highways england

A303 Stonehenge
Amesbury to Berwick Down

Written Scheme of Investigation for Archaeological Geophysical Survey

Phase 3

April 2017

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Foreword

This document comprises a Written Scheme of Investigation (WSI) outlining the initial strategy and methodology by which Wessex Archaeology will implement the programme of geophysical surveys over five areas in association with the A303 from Amesbury to Berwick Down improvement scheme. The work was commissioned by Arup Atkins Joint Venture, on behalf of Highways England.

1 Introduction

1.1 Project background

1.1.1 Wessex Archaeology has been commissioned by Arup Atkins Joint Venture (AAJV), to carry out geophysical surveys over five areas along the route of the A303 (hereafter "the Scheme") (**Figure 1**). The surveys form part of an ongoing programme of archaeological investigations being undertaken along the A303 from Amesbury to Berwick Down to inform route options.

1.2 Scope of Document

1.2.1 This specification sets out the initial strategy and methodology by which Wessex Archaeology will implement the programme of geophysical works. This specification is designed following the project requirements as provided in Archaeological Geophysical Survey Design Brief [1].

1.2.2 In format and content this document conforms with current best practice and to the guidance outlined by the following:

- Management of Research Projects in the Historic Environment [2];
- Standards and guidance for archaeological geophysical survey [3];
- Historic England's Guidelines Geophysical Survey in Archaeological Field Evaluation [4]; and *Thesauri* [5].

1.2.3 This document will be submitted to and approved by Wiltshire Council Archaeological Service (WCAS) and the Heritage Monitoring and Advisory Group (HMAG – comprising of WCAS, Historic England, English Heritage Trust and the National Trust – where surveys are sited within the Stonehenge World Heritage Site) by AAJV prior to fieldwork commencing.

2 Site Description

2.1 Location, topography and geology

2.1.1 The Scheme is located between Amesbury and Berwick Down with the individual survey areas located to the south of the A303. The five survey areas have been provided to Wessex Archaeology as provided in **Table 2-1**.

Table 2-1 Survey areas

Survey Area	OS National Grid Reference	Area (ha)
NW5	SU 09513 41702	56.7
NW6	SU 08825 41331	11.6
SW9	SU 11243 41628	9.9

2.1.2 The bedrock geology of the route is mapped as chalk of the white chalk subgroup formed in the upper cretaceous period. There are no recorded superficial deposits across the majority of the survey areas, but there are several dendriform head deposits of clay, silt sand and gravel across parts of all of the areas (NW5, NW6 and SW9) [6].

2.1.3 The areas to be surveyed are slightly undulating land, with some gradient changes located in the areas where head deposits have been recorded. However, in general the Scheme rises slightly form approximately 97 m aOD at the western extent to 107 m aOD at Long barrow roundabout. It drops down slightly to 97 m at the western extent of SW9 and then rises gently to 106 m in the east.

2.2 Archaeological and historical background

2.2.1 The archaeological context has been presented in brief within the *Archaeological Geophysical Survey Design Brief* [1] which examined the potential for the survival of buried archaeological remains within the development area and surrounding landscape.

2.2.2 One of the survey sites is situated within the Stonehenge, Avebury and Associated Sites World Heritage Site (WHS) (SW9), whilst the remaining two (NW5 and NW6) are situated outside of the boundary. All of the survey areas are however located within a landscape containing nationally and regionally important multi-period archaeology. A high density of archaeological features, potentially of national and international significance in terms of their contribution to the Stonehenge, Avebury and Associated Sites World Heritage Site's 'Outstanding Universal Value' (OUV), were identified by the Historic England National Mapping Programme project the Stonehenge World Heritage Site Mapping Project [7] surrounding the current A303 and as such much of the data on known archaeological remains from this area is derived from aerial sources.

