjusted to the source control stations with a least squares network adjustment.

Receiver independent exchange format (RINEX) data for any post-processed GNSS observations is to be retained and supplied on request. All baseline computations and network adjustments are to be provided in digital form with the survey report.

Network RTK observations are to be made using at least three periods of three-minute observations separated by at least 20 minutes. If the difference between one of the three periods and any other exceeds 30mm, it shall be discarded from the results. Network RTK stations are not to be established in isolation. Each station must be connected by spirit levelling to at least one other station. For further guidance see TSA Guidance Notes for GNSS Network RTK Surveying in Great Britain (2015) https://www.tsa-uk.org.uk/downloads/

Transformations

All transformations from GNSS derived ETSR89 coordinates to OSGB36 are to be carried out using the OSTN15® and OSGM15® transformations, licensed by the Ordnance Survey.

2.2.8 Survey marks

Permanent or temporary ground marks are to be as non-invasive as possible and preferably existing detail should be used. The client must approve the type and location of any permanent mark before insertion. In some cases, scheduled monument consent (SMC) will be required. Even the insertion of nails may require SMC. In any case, nails must only be driven into a suitable material, for example earth, gravel or a mortar joint, not historic floorboards etc.

Contractors are reminded that there is a range of penalties and powers of prosecution under the provisions of the Ancient Monuments and Archaeological Areas Act 1979 and the Planning (Listed Buildings and Conservation Areas) Act 1990 should unauthorised work be carried out or damage be caused to the building or monument.

The type of mark to be used will depend on:

- the project brief
- site limitations (including any requirement for SMC)
- ground conditions
- landowner restrictions.

For further details on obtaining scheduled monument consent in England see the following link to the Historic England website. https://historicengland.org.uk/advice/hpg/consent/smc

Permanent stations

Permanent stations must be one of the following type:

- bolt
- earth anchor
- stainless steel survey nail
- cut mark or punch mark.

Bolts should be installed by drilling and fixing with an epoxy resin type adhesive into a stable and permanent structure (not asphalt or kerb stones).

Temporary stations

The type of mark used for temporary stations may be any of the following, depending upon the above criteria:

- wooden peg or stake driven flush to the ground and with a painted top
- stainless steel survey nail

- cut mark or punch mark
- indelible pen mark on concrete surface.

Temporary survey stations are expected to remain usable for a minimum period of three weeks after delivery of the survey.

Landowners' permission

Permission of landowners must be obtained prior to the establishment of marks. The landowner must be consulted on the installation of all types of marker. Earth anchors are to be buried to a depth agreed with the landowner (normally 0.1m below ground level). Wooden pegs must be driven to ground level; they must not be left protruding above ground level as a trip hazard.

Where any form of ground penetrating station mark is to be established, with the exception of small nails or bolts, appropriate checks for underground services must be undertaken prior to installation. For marks penetrating more than 0.5m a search must be made with all appropriate utility service providers. Where temporary pegs are installed, they must not penetrate the ground to a depth of more than 0.2m.

2.2.9 Use of targets on historic fabric

Where survey targets are to be applied to historic fabric, a suitable non-marking, non-destructive method of adhesion is to be used. This must allow for the removal of the targets without damage to, or marking of, the fabric. Details of the proposed method of adhesion are to be included in the method statement for the survey. The client reserves the right to refuse application if the proposed substance is deemed to be unsuitable for historic buildings or monuments. All targets must be removed before the commission is completed; any targets remaining after completion will still have to be removed at the contractor's expense.

Surface-mounted targets must be no larger than:

- 60 by 40mm for photographic control
- 200mm by 200mm for laser scanning control.

2.2.10 Survey report

A detailed survey report is to be provided including:

- Site name and location
- Project reference number
- Dates of current survey
- Site reconnaissance details including conditions at time of survey (e.g., weather)
- Survey personnel who formed the site and processing teams
- Field equipment used
- All GNSS observations and survey network analysis, adjustment and output reports for establishing site control relative to Ordnance Survey National Grid (OSGB36) and Ordnance Datum Newlyn (ODN) where applicable
- All horizontal and vertical control survey network analysis, adjustment and output reports
- Coordinate schedule including all reference control and target coordinates
- Witness diagrams of all reference control stations – *see* 2.2.11
- Quality assurance/accuracy compliance
- Equipment calibration certificates
- Survey field records.

2.2.11 Witnessing of stations

Full witness diagrams are to be provided with the survey report for all permanently marked control stations.

Witness diagrams must include:

- coordinate values to three decimal places as eastings (X), northings (Y) and height (Z)
- a sketch diagram and dimensions to at least three points of hard detail
- a written description of the mark
- a photograph of the location.

Section 3

Standard specification for the collection, registration and archiving of laser scan data

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3.1 Definitions

3.1.1 Laser scanning

Terrestrial laser scanning is defined as the use of a ground-based device that employs a laser to automatically measure three-dimensional coordinates on the surface of an object in a systematic order and at a high measurement rate. For the purposes of this document, close-range and terrestrial laser scanners will jointly be referred to as laser scanners.

The specification of airborne lidar survey is beyond the scope of this document.

3.1.2 Point cloud

Any laser scanning system generates a point cloud which can be regarded as the raw product of a laser scan survey. A point cloud is a collection of XYZ coordinates in a common coordinate system that portrays to the viewer an understanding of the spatial distribution of a subject. It may also include additional information, such as return intensity or even colour values. Generally, a point cloud contains a relatively large number of coordinates in comparison with the volume the cloud occupies, rather than a few widely distributed points. Some instruments also provide more fundamental information on the full reflectance of the laser pulse (known as full-waveform scanners).

3.1.3 Scan registration

The process by which the laser scan data is fixed relative to the site survey control in line with the specified grid and datum requirements.

Targets located in a defined coordinate system will usually be used to register multiple scans together. Positioned using a total station theodolite, they provide additional checks on the geometric quality of the scan data and enable the transformation of the complete dataset to a common coordinate system.

It is also possible to register laser scan data together without the use of any external reference targets. Known as 'cloud-to-cloud', this target-less registration approach relies on suitably dense point clouds being captured with appropriate overlap between adjacent scans to enable sufficient matching points to be derived.

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Further information

For further information on laser scanning see the Historic England publication *Advice and guidance on the use of laser scanning in archaeology and architecture* 2018 Product Code: HEAG155 https://historicengland.org.uk/images-books/publications/3d-laser-scanning-heritage/

For an introduction to airborne lidar and its application to the historic environment see the Historic England publication *Using Airborne Lidar in Archaeological Survey - The Light Fantastic* 2018 Product Code: HEAG179 https://historicengland.org.uk/images-books/publications/using-airborne-lidar-in-archaeological-survey/

3.2 Laser scan survey

3.2.1 Method statement

The method statement, in the case of laser scanning, should as a minimum include:

- technical specifications of the proposed scanning system(s)
- the proposed point density of the scans
- the proposed targeting and registration approach

- the location of potential data voids and how they might be in filled.

3.2.2 Equipment calibration

All laser scanners must be serviced and calibrated In line with the manufacturer's recommendations prior to any work commencing. Uncalibrated equipment shall not be used under any circumstances.

The contractor is to provide copies of appropriate certification, as required, in the survey report.

3.2.3 Health and safety

Laser light can, in some cases, be harmful and therefore suitable precautions must be taken to ensure the safety of both the scanner operator and any members of the public that may encroach within the area of scanning.

Systems that use Class 1, 2 and 3R lasers operate within acceptable eye-safe limits and therefore can be used for survey purposes at publicly accessible sites. Systems that use Class 3B or 4 lasers operate beyond recognised eye-safe limits and therefore must not be used for any survey-related activity at any publicly accessible site. Signs warning visitors that scanning lasers are in use should be displayed in each scan area. These are mandatory for Class 2 and 3R laser scanning systems and optional for those using Class 1 lasers.

3.2.4 Weather

Laser scanning should not be undertaken during inclement weather (e.g., rain, snow, fog, mist, strong winds), where the quality of data will be affected due to returns and scattering from droplets, refraction of the measurement beam, or a lack of balance in the tilt compensator.

3.2.5 Accuracy of control

Laser scan targets are to be coordinated to a 3-D accuracy of either:

(a) ±3mm; or

(b) as stated in the project brief.

The scanner must be set up in a stable position while operating to ensure minimum movement and distortion within each scan.

All survey stations that are used to measure targets for the laser scanning should be located adjacent to the area where the laser scan data is to be collected and no more than 100 metres apart.

3.2.6 Control targets

The type of target used, their distribution and the method of laser scan observation to them are all discretionary. They must, however, be:

- not so large that they obscure important fabric detail
- positioned away from the principal surface being surveyed
- not attached to any important historic fabric
- arranged so as to minimise data voids in the point cloud
- removed at the end of the survey, either on completion of site work or after successful registration is achieved.

A description of the targets and proposed registration approaches must be included in the method statement.

3.2.7 Point density

The required point density and precision is defined below for the scale specified in the project brief.

	scale	*effective point density*	*precision of measurement*
Close Range	1:5	0.5mm	+/- 0.5mm
	1:10	1mm	+/- 1.0mm
Terrestrial	1:20	2.5mm	+/- 2.5mm
	1:50	5mm	+/- 5.0mm
	1:100	15mm	+/- 15.0mm

[Text Box]
Further information

Scanning at a higher density than the accuracy of the measurement may generate an impressive dataset but will result in a high level of noise within the resulting point cloud. The smaller the distance between points, the more likely it is that an object will be recorded. So as a general rule the point density should be at least half the size of the smallest feature to be recorded within the scan. The width of the measurement beam must not be greater than double the effective point density. For most instruments point density during the scanning process depends on range, so it is not normally possible to maintain a constant point density over the entire subject.

3.2.8 Data voids

Voids caused by moving obstructions, such as cars and pedestrians, will not be acceptable unless it is impossible to restrict public access into the scan area. Any obstructions that will potentially occlude areas in the scan should be highlighted in the method statement. The use of multiple scans or alternative measurement technologies for potentially infilling the data void may also be proposed.

3.2.9 High level coverage

Methods used to achieve high level coverage must be described in the method statement alongside any proposed mechanisms for stabilising the platform and laser scanner.

3.3 Registration

3.3.1 Registration methods

Scan registration must be performed using:

- control targets placed within each scan; or
- a target-less ‘cloud-to-cloud’ approach; or
- a combination of the above.

3.3.2 Registration accuracy

- Each laser scan will be required to fit to the survey control within 5mm
- Target registration must demonstrate residuals no greater than 5mm.

Where registration is to be undertaken using solely targets a minimum of four surveyed targets per scan is required, and they should be positioned to ensure good spatial geometry.

Cloud-to-cloud registrations must be referenced to the site control network using a minimum of four coordinated targets.

3.3.3 Registered scan data requirements

All laser scans are to be registered to the site control network, unless otherwise agreed. Preferably the complete scan project will be registered together. If, however, a scan project is too large then the scan registration may be broken into sub-projects.

3.4 Provision of point cloud data

3.4.1 Deliverables

As well as any derived products noted in the project brief the following deliverables may be required:

- Raw and registered scan data in formats as described in section 3.4.5.
- Metadata as described in section 3.4.6.
- A survey report including as a minimum:
    - a diagram showing the approximate scan positions
    - a diagram showing the location of all targets
    - a listing of 3-D coordinates of all control points/targets
    - a registration report showing the overall accuracy of the laser scan survey.

3.4.2 Colour information

The project brief will specify if alongside the laser intensity value, RGB colour information, acquired on a per point basis at each scan position, is required.

[Text box]
Further information

Almost all laser scanning systems provide intensity information alongside the XYZ coordinates for each 3-D point that comprises the point cloud. Most also use an imaging sensor, either located within the scanner or attached externally, to acquire separate colour imagery of the scan scene from which an RGB value for each point can be assigned. Depending on the scanner the capture of colour information can add substantially to the scanning times on site.

3.4.3 External imagery

The project brief will specify if panoramic imagery acquired with a separate camera, the optical centre of which has been aligned with the laser scanner measurement centre is required.

3.4.4 File naming convention

File names for laser scan datasets are to conform to the standard naming convention as specified in section 7.

3.4.5 File formats

The raw scan data (as collected by the scanner before processing) and any later registered versions should be delivered in both its proprietary (manufacturer specific) format and in the non-proprietary E57 data exchange format**.**

3.4.6 Metadata

Metadata (information relating to the captured scan data) must be supplied with all raw scan data and as a minimum is to include the following:

- raw data file name
- project reference number
- scanning system used including serial number
- average point density on the subject (with reference range)
- total number of points
- date of capture
- site name
- contractor name.

This metadata can either be provided in digital form for each individual scan or incorporated within each scan data file, ensuring that the required data fields are correctly included and can be retrieved using the common post-processing software.

The project brief will specify if the metadata is to be supplied using a standard template such as that published by the Archaeological Data Service
https://archaeologydataservice.ac.uk/advice/Downloads.xhtml

Section 4
Standard specification for photogrammetric survey

4.1 Definitions

4.2 Control for photogrammetric survey

4.3 Photogrammetric survey

4.4 Image acquisition

4.5 Photogrammetric processing

4.6 Vector drawing content

4.7 Orthophotographic processing

Figures

4.1 Definitions

4.1.1 Photogrammetric survey

Photogrammetric surveys are those where overlapping image sets are used together with survey control to produce a three-dimensional representation of the subject from which the required output is generated. Products may be orthophotographs, scaled drawings digitised from them, digital surface/terrain models (DSM/DTM) or other vector products derived from them (such as contour lines).