2.2.3 The Stonehenge, Avebury and Associated Sites World Heritage Site is internationally important for its complexes of outstanding prehistoric monuments [8]. The 26 square kilometres of the WHS encompasses Stonehenge, Avebury and a range of Neolithic and Bronze Age ceremonial and funerary monuments with associated sites that survive exceptionally well in the surrounding landscape. The area was a focus for ceremonial and funerary activity throughout the Neolithic and Bronze Age and there is a general potential across the Stonehenge WHS for the discovery of previously unrecorded archaeological remains relating to the prehistoric and later activity. Extensive surveys in association with the A303 Stonehenge Improvements have demonstrated the potential for archaeological remains (i.e. [9] [10] [11] [12]).

2.2.4 Two previous phases of detailed gradiometer survey and ground penetrating radar (GPR) survey have been conducted over twelve areas along the route of the A303 [13] [14]. This survey forms part of an ongoing programme of archaeological works being undertaken along the A303 between Amesbury and Berwick Down to inform the PCF Stage 2 Options Assessment Phase for the A303 improvement scheme (NGR 406767, 140697 – NGR 4152612, 142253). The project was commissioned by Arup Atkins Joint Venture (AAJV) with the aim of establishing the presence, or otherwise, of potentially significant archaeology within the Stonehenge, Avebury and Associated Sites World Heritage Site (WHS) and wider proposed assessment corridors. It also aimed to define the extent and character of any features within each survey site.

2.2.5 Wessex Archaeology was commissioned by AAJV to undertake an archaeological trial trench evaluation within the Stonehenge WHS as part of a programme of archaeological investigations to inform the design of the proposed A303 Amesbury to Berwick Down road improvement scheme [15]. Evaluation was undertaken within two investigation areas of the WHS referred to as SW1 and SW2. A total of

67 trenches were opened, 35 within SW1 and 32 within SW2. Notable features that were investigated included two early Neolithic long barrows, a small penannular ditched monument containing Beaker pottery, and the early 20th century Larkhill Military Light Railway.

2.2.6 A brief description of the known archaeological resource within the individual survey sites is given below, taken from the Heritage Gateway [16].

NW5

2.2.7 Located immediately to west of the WHS, NW5 contains no Scheduled Monuments, although it is immediately adjacent to several Neolithic and Bronze Age monuments. South-west of the area there is a long barrow (NHLE no. 1011841), which forms the origin and focal point of a linear round barrow cemetery known as the Winterborne Stoke crossroads group (NHLE No. 1011841; 1011843; 1011047). This contains 22 round barrows, including 14 bowl barrows, three bell barrows, two disc barrows, two pond barrows and a saucer barrow.

2.2.8 Along the edge of the southern boundary of the area, there is a small rounded Bronze Age enclosure, which may be associated with settlement activity and a bowl barrow (NHLE No. 1011048) which is intersected by the A303. Directly south of the A303, a field system has been identified from aerial photography, which it has been suggested are overlain by strip lynchets. Trenching along the route of the A303 has suggested that some of these features continue into NW5. Furthermore, directly north-west of Long barrow roundabout, numerous weak anomalies were identified during a geophysical survey in 1999, which are likely to be relate to archaeological features of an unknown date.

2.2.9 An undated boundary ditch traverses the area on a north-west to south-east alignment. Close to the north-western corner of the survey area there is a circular bank probably representing the site of a ploughed down round barrow.

NW6

2.2.10 NW6 is located immediately west of NW5, outside the WHS, and contains no Scheduled Monuments. An undated field system is visible on aerial photographs as a series of linear features on various alignments across the area. A possible Bronze Age boundary ditch also traverses the area on a north-west to south-east alignment. This was identified to the south-east in the previous phase of geophysical survey in SW3.

SW9

2.2.11 This area is located within the WHS and contains two Scheduled Monuments, both of which are associated with the ceremonial and funerary landscape of prehistoric monuments that surrounds Stonehenge. The eastern boundary of SW9 runs through the centre of an extant Bronze Age bell barrow, which was excavated by Hoare (1012370). To the east there is a further Bronze Age bowl barrow, also excavated by Hoare, and later re-excavated by Field in 1960 (NHLE No. 1010832). This revealed 7 burials and identified that the original grave contained two skeletons and a cremation.

2.2.12 South-east of SW9 there is a dense concentration of monuments forming the Normanton Down round barrow cemetery (NHLE No. 1009614; 1009617). This comprises several fine examples of all the major barrow types including two disc barrows and the bowl barrow known as Bush Barrow (NHLE No. 1009618).

2.2.13 Other archaeological features of this area include the one element of a complex of linear features which may have a Bronze Age origin, part of which was also identified during the initial phase of geophysical survey in SW1 [13].

3 Aims and objectives

3.1 Project Aims and Objectives

3.1.1 With due regard to the Chartered Institute for Archaeologist's *Standard and guidance for archaeological geophysical survey* [3], the principle aim of an archaeological geophysical survey is to determine, as far as is reasonably possible, the nature of the detectable archaeological resource within a specified area using appropriate methods and practices, and in compliance with the *Code of Conduct* and other relevant by-laws of the CIfA.

3.1.2 The aim of this archaeological investigation is to gather information to inform the design proposals and wider environmental disciplines for the selection of the final route options.

3.1.3 The project specific objectives for this geophysical survey are defined by AAJV as follows:

To determine the presence/absence of potentially significant archaeology within the WHS and wider proposed assessment corridors;
Define the extent and character of any features within each survey site; and
Produce an interpretive report on the findings of the survey to inform the options screening process.

4 Methodology

4.1 Access

4.1.1 The AAJV will make all access arrangements for the works, Wessex Archaeology will not deal directly with any landowners etc. unless instructed to do so by AAJV.

4.1.2 All Section 42 licences and National Trust Research Agreements will be obtained by AAJV and provided to Wessex Archaeology prior to mobilisation.

4.2 Record photographs

4.2.1 Wessex Archaeology will take sufficient dated colour photographs of all areas, including access routes, to provide a record of the original condition, and the condition on completion of all fieldwork.

4.2.2 AAJV will provide a template Site Condition Form, which will be completed and submitted on completion of all fieldwork.

4.3 Monitoring

4.3.1 WCAS/HMAG will be notified prior to commencement of work being undertaken by AAJV, unless otherwise agreed.

4.3.2 The work will be monitored by WCAS and HMAG (within the WHS) and all reasonable access will be provided to the works. Any changes in the agreed

Written Scheme of Investigation will be discussed and agreed with WCAS and HMAG (for sites within the WHS) before implementation.

4.4 Survey specification

4.4.1 The navigation display on cart-based system provides real-time positioning enabling full site coverage without the need to set up individual grid nodes across the survey areas. However, in order to ensure survey accuracy, the boundaries of the survey extent will be established using a GPS.

4.4.2 Stakeout data will be prepared in British National Grid coordinates prior to survey using AutoCAD, and survey data will be georeferenced accordingly. Individual survey nodes will be established at regular intervals for the hand-held gradiometer and ground penetrating radar (GPR) surveys, and as site boundaries for the cart-based surveys using a Leica Viva RTK GNSS instrument, which is precise to approximately 0.02 m and therefore exceeds Historic England recommendations (English Heritage 2008).

4.4.3 The surveyed areas will be tied into the National Grid using GPS survey equipment to enable the surveyed area to be independently relocated by a third party. A selection of grid points will be re-occupied after the data has been acquired and checked to confirm the accuracy of the stake out location and that no disturbance has occurred.

4.4.4 Digital mapping and archaeological information gathered during previous work will be used to support the interpretation of the geophysical data.

4.4.5 An interpretation of the geophysical anomalies will also be presented identifying likely and possible archaeological features along with linear trends and areas of increased magnetic response.

4.4.6 Further details of the geophysical and survey equipment, methods, processing and interpretation are described in **Appendix A**, **B** and **C**.

4.4.7 Following completion of these gradiometer surveys, it is proposed that any outstanding areas not investigated by geophysical survey technique will either be subject to gradiometer survey and/or trial trenching at the commencement of Highways England PCF Stage 3.

4.4.8 Any survey sites being investigated under this current round of gradiometer surveys that are deemed to contain significant archaeological potential will be further investigated by either targeted Ground Penetrating Radar and/or trial trenching, depending on the most appropriate technique to inform archaeological impacts within and outside of the WHS boundary. This would be undertaken at the commencement of Highways England PCF Stage 3.