4.1.2 Orthophotographic survey

An orthophotograph is a digital image that has been corrected for lens distortion and scale errors due to both camera tilt and depth displacement. *See* Figures 4.1 and 4.2.

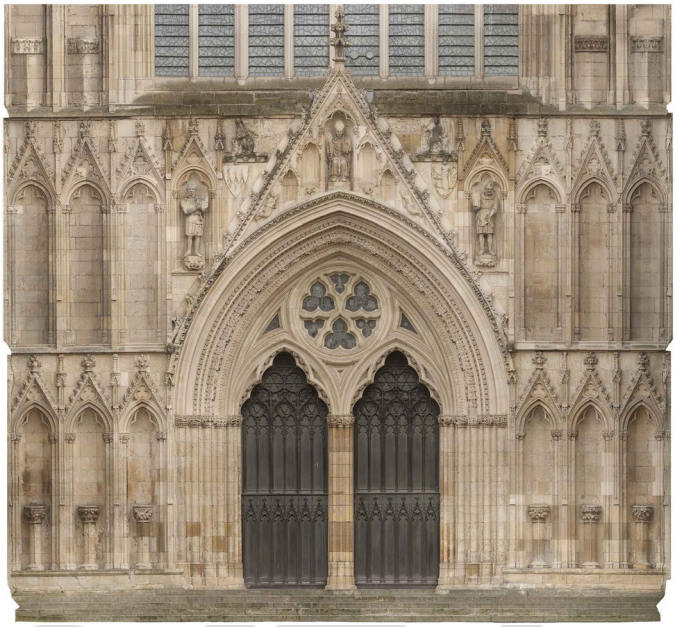


Figure 4.1: Orthophotograph derived from ground-based photography.

Figure 4.2: Orthophotograph derived from SUA aerial photography.

4.1.3 Rectified photographic survey

Rectified photographic surveys are defined as those where single photographs are taken with the image plane of the camera approximately parallel to the principal plane of the object and then further digitally corrected to remove scale errors due to camera tilt. Any requirement for rectified photography with be specified by variation in the project brief.

[Text box]
Further information

For further information on photogrammetry and its application to the historic environment see the Historic England publication *Photogrammetric Applications for Cultural Heritage* 2015 Product Code: HEAG066 https://historicengland.org.uk/images-books/publications/photogrammetric-applications-for-cultural-heritage/

4.2 Control for photogrammetric survey

4.2.1 Accuracy of control

Building Survey

Image control points are to be provided to a 3-D accuracy of either:

(a) ±3mm; or

(b) as stated in the project brief

Topographic or landscape survey

Image control points are to be provided to a 3-D accuracy of either:

(a) ±20mm; or

(b) as stated in the project brief

A listing of the 3-D coordinates is to be included in the survey report.

Where aerial imagery is used in support of topographic survey (to provide a DEM/DTM) the aerial control must be on the same coordinate system as the topographic survey.

4.2.2 Targets

For photogrammetric surveys of buildings and structures, a minimum of four coordinated control points, directly observed in the field, are to be provided for each elevation. Where practicable, targets placed on the fabric are to be used (*see* sections 1.5.2 and 2.2.9) and must:

- be no larger than 60mm × 40mm
- no thicker than 0.5mm
- have a matt, non-reflective surface finish.

Where photogrammetry is combined directly with 3-D laser scanning, for example to provide high-level infill, coordinated targets or detail points (X below) that are visible in both sets of data must be used.

For aerial photogrammetry topographic or landscape surveys, a minimum of eight coordinated control points, directly observed in the field, are to be provided. Where practicable, targets are to be used and must:

- be large enough to be easily identified at the required ground sample distance (gsd)
- have a matt, non-reflective surface finish.

4.2.3 Use of detail points

Where targets cannot be used it is acceptable to use unambiguous points of detail. A sketch diagram or annotated image showing the location of each point is to be included in the survey report. Detail points must be easily identifiable and must not be taken from the extreme edges of the subject. Whether it will:

(a) not be acceptable; or

(b) only be acceptable where absolutely essential; or

(c) be necessary,

solely to use detail points for image control will be stated in the project brief.

4.2.4 Check Points

As well as control points, a number of check points, which are not used in the adjustment, are required to verify the accuracy of the reconstruction. For building elevations, a minimum of 50% additional points are required (so if four control points are used, a minimum of two check points), for topographic surveys a minimum of 25% additional check points are required (so 12 control points requires at least three check points). The variations between measured and reconstructed point values are to be included in the survey report.

4.3 Photogrammetric survey

4.3.1 Cameras

Cameras must have a sensor array with at least 20 million pixels and each pixel must be a minimum size of 6 microns. Details of proposed cameras and lenses are to be included in the method statement. Use of a calibrated lens with a fixed focal length is either:

(a) essential; or

(b) not essential,

as stated in the project brief.

Aerial photography acquired from fixed-wing, small unmanned aircraft (SUA) may require the use of compact cameras recording in JPG format. This is either:

(a) acceptable as long as the requirements for ground sample distance (gsd), as set out in section 4.4.2, are met; or

(b) not acceptable,

as stated in the project brief.

4.3.2 Digital image requirements

Images are to be captured in RAW format where possible and these files must be supplied as well as TIFF versions. Colour imagery is to be white balanced for either daylight or artificial illumination as appropriate.

The required colour space is the Adobe RGB (1998) ICC colour profile. A standard colour chart and/or grey card is to appear in at least one of the images per subject area to provide guidance on colour balancing prior to output.

4.4 Image acquisition

The whole of the subject must be covered by overlapping imagery.

4.4.1 Imagery arrangement

Images must be acquired so as to provide the following minimum overlap:

- between adjacent images of at least 80 per cent
- between adjacent strips of images of at least 40 per cent.

4.4.2 Ground sample distance

The ground sample distance (gsd) for each image is to be a maximum as tabulated below

for 1:10 output scale, 0.5mm

for 1:20 output scale, 1mm

for 1:50 output scale, 2mm

for 1:100 output scale, 4 mm

for 1:200 output scale, 10mm

for 1:500 output scale, 20mm

[Text box]
Further information

Gsd is the size in the real world of that part of the subject represented by one pixel of a digital image. It is a function of focal length, camera to subject distance (or flying height) and pixel size.

gsd = (H/f) × p

where H = camera to subject distance or flying height, f = focal length, p = pixel size (sensor size in one axis divided by pixel count in same axis)

4.4.4 Use of oblique imagery

In general photography is to be taken square-on to the subject but oblique and/or convergent imagery will also be required to ensure suitable geometry for successful reconstruction and complete coverage of all elements of the subject.

4.4.5 High-level coverage

Where the subject to be surveyed is of a significant height, imagery must still be taken within the stated tolerances for overlap and gsd as outlined in sections 4.4.1 and 4.4.2. Aerial imagery from SUA will normally be the most efficient way of achieving this, but if this is not possible the use of access equipment is:

(a) not essential; or

(b) at the contractor's discretion; or

(c) essential,

as stated in the project brief.

4.4.6 Use of small unmanned aircraft (SUA)

All image acquisition undertaken with a SUA platform must conform to current UK Aviation Law, as detailed in the Air Navigation Order 2016. See also www.caa.co.uk/cap722

A current and valid CAA Permission for Commercial Operation or Operational Authorisation and evidence of public liability insurance cover must be supplied prior to survey commencing. The conditions listed within each individual permission\authorisation must be specifically checked to confirm they are appropriate for the specified survey task.

Full details of any proposed use of a SUA platform must be included in the method statement along with both a pre-site survey, and a risk assessment that considers all associated risks and how these will be mitigated.

[Text Box]
Further information

For further information on the acquisition of aerial imagery for photogrammetry, particularly from conventional aircraft, see RICS Earth observation and aerial surveys 6th edition global guidance note (2022) ISBN 978 1 78321 442 6 https://www.rics.org/uk/upholding-professional-standards/sector-standards/land/earth-observation-and-aerial-surveys-6th-edition-global-guidance-note/

4.4.7 Completeness of survey

Survey data obtained using photogrammetric techniques is to be as complete as possible.

The client will endeavour to provide a clear and unobstructed view for photography prior to survey commencing, but where obstructions prevent the use of images it will be acceptable to omit detail that cannot be clearly seen. Field completion by another method may be required.

Additional oblique aerial imagery at approximately 45° off-nadir (to be used for infill under isolated trees, for example) will either:

(a) be required; or

(b) not be required,

as stated in the project brief.

4.5 Photogrammetric processing

All photogrammetric processing work is to be carried out using dedicated photogrammetric software utilising overlapping imagery. The choice of software and method is discretionary but must be outlined in the method statement. Material generated must be within the stated tolerances and meet the specified standard for vector drawing extraction or orthophotograph production.

4.5.1 Accuracy of restitution

The accuracy results for all processed models are to be recorded and provided in the survey report.

4.5.2 Accuracy of processing

For the production of line drawings, digitised points must be within the accuracy figures noted below; the standard relates to the accuracy of final line width of the vector data generated.

For output at standard scales, using a 0.18mm line width these are:

for 1:10 output scale, 2mm in reality

for 1:20 output scale, 4mm in reality

for 1:50 output scale, 9mm in reality

for 1:100 output scale, 20mm in reality

for 1:200 output scale, 40mm in reality

for 1:500 output scale, 90mm in reality

4.6 Vector drawing content

See Section 5 for details of any vector drawing requirements.

4.7 Orthophotographic processing

The choice of equipment, software and method for providing the required survey are discretionary, but they must be outlined in the project method statement.

4.7.1 Accuracy of processing

All overlapping images are to be processed, so that the residuals obtained during the reconstruction procedure enable the generation of survey data that is commensurate with the required output resolution (gsd).

4.7.2 Digital surface model

Unless otherwise stated in the project brief DSM point spacing is to be:

for 1:10 output scale, 1mm maximum

for 1:20 output scale, 5mm maximum

for 1:50 output scale, 10mm maximum

for 1:100 output scale, 10mm maximum

for 1:200 output scale, 20mm maximum

for 1:500 output scale, 40mm maximum

4.7.3 Mosaic generation

The orthophotograph mosaic is to be generated so that the joins between images are not visible in the final output. Seam lines should be edited if necessary. Colour balance must be consistent and any distinct shadows in recessed areas are to be digitally removed.

4.7.4 Orthophotograph output resolution

The final output scale is to be as specified in the project brief

with a maximum gsd of

for 1:10 output scale, 0.5mm

for 1:20 output scale, 1mm

for 1:50 output scale, 2mm

for 1:100 output scale, 6 mm

for 1:200 output scale, 12 mm

for 1:500 output scale, 25 mm

unless otherwise stated in the project brief

4.7.5 Presentation of orthophotographs

All orthophotographs are to be attached to an AutoCAD .DWG file and correctly geo-referenced to the control coordinate system.

The images are to be supplied as either:

(a) TIFF files; or

(b) geoTIFF files,

as stated in the project brief. Where geoTIFF is specified, a separate world file for each image is also required.

Section 5
Standard specification for measured building survey

Figures

5.1 Measured building survey

5.1.1 Definition of measured building survey

For the purpose of this specification 'measured building survey' is defined as the supply of metric survey data pertaining to buildings and presented as plans, sections, sectional elevations and elevations.

5.2 Description of products

The survey is to be supplied as a CAD drawing in the form of plans, sections, sectional elevations and elevations presented graphically (i.e., using lines and symbols). Where necessary the graphical data should be supplemented by text annotation (e.g., description of floor covering and material, height information). The correct use of line type, line weight and layers is essential in order to present the drawing elements in accordance with architectural convention. The building subject is to be presented using an orthogonal projection (i.e., the plan, section, sectional elevation or elevation is to be shown as a parallel projection onto a horizontal or vertical reference plane as described below).

5.2.1 Plan

A view of the structure as seen in a horizontal reference plane defined by the cut-line. The plan will show information above and below the reference plane unless this information is covered on another plan. The cut-line will reveal full architectural detail, deformation or displacement both at the height of cut and also above and below it. It should be made as informative as possible by cutting across door and window openings.

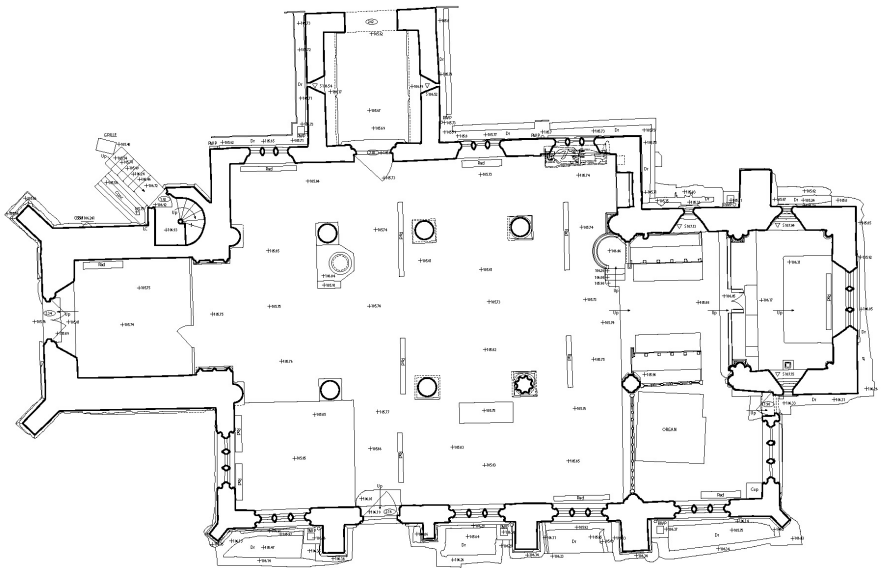


Figure 5.1: Plan showing use of line weights. Originally prepared for presentation at 1:50 scale.

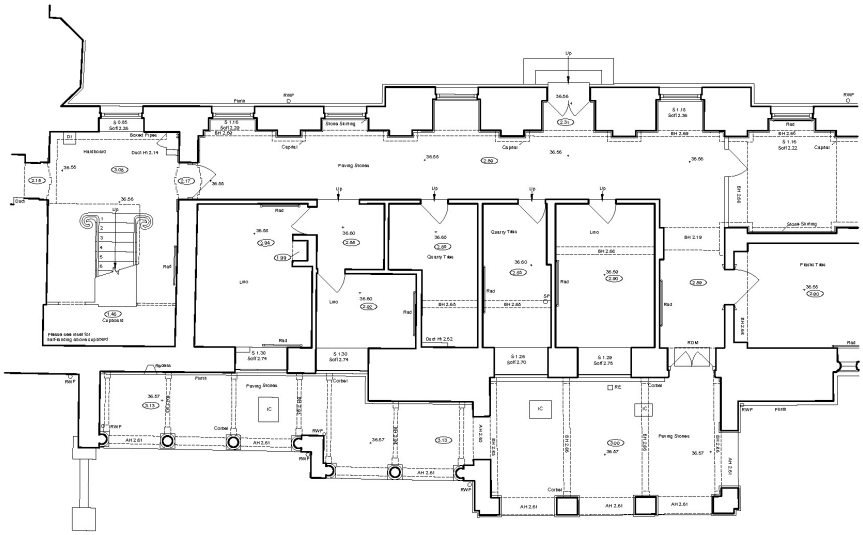


Figure 5.2: Example of the use of symbol and text on a plan prepared for presentation at 1:50 scale.

5.2.2 Section

A view of the internal space of the subject showing only those elements (including the thicknesses of walls) cut by a vertical reference plane.

5.2.3 Sectional elevation

A view of the internal space of the subject as seen from a plane defined by the cutline or section line and showing all detail revealed by that view. Major structural components not visible (e.g., hidden from view or in front of the cut-line) may be required to be shown by use of a dashed line.

5.2.4 Elevation

A view of a facade or wall of the subject as an orthographic projection.

[Text Box]
Further information

A plan (Figs. 5.1 and 5.2) is a convention for showing the horizontal extent of a building. A cut-line is required to show the walls of the building. The convention is for the cut-line to follow the height of a line between hip and shoulder height of a person standing. The cut-line is not simply a height at which the plane of projection is set, for it can vary. Clients are advised to closely specify a desired cut-line if there is ambiguity over the suitable height of the line (e.g., at changes in floor level or where buildings are built into a slope). A section line can be taken anywhere through the building (Fig. 5.3). The section line defines a plane of projection for the preparation of an elevation view. Section lines must be clearly defined in terms of position, extent and direction of view. They can be adjusted to include or exclude features (e.g., chimneys), but the line must remain parallel to the original plane. The exact position of the section lines needed to show the required aspects of the building when projected as a sectional elevation should be clearly delineated on sketch diagrams to accompany the project brief. Sections and sectional elevations are different (Fig. 5.7). Determining the cut-line and the direction of view as well as the detail to be included is important. The term section refers to a simple profile but is often taken to mean a full-height sectional elevation. It is essential that the terms are used correctly.

5.3 Control for measured building surveys

5.3.1 Control of survey data

The control of measured building surveys is to be achieved principally by use of an adjusted traverse network and must meet the performance described in section 2.2. However, it will also be acceptable to derive survey from laser scan point cloud controlled as specified in section 3.

5.3.2 Heights on floor plans

Where plans for more than one floor level are required the heights shown for each floor must be given relative to a single datum. Multiple arbitrary datum points for each floor must not be used.

5.3.3 Accuracy of survey data

The plan position of any well-defined detail shall be accurate to ±0.3mm rmse at the specified plan scale when checked from the nearest survey control station.

To verify the achievement of the specified tolerances, the following may be required:

- booked data showing directly measured dimensions;
- coordinate data and their provenance, where dimensions between points have not been directly measured.

5.3.4 Precision of detail measurement

The precision of detail measurement is to be as specified in section 2.1.2.

5.4 Drawing content

5.4.1 Detail required

The required scale of survey will determine both the level of detail and the expected precision. The level of detail refers to the density of information, while precision refers to the performance of the measured points used to delineate the detail. At a larger scale, such as 1:20, a plan, section or elevation will show more information than at a smaller scale, for example 1:50 or 1:100.

Detail comprises the visible features delineated within a plan, section or elevation such as openings, straight joints, roof scars, the jointing of masonry, the outline of fittings and fixtures or the outline of materials used. Sectional detail is to include eaves, sills, lintels, sashes etc.

1:100 and 1:50 scale

The smallest plottable detail is 0.2mm (at 1:50 scale this equates to a 10mm × 10mm object), so a degree of generalisation is required.

- Large linear objects, such as skirting or cornices, must be shown as a light line inside the wall or cut line.
- Annotation indicating floor material and direction of floorboards is to be included. A single line can be used to show joints in timber or for floor coverings.
- Openings in plan may be generalised, but must show an indication of the type of detail by careful use of an approved symbol for sash, mullion, door swing and lining.
- For elevations at 1:100, repetition of a single measured window is permitted in cases where they are demonstrably similar.

- Overhead detail, such as beams, vaults, stair flights, reveals etc, must be shown as a dashed line.

1:20 scale

All detail and annotations that would appear at 1:50 will also be present at 1:20. In addition, all visible architectural features must be shown, including:

- mouldings and sculptural detail from actual size source material (such as a profile trace or measured drawing)
- all stone by stone detail and galleting for elevations
- floor detail such as the plan of stone flags or floor tiles for plans
- timber components with pegs, peg holes and open or re-used joints plotted using a separate line to describe each component
- eroded edges as seen in the required view to show the condition of the fabric
- the deformation of wall surfaces at the cut-line and foot of wall line
- openings in full detail as apparent from the plane of reference.

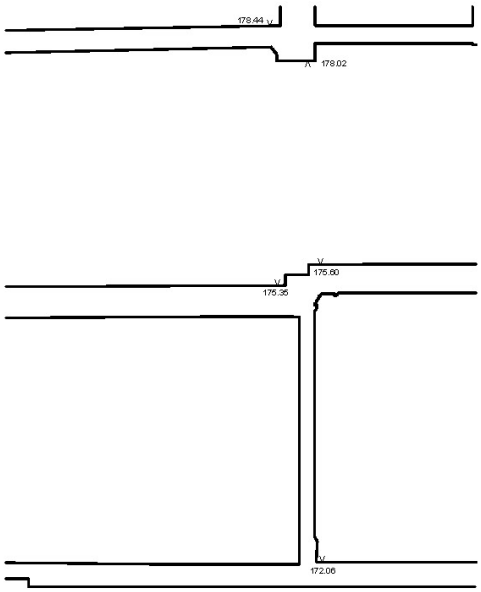


Figure 5.7: Section and sectional elevations: top left, profile or section; bottom left, sectional elevation – 1:50 level of detail; bottom right, sectional elevation – 1:20 level of detail.

5.5 Drawing convention

5.5.1 Curved features

Curved features should be presented either:

(a) unwrapped so as to provide a true-to-scale representation; or

(b) as an orthogonal view,

as stated in the project brief. The method proposed for any required unwrapping of data must be outlined in the method statement.

5.5.2 Depiction of cut-line (plan and section)

The cut-line(s) must be shown with a line weight of a thickness determined by the output or plot scale.

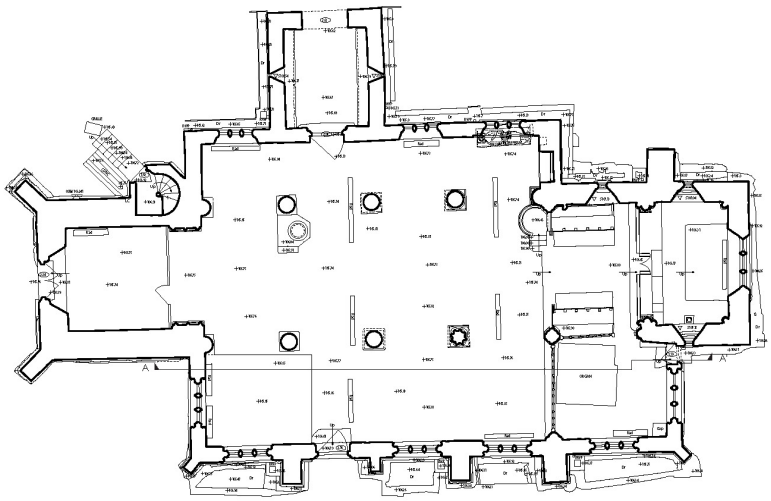
Sections and sectional elevations

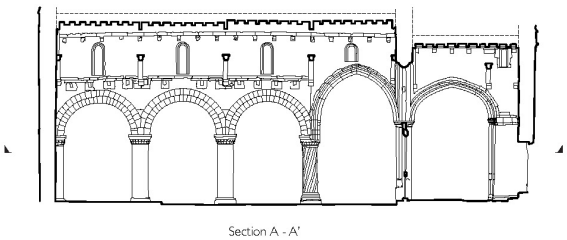
The cut-lines of any sections or sectional elevations should be clearly shown on either:

(a) the accompanying plan; or

(b) a key plan,

unless otherwise stated in the project brief.
The line must include arrows showing the direction(s) of view (Fig. 5.3).





Section A - A'

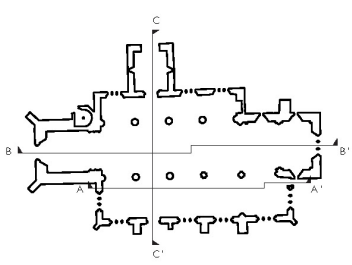


Figure 5.3: Section lines; top, shown related to plan; bottom, multiple sections depicted on a key plan.

Building footprint

The contact lines between the building and the ground (also known as the ground line, when visible in elevation) must be shown with a lighter line than the cut-line. The visibility of the line will depend on the wall, its inclination and the required scale.

The building footprint is to be:

(a) shown; or

(b) omitted; or

(c) recorded in 3-D in a frozen layer,

as stated in the project brief.

[Text Box]
Further information

The building footprint or ground or floor line is the line at the foot of the wall. Plans of vertical walls that have a constant width over their full height will not show this line unless it is specifically requested. Where a wall has a batter or sits on a plinth, the line will be visible and should appear on the plan.

5.5.3 Use of symbols

Symbols may be used as tabulated below. Level and dimension values are to be shown to two decimal places throughout.

item	scale	size on plot	symbol
door swing	1:20	full extent of swing	shown as an arc
	1:50	open at 90° or 45°	
levels	1:20 and 1:50	2mm cross, text 2mm plot height	cross with value to top right
step direction		text 2mm plot height	arrow pointing up direction of run, labelled 'up'
glazing detail		0.25mm line	single line on centre of window frame; frame beads omitted
room height		text 2mm plot height	enclosed in an ellipse
window/door opening height		text 2mm plot height	small upward and downward pointing open arrow heads
window/door soffit/lintel height		text 2mm plot height	small upward pointing open arrow head
window/door sill/threshold height		text 2mm plot height	small downward pointing open arrow head
roof survey – direction of fall			arrow pointing down slope
windows and doors	1:100	repetition of a single measured type permitted	

5.5.4 Point density and line quality

Point density and line quality is to be in accordance with the performance specified in Section 2.1.

5.5.5 Use of 'best profile'

The depiction of architectural forms requires special attention to the detail of functional openings such as sills, door openings, splays, mullions, plinths etc. Mouldings must be shown as completely as possible, with the 'best profile' shown. Where a profile of a damaged or eroded moulding can be derived with certainty it should be shown 'as complete' with the cut-line profile shown as a dashed line.

5.5.6 Assumed detail

Assumed detail should be presented using dashed lines, clearly indicated and on a separate layer. If detail is absent from a drawing, then the space is to be annotated with an explanation (e.g., 'no access', 'obscured at time of survey' etc).

5.5.7 Use of text

Text is only to be used if the information needed cannot be displayed as a graphic component of the drawing. Use of text is restricted to:

- annotation of direction of steps
- description of material and services using appropriate abbreviations
- values of spot heights, room heights etc
- notification of restrictions to survey (*see* section 5.5.6)
- as required by Section 8.

The text height is to be 2mm at the plot size.

The text style is to be either:

(a) Arial; or

(b) as stated in the project brief.