4.5 Gradiometer survey specification

4.5.1 The detailed gradiometer survey will be conducted using Bartington Grad-01-1000L gradiometers at 1 m intervals mounted on either a non-magnetic cart or on a hand-held frame with an effective sensitivity of 0.03 nT.

4.5.2 Data will be collected at 0.25 m intervals along transects spaced 1m apart, in accordance with Historic England guidelines [4]. Data will be collected in the zigzag method.

4.5.3 Data from the survey will be subject to minimal data correction processes. These would typically comprise a zero mean traverse function (±5 nT thresholds) to correct for variations in the calibration between the Bartington sensors used, and a de-step function to account for variations in traverse position due to varying ground cover and topography. These two steps are generally applied to all survey areas, with no further filtering or interpolation.

4.5.4 The data will be processed using commercially available and in-house software which allows greyscale and trace plots to be produced. Minimal processing will be applied to the data and typically includes bounded zero mean traverse and destagger functions.

4.6 Ground penetrating radar survey specification

4.6.1 The GPR survey will be conducted using a Malå RAMAC XV11 monitor and control unit with a shielded antenna. This is mounted on a rough terrain cart which is fitted with an odometer to measure horizontal distance along the ground surface.

4.6.2 The central frequency of the antenna(e) depends on the types of target being investigated. Lower frequency antennae are able to acquire data from deeper below the surface at reduced resolution, whereas higher frequencies allow imaging of smaller near-surface targets, at the expense of deep penetration. To allow for a range of ground conditions and target depths, Wessex Archaeology generally deploys two, or more, antennae of different frequency, though not necessarily across the entirety of the Site.

4.6.3 A field test of the antenna frequency will be undertaken at the outset of the survey using a 500 and 250 MHz antenna in accordance with Europae Archaeologiae Consilium [17] and Historic England guidelines [4]. The antenna frequency likely to provide the most information regarding the nature of archaeological remains within each area will be used predominantly. Transects will be collected in the zigzag method where practically possible.

4.6.4 Data from the GPR survey will be subject to standard processing, typically including gain and wobble correction and navigational verification. Further processing such as migration, Hilbert transformation, band-pass and low-pass filtering may be undertaken where appropriate. Topographic data will be used to correct for the angular offsets caused by the variation in aspect of the terrain along the profile.

4.7 Preliminary schedule

4.7.1 The three survey areas that are anticipated to be subject to detailed gradiometer survey as shown in **Table 4-1**. A timetable for the GPR survey will be dependent upon access availability.

4.7.2 The fieldwork will be undertaken Monday-Friday, with the usual working day starting at 08.00 and ending at 16.00.

4.7.3 Preliminary results in the form of a short description of any key features identified and an initial interpretation plan will be submitted within seven days following completion of each survey area to the client.

4.7.4 The GPR areas will be targeted where areas of significant archaeology have been detected by the detailed gradiometer survey.

Table 4-1 Preliminary gradiometer schedule

Survey Area	Area (ha)	Anticipated Method	Anticipated Duration	Anticipated Start Date
NW5	56.7	Cart 1 Cart 2	7 days 7 days	18/04/2017
NW6	11.5	Cart 1	2 days	TBC (under crop)
SW9	9.9	Cart 1	2 days	02/05/2017

4.8 Health and Safety

4.8.1 Health and Safety considerations will be of paramount importance in conducting all fieldwork. Safe working practices will override archaeological considerations at all times.

4.8.2 All work will be carried out in accordance with the *Health and Safety at Work etc. Act* 1974 and the *Management of Health and Safety Regulations* 1992, and all other relevant Health and Safety legislation, regulations and codes of practice in force at the time.

4.8.3 Wessex Archaeology will supply a copy of their Health and Safety Policy and a Risk Assessment to AAJV before the commencement of any fieldwork. The Risk Assessment will have been read and understood by all staff attending the Site before any groundwork commences.