Text is to be positioned on the drawing such that it is:

- aligned with the sheet edge if possible
- aligned with large linear objects
- as close as possible to the object described
- not overlapping or breaking plotted lines
- preferably to the upper right of the object described.

If the upper right default position causes text to be in conflict with detail or other text, it is to be placed elsewhere in the following order of preference:

- 1 upper left
- 2 lower left
- 3 lower right
- rotated at default position to avoid clash

5.5.8 Overhead detail on plans

Large-scale surveys will require the depiction of the principal features of overhead structures such as vaults, beams, gantries, ceiling details, high level windows, roof lights, pulleys, murder holes etc. The annotation 'at high level' or '(at HL)' can be used to indicate detail above the plan height if it is not clear from the plotted lines alone.

Vaults, at 1:50 and 1:20 scale, should be shown by a plot of the rib lines, with imposts and bosses in outline. A single dashed line indicating the centre line of the rib may be used at 1:100 scale.

Overhead detail is to be:

(a) recorded in 3-D and plotted at true height; or

(b) plotted in 2-D congruent with all other plan detail,

as stated in the project brief.

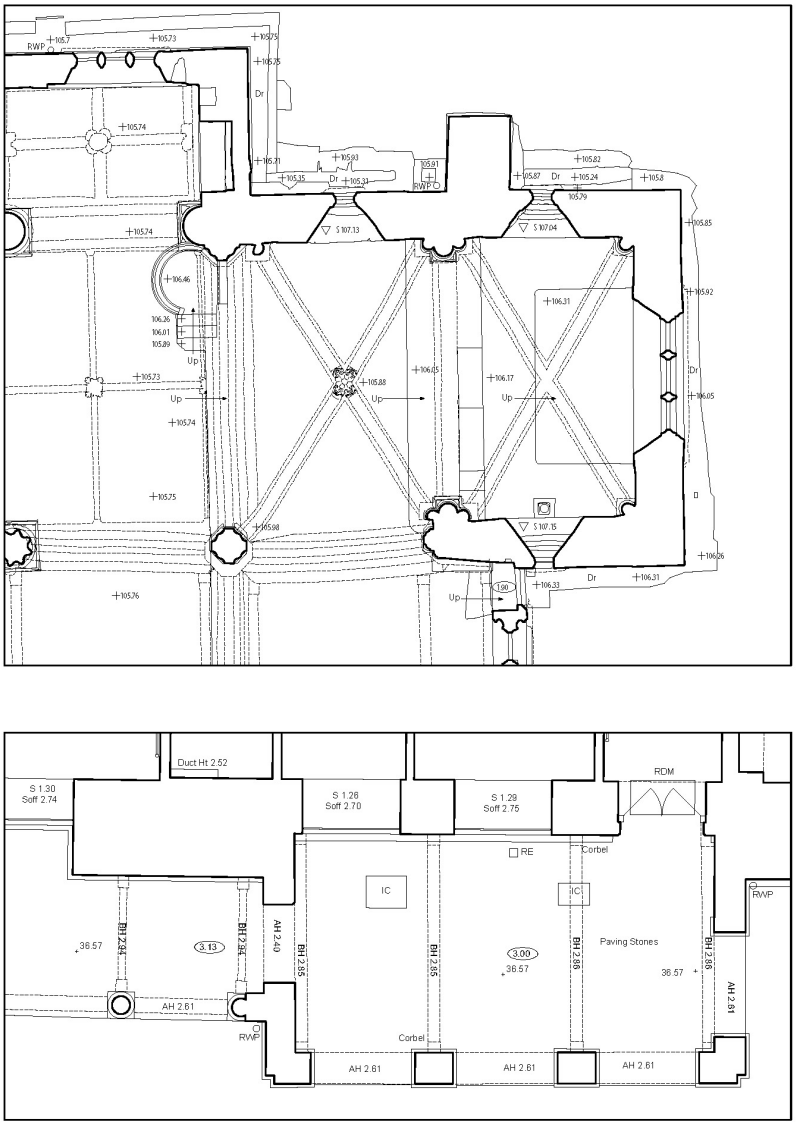


Figure 5.4: Examples of overhead detail; top, plan with a vaulted ceiling – 1:20 level of detail; bottom, overhead beams on a plan – 1:50 level of detail.

5.5.9 Floor detail on plans

Plans at 1:20 and 1:50 scale are required to show the following floor details:

- changes in floor treatment
- changes in floor level
- steps: the line of tread noses (continuous) and risers (dashed, if undercut)
- flagstones etc, depending on scale.

Fixings to walls and floor as seen on the cut-line (hinges, sockets, niches etc) should be shown in a line thickness greater than that used to depict all other detail.

5.5.10 Treatment of staircases on plans

The required convention for the depiction of stairs is to show the plan as seen from the cut-line and to use a break line to show the interruption of the plan, (Fig 5.5). Where stairs

include detail such as half landings between floors that would not otherwise appear on a drawing, an inset plan is to be used. Overhead detail is to be shown as required by section 5.5.8.

Levels on steps and stairs should be shown either:

(a) on each landing (i.e., at the top and bottom of each flight); or

(b) on all treads.

Stairs are:

(a) to be annotated with numbers to each tread; and/or

(b) annotated with 'up' arrow as described above (5.5.3); or

(c) not to be annotated.

See project brief.

Figure 5.5: Examples of the treatment of staircases on plans.

5.5.11 Services

Large components such as radiators, exposed pipe-work, shafts, ducts etc must be shown in full detail. Smaller components may be indicated by standard symbol and/or annotation. The following services details must be shown and annotated with service type:

- large fittings only
- pipe-work
- rainwater goods
- duct-work
- electrical fittings (in elevations only).

Electrical wiring and fittings are not usually required to be shown on plans unless specified in the brief.

5.5.12 Levels

Levels must be shown relative to the vertical datum as specified in Section 2.

Levels must be located at the following locations where applicable:

- thresholds
- either side of door openings
- centre of each room
- in each corner of each room
- interior sills
- exterior sills on centre of sill boards
- lintel soffit.

The heights of window and door openings shall be either:

(a) as indicated by soffit/lintel and sill heights; or

(b) shown as an opening height,

as stated in the project brief.

Floor to ceiling heights are required for each room and are to be shown enclosed in an ellipse.

5.5.13 Roof survey

Roof survey drawings can be presented in one of two states: either with the roof cover (slates, tiles, lead etc) on or with the roof cover off. A survey may be required to show rafters and trusses or trusses only.

A roof plan is required showing:

(a) ‘cover on’; or

(b) ‘cover off’; or

(c) ‘cover off trusses only’,

as stated in the project brief.

In all cases the roof must be shown in plan, i.e., looking straight down.

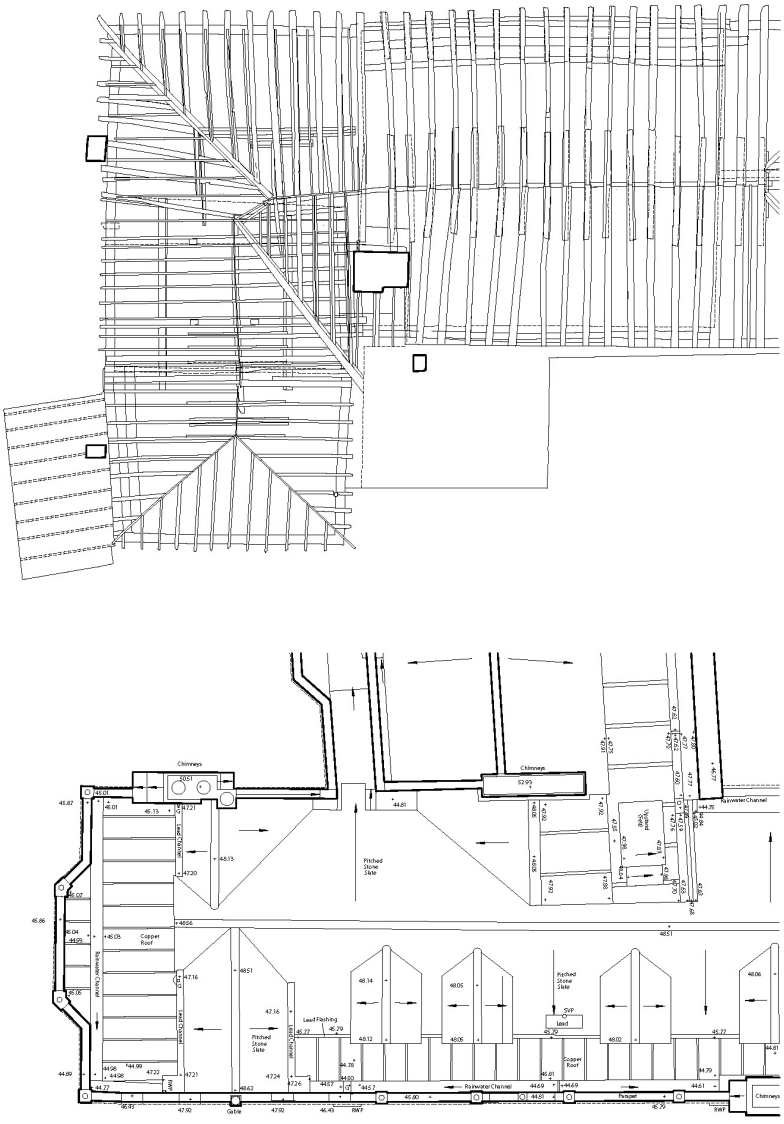


Figure 5.6: Roof plans: top, example of plan with cover off; bottom, example of plan with cover on.

Appendix 5.1 CAD layer names for measured building survey

layer	line type	line weight (mm)			description
		1:20	*1:50*	*1:100 or above*	
0A-chimney	continuous	0.35	0.25	0.25	
0A-cutline	continuous	0.5	0.35	0.35	the cut or plan line
0A-detail	continuous	0.18	0.18	0.13	below plan detail, outside cutline
0A-detail_hidden	dotted	0.13	0.13	0.13	below plan detail, inside cutline
0A-fine_detail	continuous	0.09	0.13	0.13	below plan fine detail, outside cutline or within detail on elevations
0A-detail_project	dashed	0.18	0.18	0.13	projected – in front of section line
0A-grid	continuous	0.18	0.18	0.18	grid points to be frozen on presentation
0A-gridtxt	continuous	0.18	0.18	0.18	all text associated with the grid: annotation to be aligned with the grid line
0A-inst_cntl	continuous	0.13	0.13	0.13	control positions – to be frozen on presentation
0A-joist	continuous	0.13	0.13	0.13	
0A-level	continuous	0.13	0.13	0.13	
0A-level_text	continuous	0.13	0.13	0.13	
0A-trav	continuous	0.13	0.13	0.13	control diagrams – to be frozen on presentation
0A-overhead	dashed	0.13	0.13	0.13	overhead detail – 2mm line, 1mm spacing
0A-opening	continuous	0.25	0.25	0.18	lines describing the edges of openings, changes of plane or skyline
0A-plinth	continuous	0.13	0.13	0.13	plinth lines in plan, inside building
	continuous	0.25	0.18	0.13	plinth lines in plan, outside building
0A-purlin	continuous	0.13	0.13	0.13	
0A-rafter	continuous	0.13	0.13	0.13	
0A-svs_elec	continuous	0.13	0.13	0.13	
0A-svs_fire	continuous	0.13	0.13	0.13	
0A-svs_foul	continuous	0.13	0.13	0.13	
0A-svs_gas	continuous	0.13	0.13	0.13	
0A-svs_other	continuous	0.13	0.13	0.13	
0A-svs_water	continuous	0.13	0.13	0.13	
0A-text	continuous	0.13	0.13	0.13	

0A-title	continuous	0.35	0.35	0.35	
0A-truss	continuous	0.25	0.25	0.25	
0A-wallplate	continuous	0.13	0.13	0.13	
Additional layers for vault surveys					
0A-boss	dashed	0.13	0.13	0.13	bosses may be shown as an outline
0A-cap	dashed	0.13	0.13	0.13	capital, impost or abacus
0A-corbel	dashed	0.25	0.25	0.25	on plans, if at high level, shown as an outline
0A-rib	dashed †	0.13	0.13	0.13	for the rib lines; to be expanded according to rib type if required
0A-shaft	dashed	0.5	0.35	0.35	on plans, usually shown as a cut-line; on sections, use detail line weight

This is not an exhaustive list.

New layers may be created so long as they are prefixed with 0A-.

The cut line of a building or feature should be of a heavier weight than lines used for other detail.

A dot and peck line type should be used to indicate any or all of the line types in the table if there is a conflict of lines and for boundaries if required to avoid confusion. The dot and peck line should comprise a line 1mm in length separated by a 0.5mm gap from a dot of 0.18mm, with a 0.18mm line width.

A dotted line may be used for clarity if there are a large number of dashed lines on the drawing sheet.

In AutoCAD, LTGEN is to be set to on.

Section 6
Standard specification for topographic survey

Figures

6.1 Topographic survey

6.1.1 Definition of topographic survey

For the purposes of this document topographic survey is defined as the controlled measurement of natural and artificial landscape features. It is to be presented as either:

(a) a two-dimensional (2-D); or

(b) a three-dimensional (3-D),

dataset reading as a plan as stated in the project brief. Profiles and a digital terrain model (DTM) may also be required (*see* section 6.6).

6.2 Description of products

For the purpose of producing large scale topographic survey, the following definitions apply.