4.8.4 Wessex Archaeology has both public liability (£10,000,000) and professional indemnity insurance (£5,000,000).

4.8.5 The geophysical survey team will be aware of safe working practices, safety equipment, emergency procedures and specific information relating to environmental conditions likely during fieldwork.

4.8.6 A low risk of Unexploded Ordnance (UXO) has been identified within parts of the survey area [18]. Accordingly, any suspect items discovered will immediately be reported to AAJV. Staff will not touch or move any suspect items and will take steps to clear the immediate area of staff and any other contractors or members of the public who may be present. Full details of the procedure to follow in relation to UXO will be contained in the Risk Assessment.

4.9 Reporting

4.9.1 An interim draft results report will be issued to the AAJV within 1 week of completion of each gradiometer survey site, which will inform design of the GPR surveys. On completion of the GPR surveys, a draft geophysical survey report containing all site surveys will be submitted to the client for comment within four weeks. A final draft version of the report will be issued within a further two weeks to WCAS and HMAG by the AAJV for final comments before completing.

4.9.2 The report will include the following elements:

- The name(s) of the investigators/contractors, title, date, report reference number and client details;
- A non-technical summary including the basis for the survey, its aims and results;
- Introduction including site location plan, site history, National Grid Reference, site description;
- An account of the background to the project and circumstances of work;
- The aims and objectives of the survey; and
- The methodology used.

4.9.3 The results of the survey will include:

- Plans at appropriate scales to include, raw data, greyscale plot, XY trace plot, interpretative plot. Each illustration will contain a scale bar and north arrow;
- A figure and text to demonstrate that the survey has been accurately geo-located;
- Detailed survey results and interpretation;
- Recommendations regarding further archaeological work necessary on site in advance of, or during, development where relevant;
- References to all primary and secondary sources consulted; and
- Appendices to include details of the geophysical and survey equipment, methods and processing undertaken and full definitions of the interpretation terms used in the report.

4.9.4 Wessex Archaeology shall retain full copyright of the client report under the Copyright, Designs and Patents Act 1988 with all rights reserved; excepting that it hereby provides an exclusive licence to AAJV for the use of the report by AAJV in all matters directly relating to the project as described in the specification.

4.10 Archiving

4.10.1 The information will be deposited within the relevant local authority where it can be freely copied for the purposes of archaeological research or Development Control within the planning process.

4.10.2 Details of the survey will be submitted online to the OASIS (Online Access to the Index of Archaeological Investigations) database within six months of the completion of all site work or upon release of information by Highways England.

4.10.3 An accession number, if required, will be sought prior to work commencing.

4.10.4 Material archived will include the raw data in Geoplot usable format.

4.10.5 If the requirements of this project change, a variation can be requested. The complete project archive will be prepared in accordance with Schmidt *et al*. (2001) *Geophysical Data in Archaeology: A Guide to Good Practice* (ADS) and those required by WSHER.

4.11 Project team

4.11.1 The project will be managed overall by Lucy Learmonth for Wessex Archaeology.

4.11.2 The work will be undertaken by Wessex Archaeology's in-house geophysics team. Lucy Learmonth as Terrestrial Geophysics Manager will be responsible for the day

to day running of the geophysical survey work from fieldwork through data processing, interpretation and reporting.

4.11.3 Dr Paul Baggaley as Chief Technical Officer and Caroline Budd as Chief Operating Officer at Wessex Archaeology will be responsible for the work and Paul is, in turn, responsible to the Chief Executive. The Chief Executive, Chris Brayne, has ultimate responsibility for the maintenance of quality standards for all work within Wessex Archaeology.

4.11.4 Fieldwork will be undertaken by experienced members of the geophysics team and will comprise geophysicists from our Salisbury Office.

4.11.5 All nominated Wessex Archaeology staff are appropriately qualified and experienced for their project role. Wessex Archaeology reserves the right to vary project staff according to the operational demands of its overall programme. Career profiles can be provided on request.