Plan

This will be either:

(a) a vertical orthographic projection onto a horizontal reference plane; or

(b) a cartographic projection and a scale factor may be applied,

as stated in the project brief.

The plan may incorporate information above and below the reference plane; buildings shown will normally be cut on a different horizontal plane to that used for the main plan. The view is to be presented both as plotted or drawn 'hard copy' such that there is no discrepancy beyond permitted standard error (*see* section 2) and as a CAD file containing the same data as the plot.

Profile

A horizontal orthographic projection onto a vertical reference plane. Profiles will show the surface or cross section of the ground, including the thickness of any walls. The end points and line taken by the profile(s) should be clearly marked on a key plan. The vertical exaggeration for such views shall be ×1 unless otherwise stated.

Detail

The visible features, excluding the surface of the terrain, shown on the plan. It may be considered either 'hard' or 'soft'.

Hard detail is that defined with a clearly visible edge, for example a kerb.

Soft detail has an undefined edge or surface, for example earthworks.

6.3 Survey control

6.3.1 Coordinate system

Where use of the OSNG is specified, the primary site control, or starting coordinates for it, is to be established by means of GNSS observation as specified in Section 2. The scale factor used must be reported in the survey documentation.

The method statement must describe the equipment and procedures to be employed so as to achieve the precision specified in section 2.1.2.

Secondary control may be achieved by traverse observations.

6.3.2 Adequate site cover

The control network or traverse must extend so that stations are in reasonable proximity to the perimeter of the survey area and the detail to be mapped.

The distribution of stations is to be either:

(a) at the discretion of the surveyor; or

(b) decided in consultation with the client,

as stated in the project brief.

6.3.3 Contours

Contours shall be correct to an rmse of better than one third of the contour interval, where a representative sample of points on contour lines is checked by precise measurement from the nearest control point (and hence 95.4 per cent of a representative sample shall be correct to better than half of the specified contour interval).

6.3.4 Spot heights

Spot heights shall be correct to an rmse of better than one quarter of the contour interval, where a representative sample is checked by precise measurement from the nearest control point (and hence 95.4 per cent of a representative sample shall be correct to better than 0.4 of the specified contour interval).

6.3.5 Precision of detail measurement

The precision of detail measurement is to be as specified in section 2.1.2.

6.4 Detail required

6.4.1 Scale

Topographic survey is required at a scale as specified in the project brief.

If the survey is to be presented at more than one scale, different sizes of text are to be layered in the CAD file so that they may be segregated to allow for legibility at both scales.

It may be necessary to carry out some of the survey at a larger scale than that commensurate with the plot scale. Reference will be made in the project brief as to the area and nature of 'over scale' survey required. At 1:500 scale, a degree of generalisation from the 1:200 level is acceptable. The smallest plottable detail is 0.2mm × 0.2mm, which equates to 100mm × 100mm at 1:500 scale, therefore symbols should be used to describe visible features smaller than this.

For all hard detail the accuracy of planimetric information shall be such that the plan position of any point shall be correct to within +/-20mm rmse when checked from the nearest permanent control station when surveyed for presentation at scales between 1:100 and 1:200. At 1:500 scale, any point of hard detail shall be correct to within +/- 30mm rmse.

6.4.2 Detail required

The following general categories of information shall be surveyed:

- roofed buildings/structures (Fig. 6.1)
- roofless/ruined structures
- temporary/mobile buildings
- visible boundary features: walls, fences and hedges
- roads, trackways, footways and paths
- street furniture
- statutory authorities' plant and service covers where visible
- changes of surface
- isolated trees/wooded areas/limits of vegetation (Figs. 6.2 and 6.3)

- pitches/recreation
- private gardens or grounds (off-site areas)
- water features
- earthworks
- industrial features
- railway features (with arranged access)
- above ground services
- underground services (Fig. 6.5)
- other (specify).

All of the above are to be presented using the specified cartographic conventions (*see* section 6.6), and either drawn or depicted using symbols dependant on output scale. The plans should have a fixed control network and measurable repeatability of precision commensurate with the required scale (section 2.1.2).

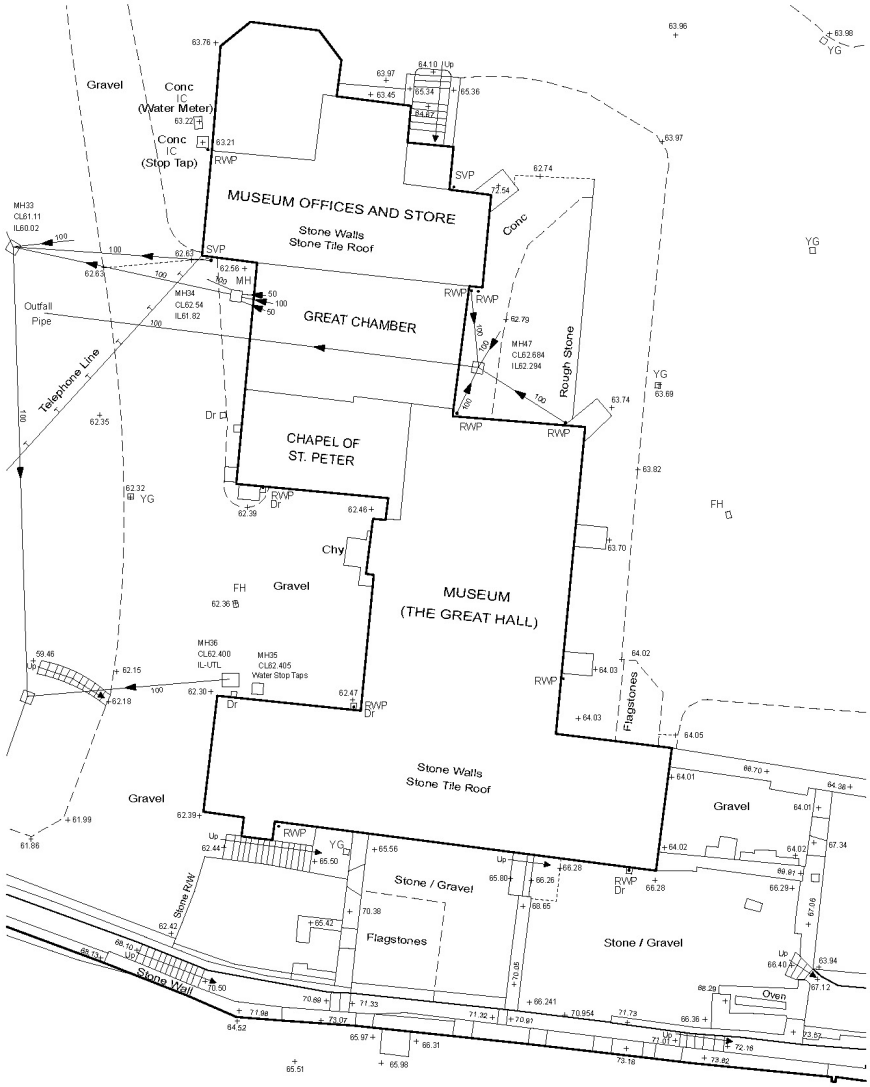


Figure 6.1: Occupied buildings and associated detail. Originally prepared for presentation at 1:200 scale.

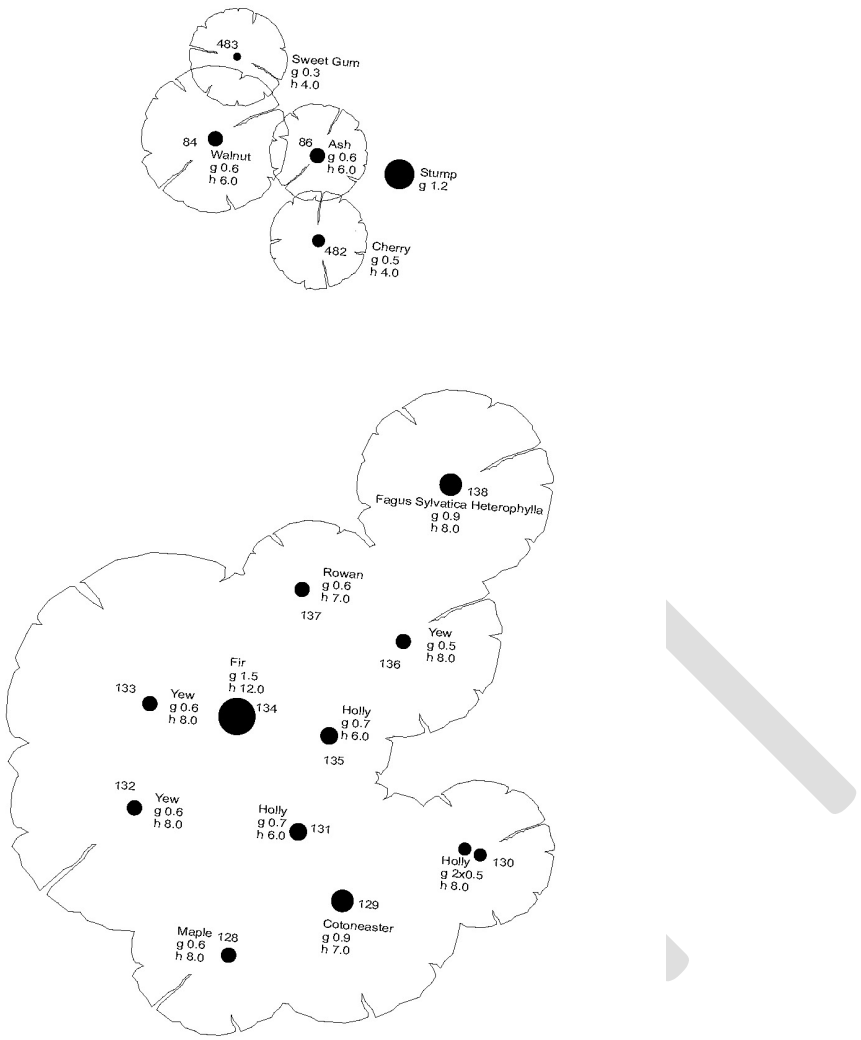


Figure 6.2: Depiction of trees; top, canopies untrimmed; bottom canopies trimmed to the overall envelope.

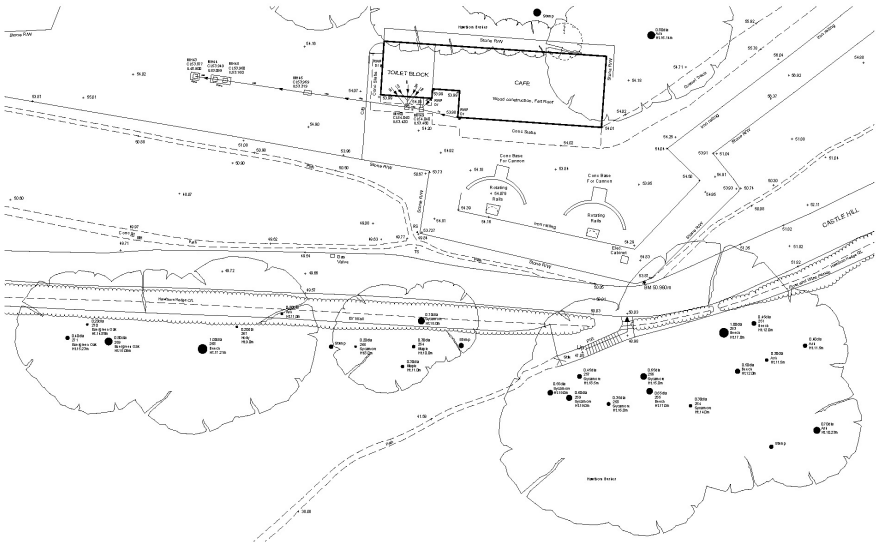


Figure 6.3: Depiction of hedges (including centreline). Originally prepared for presentation at 1:200 scale.

6.4.3 Obstructed ground

Details or contours that cannot be represented to the specified accuracy without extensive clearing shall be:

(a) surveyed approximately and annotated accordingly; or

(b) surveyed, following clearance by the client; or

(c) surveyed, following clearance by the survey contractor,

as stated in the project brief.

6.5 Underground services

An accurate base plan is essential for the plotting of underground utility services. If such a plan does not exist it will be necessary to produce one (Fig. 6.5).

Underground services surveys will be undertaken using one or more of the following methods:

(A) Consulting underground service records. (To be taken from statutory or other authorities' record drawings and plotted to agree as closely as possible with surveyed surface features.)

(B) Direct visual inspection. (Accessible inspection chamber covers should be lifted where permissible and services positively identified.)

(C) Direct visual inspection supplemented by consulting service record drawings.

(Accessible inspection chamber covers should be lifted where permissible and services positively identified. Routes of services between access points to be taken from record drawings and plotted to agree as closely as possible with surveyed surface features and trench scars where obvious.)

(D) Full investigation, including electronic tracing. (Services to be fully investigated by visual survey supplemented by electronic or other tracing of inaccessible routes.)