4.12 Quality and Code of Practice

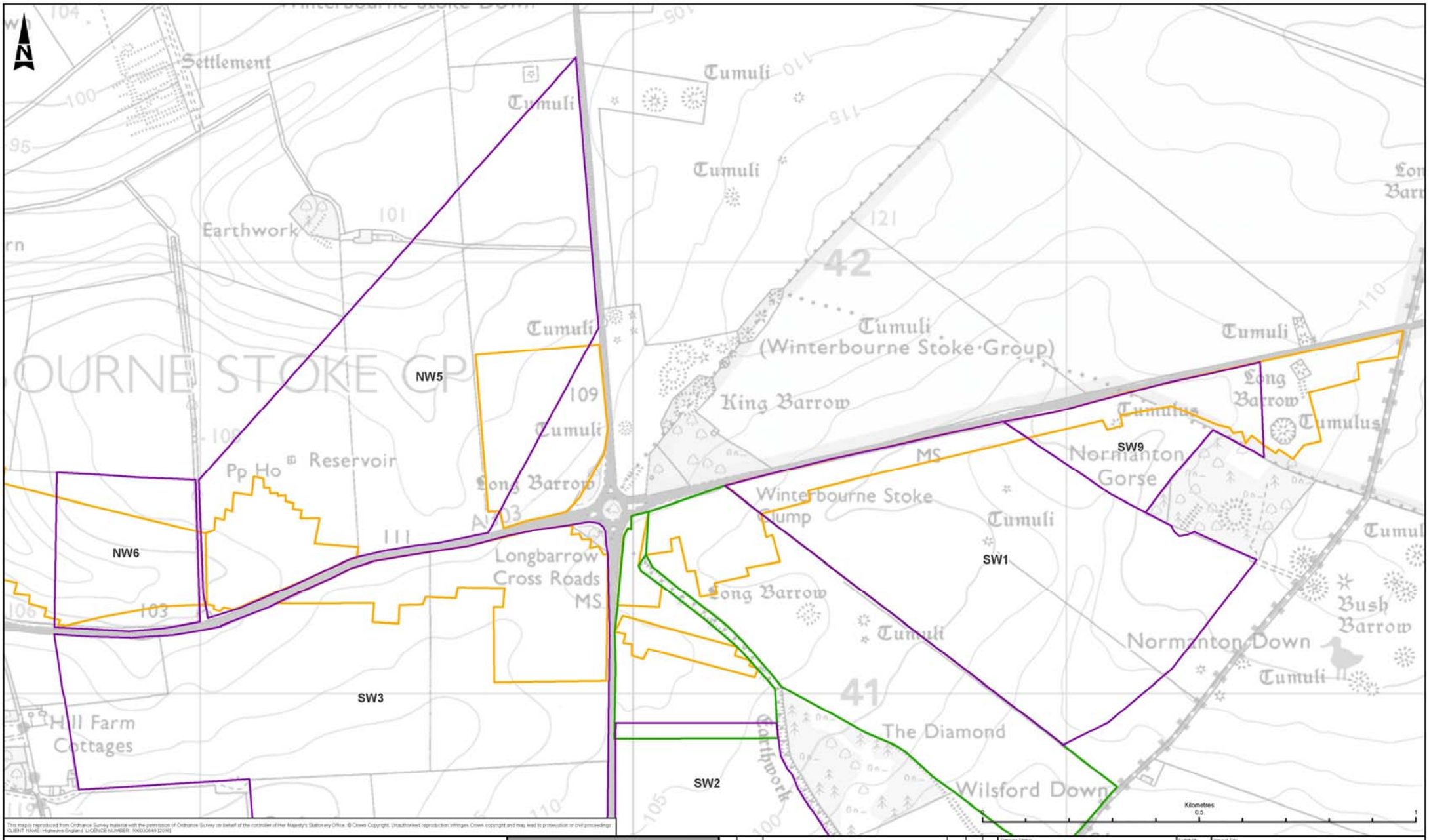
4.12.1 Wessex Archaeology is an archaeological organisation registered with the Chartered Institute for Archaeologists.

4.12.2 Wessex Archaeology endorses the Code of Practice and the Code of Approved Practice for the Regulation of Contractual Arrangements in Field Archaeology of the Chartered Institute for Archaeologists.