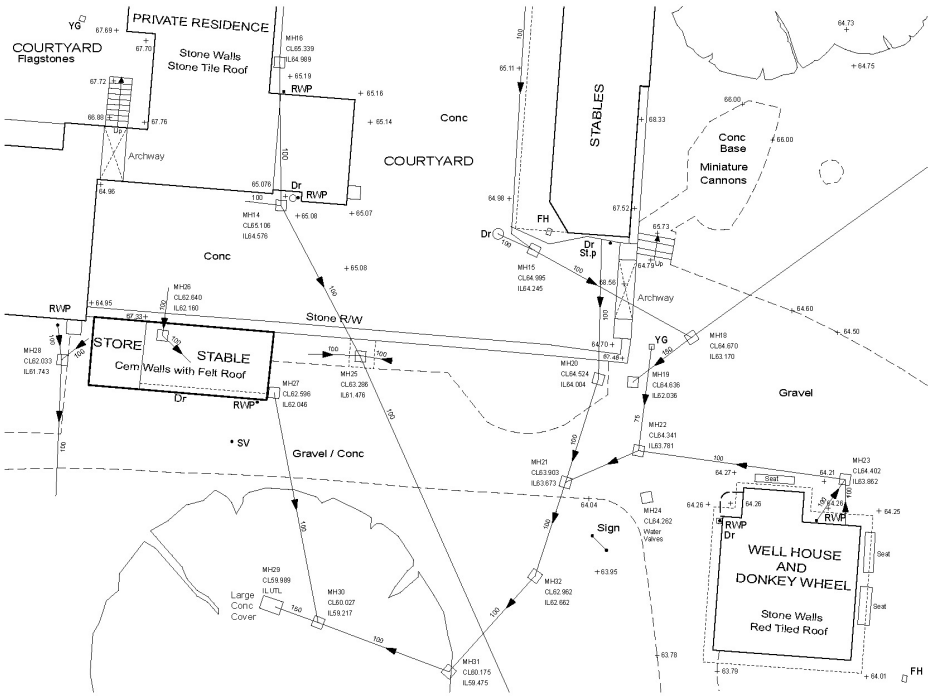


Figure 6.5: Depiction of underground services. Originally prepared for presentation at 1:200 scale.

[Text box]

Further information

(A) Record information

Existing information taken from record plans covering underground services is often incomplete and of doubtful accuracy. It should usually be regarded only as an indication and cannot be guaranteed.

(B, C) Underground services surveys

Drainage covers should not be lifted without the permission of the owning authority. Many local authorities do not permit their inspection covers to be lifted but will provide some information for a standard fee.

(D) Electronic tracing

This is a more reliable method of locating buried services. On heavily built-up sites 85 per cent completeness is probably all that can be expected. Plan accuracies of +/-150mm may be achieved but this will be dependent on the depth of the service below ground level. Where similar services run in close proximity, separation may be impossible. Successful tracing of non-metallic pipes may be limited. Further guidance, if required, on utility surveys can be obtained free of charge from The Survey Association (TSA) at: https://www.tsa-uk.org.uk/downloads/

For a comprehensive specification, see: PAS 128:2104 Specification for underground utility detection, verification and location (2014), British Standards Institution, ISBN 978 0 580 79824 5, available from the BSI shop http://shop.bsigroup.com

6.5.1 Extent of survey required

Services listed below shall be surveyed by one or more of the methods listed above as indicated in the project brief. All work should be carried out with due regard to the Health and Safety regulations for working within confined spaces.

- Surface water drainage
- Foul drainage
- Water
- Gas
- Electricity
- Telecommunications
- Other services
- Other underground features.

6.5.2 Services information

Information derived from survey methods (B), (C) and (D) shall be supplied as either:

(a) invert levels, pipe diameters and annotations on drawings or digital files; or

(b) inspection chamber description sheets,

as stated in the project brief.

The date of inspection/survey must be included.

6.5.3 Derived information

Where information is derived from statutory authorities' record drawings, a schedule shall be provided giving full details (e.g., drawing number, scale, date etc). All information taken from records shall be clearly identified as such in the survey product and placed on a separate layer.

6.5.4 Report

A report shall be submitted indicating any anomalies between surveyed data and records, detailing likely accuracies achieved and commenting on services not located for any reason (e.g., unliftable or hidden covers). All identified features should be highlighted in this report.

6.6 Drawing convention

6.6.1 Landform, earthworks and surface terrain

Landform, earthworks or surface terrain are to be indicated by:

- surveyed contour
- form line
- annotation
- spot height
- hachure.

6.6.2 Contouring and DTMs

Contours are required to represent the surface characteristics of the terrain. They are to be shown with contour values reading up the slope at a density sufficient to identify all contours without ambiguity. Where contour values are inserted the contour lines must be broken to ensure legibility. The contours must be shown cut by buildings and structures, including the batter of masonry fortifications built into earthworks. Contour lines must be appropriately smoothed after interpolation to avoid lines with sharp changes in direction (Fig. 6.6).

Contours derived from a DTM must not reveal the geometric model used to construct the surface. Care must be taken to ensure that the presence of detectable edges is only a result of such edges being part of the landscape. Breaklines shall be used to ensure that the DTM accurately describes the landform to be depicted by identifying changes of slope at, for example, the tops and bottoms of ditches and banks. When earthworks are mapped, attention must be paid to the surface and its intersection with objects such as gun emplacements, battered walls, chimneys etc, so that a plan of the building components can be seen clear of the contours used to describe the earthworks or landform surrounding them. For the required accuracy of contours (*see* section 6.6.3).

Plans at 1:100 and 1:200 scale are to be contoured at a vertical interval of either:

(a) 0.25m; or

(b) as stated in the project brief.

Plans at 1:500 scale are to be contoured at a vertical interval of either:

(a) 0.5m; or

(b) as stated in the project brief.

Thicker index contours are to be shown as multiples of 1m or as stated in the project brief.

Hachures may be used to supplement contoured information and to describe subcontour detail (Fig. 6.4).

Sufficient levels for the DTM shall be surveyed such that the ground configuration, including all discontinuities, is represented on the survey plan.

The maximum spacings for DTM points are:

scale	ground spacing	distance on plan
1:100	5m	50mm
1:200	10m	50mm
1:500	10m	20mm

Where a DTM is the final product, the density of levels shall be such that the surface of the model is constructed within 0.1m of the true surface when verified by check measurement. The density of levels shall be at least 1m for surfaces with earthworks or 5m for open ground.

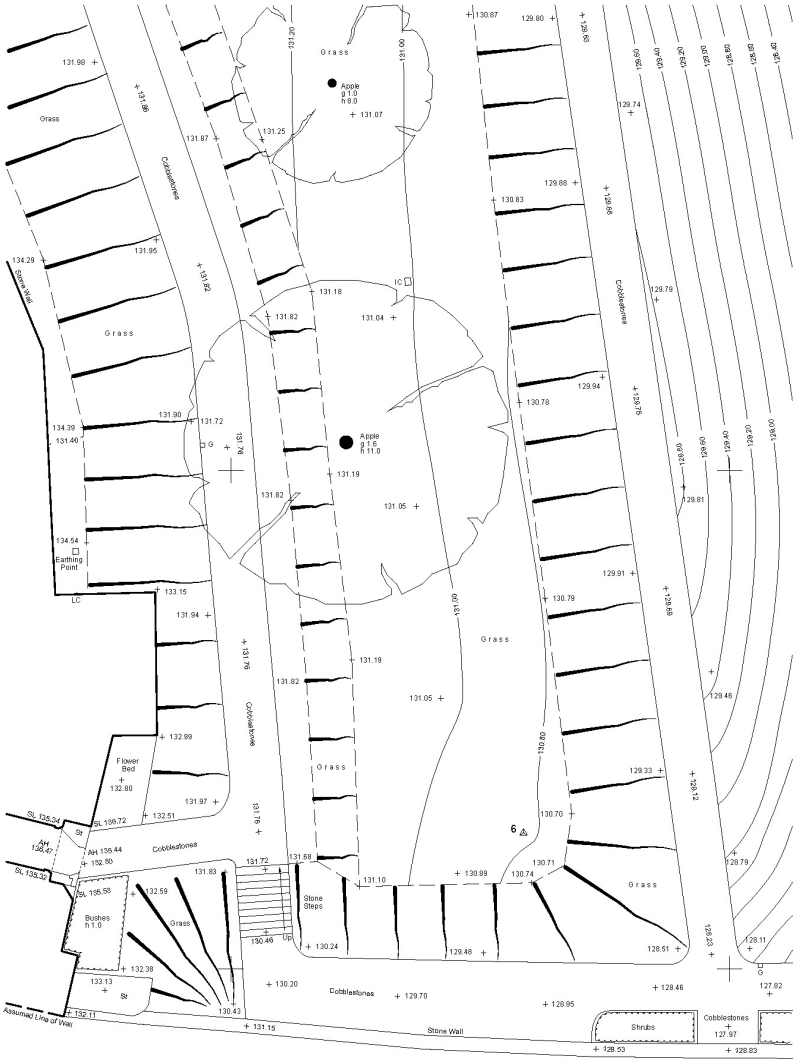


Figure 6.4: Use of hachures to supplement information from contours. Originally prepared for presentation at 1:200 scale.

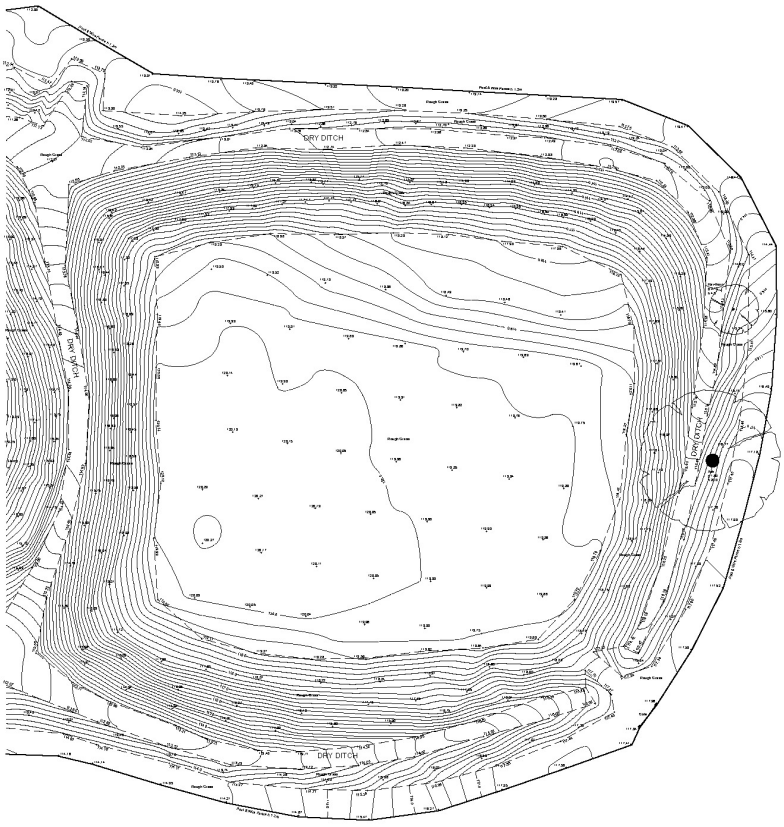


Figure 6.6: Contours generated from a DTM and breaklines. Originally prepared for presentation at 1:200 scale.

6.6.3 Location of spot heights

Spot heights shall be shown in the following positions, except where the ground is obscured by vegetation or other obstructions:

- at salient positions such as top, bottom and along the centreline and mid-point of slopes, ditches, embankments and earthworks
- at the top and bottom of features described by hachure to support the form lines
- at significant changes of gradient, along the centre and edges of road, tracks and water courses, at between 50mm and 100mm at map scale
- in flat areas (where the horizontal distance between contours generally exceeds 30mm at map scale) at intervals between 30mm and 100mm at map scale
- at the sill tops and thresholds of buildings, ruins and building fragments
- at the base of walls showing height of ground at the corners, buttresses and change of direction of walls; to include corresponding positions either side of a freestanding wall
- wall tops on ruined walls, to indicate major changes in wall height and maximum height; large and irregular ruined walls may not require levels other than a general indication of height
- at regular intervals along dwarf walls, showing the height of ground at the wall base and wall top
- at changes of surface treatment (e.g., the edges of grassed areas and hard standing, paths, walkways etc)
- at the surface of drainage inspection covers, the invert level of drainage pipes, on the edge of rainwater gullies and along rainwater channels

- at the edges and high points of large fragments of buildings (fragments of 1m × 1m size or greater on any edge at actual size)
- at the top and bottom (and if practicable on each tread) of flights of steps
- at the base of the bole of large trees.

The required control and precision of vertical data is described in Section 2 and at 6.3.

The standard point descriptor must be a cross of no more than 2mm × 2mm at plot size, the intersection of which shall represent the given coordinate value. The symbol is to be aligned with the sheet edge. The point descriptor shall be used for the depiction, with appropriate annotation, of spot heights and reference points. Spot height text shall be 2mm high at plot scale and given to 2 decimal places.

6.6.4 Depiction of trees and vegetation

Vegetation is to be indicated by a standard scaled symbol and text description of species by common name.

Trees are to be plotted as up to four components: the base, bole, canopy/spread and envelope. Trees are considered to be identifiable as such if they are 5m or greater in height, unless of a species known as a shrub (such as laurel) and lacking an identifiable bole.

If less than 5m, high trees should be depicted as vegetation. Trees, including the bole, are to be shown to scale. Any displacement of the tree canopy from the bole should be shown. Single small trees in unobstructed terrain should be shown even if they may not be of a size that normally qualifies for depiction. Small trees of less than 5m in height are to be layered in the CAD file separately to aid landscape management.

General points

The bole is to be plotted at 1.5m above ground level and to include multiple grouped boles. They are to be a scaled and hatched shape that appears solid on the plotted drawing sheet. The hatching used must be consistent for all bole sizes.

The spread of the canopy is to be shown as a standard scaled symbol. At 1:200 scale and greater, the canopies are to be contained within the digital file such that both the individual spread per tree is shown in one CAD layer and the envelope of a group of trees is shown in another (*see* Appendix 6.1 and Fig. 6.2). At 1:500 scale, depiction of the envelope only is sufficient. Where a small tree has an extensive canopy spread over other vegetation, the canopy should be mapped as a dashed line.

Trees are to be annotated with the following information:

- the girth at breast height
- the tree number where visible
- species by common name
- height to the nearest 0.5m.

For vegetation, hedges are to be depicted using a linear symbol. They shall be surveyed so that the centre line, width and descriptive annotation are clearly shown on the plan (Fig. 6.3).

The extent and type of other vegetation is to be shown, annotated in a similar manner to that used for hedges.

6.6.5 Text style and positioning

For annotation, levels, index contours and descriptions of form or surface treatment the height of text should not exceed 2mm at plot scale. For major objects the text shall be 5mm in height at plot scale.

The font used is to be either:

(a) Arial; or

(b) as stated in the project brief.

Text is to be positioned on the drawing such that it is:

- aligned with the sheet edge if possible
- aligned with large linear objects
- as close as possible to the object described
- not overlapping or breaking plotted lines
- preferably to the upper right of the object described.

If the upper right default position causes text to be in conflict with detail or other text, it is to be placed elsewhere in the following order of preference:

- 1 upper left2 lower left
- 3 lower right
- rotated at default position to avoid clash

6.6.6 Treatment of steps

Where space on the drawing allows, an arrow pointing up a flight of steps should be used to support level information. The symbol should extend the full length of the flight and must be labelled 'up'.

6.6.7 Depiction of buildings and walls

For roofed structures, the cut line is to be at:

(a) ground level; or

(b) sill height,

as stated in the project brief and should show returns for doors and windows on the outside only.

Roofless or ruined structures must have their internal layout (such as walls or columns) shown.

Spot levels must be shown on sills, thresholds and floors.

Annotation indicating floor, wall and roof material as well as building height is to be included.

On plans at scales of 1:100 or larger, floor detail will be required if visible.

Free-standing walls must be shown at a nominal plan height, with lines closed to show openings, where possible.

Additional detail below the plan height (sills, thresholds and floor treatments etc) will either:

(a) be shown; or

(b) not be required,

as stated in the project brief.

At 1:200 scale detail such as plinths may be omitted if the projection from the wall line is less than 2mm at plot scale.

Where a wall is leaning over significantly from the line of its base, it will be necessary to show the true plan position of both the top (or nominal plan height) and bottom of the wall.

6.6.8 Above-ground utilities and boundaries

Services, roads, tracks, watercourses, fences, boundaries etc are to be delineated by use of:

(a) surveyed lines; and/or

(b) symbol; and/or

(c) text.

Fence lines are to be indicated by the plotted plan position of posts; the position and width of gates is to be to scale. At 1:500 scale or smaller, building openings, gates and the position of fence posts in plan may be generalised, i.e., depicted by a symbol or line type.

Ditches are to be shown by a dashed line showing the top of bank. Bottom of bank is to be supported by a spot level at changes of height for each surveyed line.

Overhead services such as telephone or electricity cables are to be shown with a distinctive line type and annotated with the service description and height above OS datum.

Appendix 6.1 CAD layer names for topographic survey

CAD layer	colour	line type	line weight (mm)		description of content
	Numbers in brackets are AutoCAD colours		*up to 1:200*	*1:500 and over*	
0T-breakline	black	dashed	0.18	0.13	in support of contour or hachure, to describe e.g., top and bottom of slope
0T-cntltxt	black	continuous	0.25	0.18	schedule of coordinates for control stations; to be shown to three decimal places with a description of the marker used; may be included on data sheet for project or as separate file
0T-contour	green	continuous	0.18	0.13	minor contours
0T-contour-index	red	continuous	0.25	0.25	index contours; to be broken to accept contour value; text to be positioned so that the top of the text faces up slope
0T-cut	black	continuous	0.5	0.35	the line of cut for plans
0T-cut_profile	black	continuous	0.5	0.35	the line of cut for sections and profiles
0T-detail	black	continuous	0.18	0.13	lines used to plot hard detail
	black	continuous	0.18	0.13	wall tops
	black	continuous	0.18	0.13	internal features in roofless buildings
	black	continuous	0.18	0.13	dwarf walls under 300mm high, dashed where edge is uncertain
	black	dashed	0.18	0.13	indicate the position of a wall visible as a sub-contour feature
	black	dashed	0.18	0.13	roof overhangs or buttresses, walls leaning outside wall base
	black	dashed	0.25	0.25	roof overhangs or buttresses, walls leaning inside wall base
0T-footprint	black	continuous	0.25	0.25	ground line, line at the base of a batter or where height of ground becomes part of the building plan
0T-grid	black	continuous	0.25	0.25	indicate the grid using annotated margin marks and associated text (as per txt layer). Length of line not to exceed 5mm at plot scale. Grid intersections should be shown by an 8mm cross
0T-gridtxt	black	continuous	0.25	0.18	all text associated with the grid; annotation to be aligned with grid line
0T-hachure	black	continuous	0.18	0.18	hachures
0T-hdge	brown (36)	continuous	0.18	0.13	hedge line at ground level
0T-hgdeOL	light brown (34)	continuous	0.18	0.13	outline limit of hedge spread

0T-inst_cntl	black	continuous	0.25	0.25	all control data with the exception of traverse lines (on layer 0T-trav) and text other than station symbol and target descriptors; datum lines indicated as a 5mm horizontal line on either side of the plotted subject with annotation in text 3mm high; plumb lines to be indicated in the same manner; station symbol to be a triangle with centre mark 3mm high
0T-level	black	continuous	0.25	0.18	level point descriptor
0T-level_text	black	continuous	0.25	0.18	spot levels to two decimal places with associated text rotated so that it is legible with all layers on. Where available space forces the level or any other text to cross other lines a break should be used to ensure clarity
0T-overhead	black	dashed	0.25	0.18	lines indicating overhead detail
0T-path	black	dashed	0.18	0.13	to show a pathway where there is no kerb or channel
0T-remote	black	continuous	0.25	0.18	lines indicating information remote from the line of cut
0T-subt	black	dashed	0.25	0.18	to show an underground feature such as the path of a traced water course or ice house
0T-surface	black	dashed – dashes to be 2mm with a 1mm gap at plot scale	0.18	0.13	to delineate the outline areas of different ground treatment or material
0T-svs_d	black	continuous	0.18	0.18	derived service information
0T-svs_elec	red	continuous	0.18	0.18	electrical services – to be expanded as required
0T-svs_fire	red	continuous	0.18	0.18	fire control services e.g., hydrants
0T-svs_foul	light brown (34)	continuous	0.18	0.18	drainage – foul; show direction of flow
0T-svs_gas	blue	continuous	0.18	0.18	gas services
0T-svs_rw	lilac (175)	continuous	0.18	0.18	drainage – surface water; show direction of flow
0T-svs_tele	orange	continuous	0.18	0.18	for telephone lines; poles to be shown, lines to be shown as an overhead detail with a dashed line
0T-svs_water	turquoise (121)	continuous	0.18	0.18	water supply
0T-text	black	continuous	0.25	0.18	all text except title, control text, tree data and text associated with height information. Text should be positioned to avoid overwriting detail when the layer is on with all other layers
0T-title	black	continuous	0.35	0.25	rubric, key, logos, north signs, scale bars and all associated text
0T-trav	black	continuous	0.25	0.18	traverse lines with annotation of

					reduced angles, distances and station coordinates (if other than WORLD coordinate system is used)
0T-tree	green	continuous	0.25	0.25	tree bole hatched solid
0T-treeA	green	continuous	0.18	0.13	canopy spread by individual tree
0T-treeB	green	continuous	0.18	0.13	canopy spread trimmed to envelope
0T-treeM	green	continuous	0.18	0.13	tree less than 5m in height
0T-treetxt	green	continuous	0.25	0.18	tree – descriptive text
0T-veg1	dark green (96)	continuous	0.18	0.13	limit of vegetation, to be subdivided if needed
0T-wall_top	black	continuous	0.25	0.25	lines used to describe wall tops inside the line of cut (i.e., the view of the wall looking from above) if this varies significantly from the cut-line

This is not an exhaustive list.

New layers may be created so long as they are prefixed with 0T-.

(a) General considerations

The cut-line of a building or feature should be of a heavier weight than lines used for other detail.

A dot and peck line type should be used to indicate any or all of the line types in the table if there is a conflict of lines and for boundaries if required to avoid confusion.

A dotted line may be used for clarity if there are a large number of dashed lines on the drawing sheet.

In AutoCAD, LTGEN is to be set to on.

(b) Dashed lines

The line type should be controlled so that dashes are 0.5mm long with a 0.5mm gap at the plot scale. The exception is for lines showing changes in surface treatment where the dashes should be 2mm with a 1mm gap.

(c) Dotted lines

A dotted line should be a 0.18mm or 0.25mm diameter dot at a 2mm to 5mm interval, depending on the map scale plotted.

(d) Dot and peck lines

The dot and peck line should comprise a line 1mm in length separated by a 0.5mm gap from a dot of 0.18mm, with a 0.18mm line width.

Section 7
Standard specification for the supply of building information modelling (BIM)

Figures

7.1 Definitions of terms

7.1.1 What is BIM?

The term 'BIM' is the widely used acronym for building information modelling, which is the process of digitally representing the physical and functional characteristics of a building.

7.1.2 How can BIM be used within a heritage project?

BIM is a process that enables the entire project team to collaborate and create a single source of data that assists design, construction, facilities management and other related processes by allowing the extraction and updating of information throughout the life cycle of the building.

[Text box]
Further information on BIM and its application to historic structures can be found in the Historic England publications

BIM for Heritage - Developing a Historic Building Information Model (2017) Product Code: HEAG154 https://historicengland.org.uk/images-books/publications/bim-for-heritage/

BIM for Heritage - Developing the Asset Information Model (2019) Product Code: HEAG271 https://historicengland.org.uk/images-books/publications/bim-for-heritage-aim/

7.1.3 Purpose and scope of this document

This section of the specification relates to the creation of a 'BIM-ready' dataset. The initial capture of the required level of geospatial data will be defined in sections 2, 3, 4, 5 and 6 of this specification as appropriate.

7.2 BIM development

7.2.1 Level of detail

The required BIM data is to be constructed to the following level of detail:

(a) *Level 1:* basic outline of the building/structure represented as a solid object using representative component information but with no architectural detail depicted; or

(b) *Level 2:* outline of the building/structure represented as a solid object with principal architectural features included using generic components; or

(c) *Level 3:* outline of the building/structure represented as a solid object with all architectural features and major service detail included using generic components; or

(d) *Level 4:* detailed survey of the building/structure represented as a solid object including all architectural detail, services and custom developed components to accurately represent fabric type; or

(e) as stated in the project brief.

See Fig. 7.1 for example of levels 2 to 4.

Specific features to be modelled or custom components to be developed are given in the project brief.

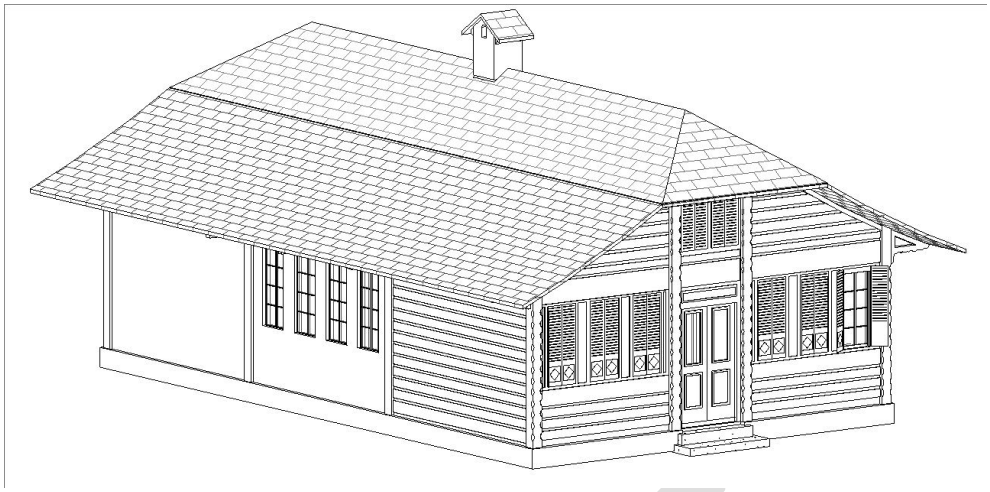


Figure 7.1: A BIM model at three levels of detail – level 2 at the rear, level 3 in the middle and level 4 at the front.

7.2.2 Modelling tolerance

The generally accepted tolerances of BIM modelling are as defined by the level of detail selection.

Variations required for individual components, are given in the project brief.

7.3 Supply of BIM data

7.3.1 BIM data formats

All BIM-ready files are to be supplied as:

(a) IFC format; and/or

(b) Autodesk Revit .RVT format; or

(c) as stated in the project brief.

7.3.2 Deliverables

The BIM data is to be supplied:

(a) with the component library; or

(b) without the component library but referencing that which was used; or

(c) using another form of library information as stated in the project brief.

The base 3-D survey files:

(a) are to be included and registered with the BIM data; or

(b) are not required; or

(c) are to be provided in another form as stated in the project brief.

7.4 BIM references

7.4.1 Existing standards

Where there is a specific requirement to reference an existing BIM standard the title, section, paragraph and relevance to the project will be noted in the project brief.

Section 8
Format, presentation and provision of survey data

8.1 Digital data

8.1.1 CAD and digital image filenames
8.1.2 CAD data format
8.1.3 Digital image format

8.2 CAD requirements

8.2.1 Use of CAD coordinate systems
8.2.2 Insertion point
8.2.3 CAD drawing unit
8.2.4 Line type
8.2.5 Use of paper space

8.3 Presentation

8.3.1 Drawing sheets
8.3.2 Standard sheet views
8.3.3 Layout
8.3.4 Numbering of sheets
8.3.5 Data sheet for measured building and topographic survey
8.3.6 PDF drawing sheets

8.4 Survey report

8.4.1 Imagery metadata

8.5 Provision of survey material

8.5.1 Samples
8.5.2 Preliminary issue
8.5.3 Transfer medium

Appendix 8.1 Abbreviations for survey annotation

Figures

Figure 8.1: Standard drawing sheet format (with plan aligned to border).

8.1 Digital data

8.1.1 CAD filenames

All CAD filenames are to be at least eight characters in length and must comply with the following file naming system. The standard abbreviation for the site will be as noted in the project brief.

Characters	Description
1-3	Standard abbreviation of the monument name, e.g., DOV (Dover Castle)
4-5	Year survey carried out e.g., 22 (2022)
6	Type of survey
	P (photogrammetry – original images and 3-D CAD data)
	Q (photogrammetry – CAD drawing sheets)
	R (rectified photography – images and CAD files)
	O (orthophotography – images and CAD files)
	L (laser scan data)
	M (measured building survey)
	T (topographic survey)
7-8+	Sequential file number from 01 or 001 if there will be more than 99 files

e.g., DOV22T01.DWG, DOV22M01.DWG.

8.1.2 CAD data format

All CAD files are to be either:

(a) AutoCAD version 2010 .DWG; or

(b) as stated in the brief.

8.1.3 Digital image format

Digital images are to be supplied either:

(a) as shown below

- the original digital images as RAW files plus uncompressed 8-bit TIFF versions
- where the images are orthophotographs, as TIFF files; or

(b) as stated in the brief.

8.2 CAD requirements

8.2.1 Use of CAD coordinate systems

A user coordinate system (UCS) other than the world coordinate system (WCS) can be used to facilitate the presentation of the survey (or part thereof) on the desired sheet layout. Any such UCS must be saved with a name related to its function (e.g., 'SHEETVIEW' for a UCS set-up for a drawing sheet).

Where possible all height datum lines or level ticks in a drawing are to have the correct height value on the vertical axis. Where two or more elevations are presented on the same drawing sheet, one above the other, then the datum lines or level ticks of the same value are to be separated by a whole number of metres.

8.2.2 Insertion point

The default origin of (0,0,0) in the WCS is to be used for xref insertions.

8.2.3 CAD drawing unit

The CAD drawing unit is to be either:

(a) 1m; or

(b) as stated in the project brief.

8.2.4 Line type

A dashed line type is to be used for dashed lines as opposed to using a broken line. The line-type scale is to be commensurate with the plot scale so that it actually appears as a dashed line when plotted.

8.2.5 Use of paper space

Either:

(a) Paper space is to be used for the production of all drawing sheets and must be set up as follows:

- 1 plotted mm = 1mm in paper space
- there is to be a specific paper space layout tab for each view or drawing sheet
- the viewport(s) must be locked to prevent accidental changing of the scale
- where elevations are presented, one above the other, in the same layout separate viewports should be employed so that the elevations remain at their true height in model space (*see* section 8.2.1).

Or

(b) paper space is not to be used. Each printed drawing sheet must be represented by a unique CAD file.

See project brief.

8.3 Presentation

8.3.1 Drawing sheets

All drawing sheets are to be formatted on ISO A size standard sheets.

Either:

(a) the client will supply the contractor with a standard sheet format (including a standard north arrow, scale bar and rubric), as a CAD file, that must be used for all plotted sheets; or

(b) the contractor is to prepare a suitable sheet format for approval by the client

as stated in the project brief.

See Fig 8.1 for an example of a drawing sheet.

Where hard copy is required, each formatted CAD drawing sheet or paper space layout is to be printed. Where PDF versions are required there is to be a separate file for each layout (see section 8.3.6).

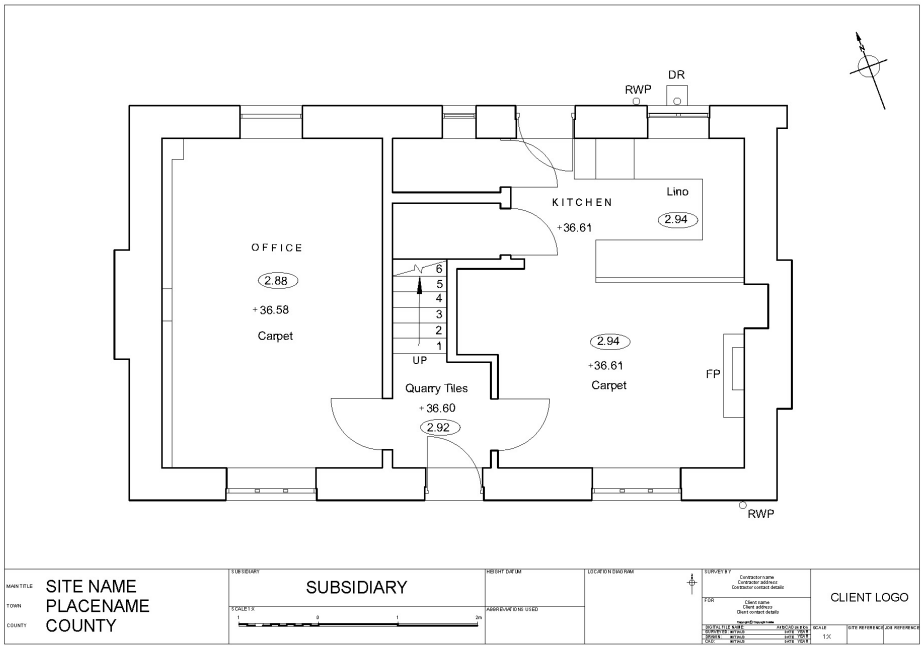


Figure 8.1: Standard drawing sheet format (with plan aligned to border).

8.3.2 Standard sheet views

Elevations and sectional elevations

Each subject to be surveyed is to be presented as an orthogonal view and, as far as is practical, all data should be presented 'square-on' to the plotted sheet. Where an elevation or image extends over more than one sheet either:

(a) an overlap between sheets of at least 0.5m in reality is required; or

(b) the detail is to be butt jointed,

as stated in the project brief.

Small registration crosses are to be printed on each sheet so that adjacent sheets can be accurately aligned.

Measured building plans

Plans are to be orientated so that north is towards the top of the sheet or the principal axes of the building are parallel to the sheet edges. Where possible, the grid should be parallel to the sheet edges. If a skewed grid is unavoidable to fit the subject logically on the sheet, then text associated with the grid must be on the same alignment as the grid with all other text aligned parallel to the sheet edge.

Topographic surveys

Topographic surveys either:

(a) must be orientated so that north is at the top of the sheets; or

(b) may be orientated so that the detail fits the sheet and the grid is skewed,

as stated in the project brief.

For all measured building plans and topographic surveys, each drawing sheet must have a north arrow. The north arrow should not clash with any detail.

8.3.3 Layout

The following project specific information is to be included within the standard sheet layout:

- Each area surveyed is to be named correctly on the drawing sheet with reference to the actual orientation of the historic building or monument.
- Sub-titles should be placed to the bottom left of the subject where possible so that there is no risk of a title being shared by two different views. Sub-titles such as 'section at AA looking west' must refer to a clearly marked key plan or accompanying plan sheet.
- A location diagram is to be included in the title box of each drawing sheet. The diagram may be schematic if necessary and should be easily understood by a third party.
- The name of the CAD file, used to generate each sheet is to be included in the title box (*see* section 8.1.1).
- A grid for plans and topographic surveys is to be shown as intersection points or rapier marks on the sheet edge.
- Level ticks for elevations, related to the site datum, are to be placed down each side of the drawing sheet.
- A north arrow, scale bar, height datum description or reference and a key to any abbreviations used are to be included.
- Where detail extends over more than one sheet a reference diagram of the sheet layout is required.

8.3.4 Numbering of sheets

Each sheet of the survey should have a unique reference number starting at 1.

8.3.5 Data sheet for measured building and topographic survey

One sheet is to be the data sheet and must contain the following details:

- a control network diagram
- a sheet layout diagram
- witness diagrams for permanently marked points
- the listing of coordinates for all survey stations in eastings (X), northings (Y) and height (Z) to three decimal places
- a full description of height data including benchmarks, where used, with the levels to three decimal places.

8.3.6 PDF drawing sheets

Where PDF versions of drawings are required, these must meet the following criteria:

- The drawing is to be at the correct scale, as noted in the title box, when printed at 100 per cent.
- All line work is to be black except for logos etc in the title box, which should be their true colour.
- Each drawing sheet is to be represented by a separate PDF file, even when derived from multiple layout tabs in the same CAD drawing.
- Each file is to be named with the same file name as the CAD drawing file and with a suitable suffix if derived from multiple layout tabs eg DOV22T01(01) etc.

8.4 Survey report

A survey report is to be supplied containing a brief description of the project, plus the following:

- a traverse diagram
- witness diagrams for permanently marked points
- a listing of coordinates of all traverse stations and control points in eastings (X),northings (Y) and height (Z) to three decimal places,

and where applicable:

- photo location diagram
- control prints
- target location diagrams
- calibration certificates.

8.4.1 Imagery metadata

Each image file is to include the following minimum level of metadata in the appropriate IPTC and EXIF fields.

Field	**Comments**
Site name	
Part of site	
List entry number	*where applicable*
Project reference number	*or job number*
Contractor's name	
Image number	*each image must have a unique number*
Camera type	*make and model*
Lens etc	
Exposure information	*for original images*
Date	*photograph captured or image created*

8.5 Provision of survey material

8.5.1 Samples

Either:

(a) an initial sample of the survey in the form of a PDF file and CAD file (with attached image files as appropriate) is to be provided to the client for approval before the rest of the survey is processed; or

(b) samples are not required,

as stated in the project brief.

8.5.2 Preliminary issue

Before the final issue of CAD files and attached, imagery where applicable, a full set of preliminary PDFs is to be supplied.

8.5.3 Transfer medium

All of the required digital data and the survey report are to be supplied by:

(a) email; and/or

(b) file transfer service; and/or

(c) a portable hard drive or solid state/flash drive.

All drives are to be suitably labelled with the project name, date and survey reference number.

Appendix 8.1 Abbreviations for survey annotation

word	abbreviation	word	abbreviation
aggregate	Agg	lath and plaster	L&P
air brick	AB	lead	Pb
aluminium	Al	manhole	MH
approximate	approx	OS bench mark	OSBM
arch height	AH	overhead	O/H
asbestos	Asb	petrol interceptor	PI
asphalt	Ap	radiator	Rad
beam height	BH	radius	Rd (state units)
bitumen	Bit	rainwater hopper	RWH
brickwork	Bk	rainwater pipe	RWP
cast iron	CI	recessed doormat	RDM
ceiling	C	reinforced concrete	RC
centre line	C	rising main	RM
cement	Cem	rain water outlet	RWO
clearing eye	CE	rain water pipe	RWP
concrete	Conc	rodding eye	RE
corrugated	Corr	round	Rd
cover level	CL	sill	S
cupboard	Cup	site bench mark	SBM
diameter	Dia (state units)	skirting board	Skrtg
downpipe	DP	soffit	Soff
drain	Dr	soil pipe	SP
drinking fountain	DF	soil and vent pipe	SVP
drive shaft	D shft	springing line	SL
earth closet	EC	stair	Str
earth rod	ER	stand pipe	St.P
electricity	Elec	stone	St
fire hydrant	FH	stop valve	SV
fireplace	FP	street gully	SG
floor	Flr	surface level	SfceL

grease trap	GT	survey station	STN or STA
ground level	GL	temporary bench mark	TBM
gully	G	void	Vd
height	Ht	volume	Vol (state units)
high level	HL	void	Vd
inspection cover	IC	wall	W
interception trap	IT	wash hand basin	WHB
internal	Int	waste pipe	WP
invert	Inv	water closet	WC
invert level	IL	width	W (state units)
lamp post	LP	window head height	WH
lightning conductor	LC	yard gully	YG