4.12.3 All core staff would be of a standard approved by Wessex Archaeology, be employed in line with The Chartered Institute for Archaeologists Codes of Practice and be members of the Chartered Institute for Archaeologists or be appropriately qualified.

4.12.4 Wessex Archaeology is an ISO 9001:2008 accredited organisation (certificate number FS 606559), confirming the operation of a Quality Management System which complies with the requirements of the standard and covering its professional archaeological and heritage advice and services. The award of the ISO 9001 certificate, independently audited by the British Standards Institution (BSI), demonstrates Wessex Archaeology's commitment to providing quality heritage services to our clients. ISO (the International Organisation for Standardisation) is the most recognised standards body in the world, helping to drive excellence and continuous improvement within businesses.

1 Figures



LEGEND

GEOPHYSICAL SURVEY AREAS

- NW5 = 567,605m²
- NW6 = 115,115m²
- SW9 = 99,915m²
- HISTORIC ENGLAND (2015)
- 2004 SCHEME

DRAFT

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks (Reference shall also be made in the design hazard log)

Construction	None
Maintenance / Cleaning	None
Use	None
Decommission / Demolition	None

Rev	Date	Description	By	Chkd	Appd
P01.1	07/04/17	WORK IN PROGRESS	RJS	LB	SH

Drawing Status: WORK IN PROGRESS
Suitability: S0
Client: highways england
Designers: ARUP ATKINS

Project Title: A303 AMESBURY TO BERWICK DOWN
Drawing Title: ADDITIONAL GEOPHYSICAL SURVEYS

Scale	Designed	Drawn	Checked	Authorised
1:8,000	N/A	RJS	LB	SH
Original Size	Date	Date	Date	Date
A3	N/A	07/04/17	07/04/17	07/04/17

Drawing Number: Project - Originator - Volume - Location - Type - Role - Number
HE551506 - AA - EHR - D_SWI - DR - YE - 000053
Revision: P01.1

Abbreviations List

AAJV	Arup Atkins Joint Venture
CIfA	Chartered Institute for Archaeologists
GPR	Ground Penetrating Radar
GPS	Global Positioning System
HMAG	Heritage Monitoring and Advisory Group (comprising of Historic England, English Heritage Trust, WCAS and the National Trust)
WCAS	Wiltshire Council Archaeological Service
WHS	World Heritage Site

References

[1] AAJV, A303 Amesbury to Berwick Down, Archaeological Geophysical Survey Design Brief, unpublished client brief, 2016.

[2] Historic England, Management of Research Projects in the Historic Environment: The MoRPHE Project Managers' Guide, 2015.

[3] CIfA, Standard and Guidance for archaeological geophysical survey, Chartered Institute for Archaeologists, 2014.

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[9] GSB, Report on Geophysical Survey: A303 Amesbury to Berwick Down, unpublished client report, Report No 92/3, 1992.

[10] GSB, Geophysical survey: A303 Stonehenge VII, unpublished report, Report No 2001/75, 2001a.

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[12] Wessex Archaeology, Stonehenge Archaeological Surveys. Archaeological Evaluation Reports, unpublished client report, 2003.

[13] Wessex Archaeology, A303 Amesbury to Berwick Down, Wiltshire: Geophysical Survey, unpublished client report, 2016.

[14] [18] A303 Amesbury to Berwick Down, Wiltshire: Geophysical Survey, Phase 2, unpublished client report., Forthcoming (2017).

[15] Wessex Archaeology, A303 Amesbury to Berwick Down, Wiltshire: Archaeological Trial Trench Evaluation, unpublished client report, 2016.

[16] Historic England, National Heritage List for England, [accessed 14/02/17], 2017.

[17] Schmidt, A., Linford, P., Linford, N., David, A., Gaffney, C., Sarris, A. and Fassbinder, J.,Guidelines for the use of geophysics in archaeology: questions to ask and points to consider. EAC Guidelines 2. European Archaeological Council: Belgium., 2015.

[18] Dynasafe, Explosive Ordnance Desktop Threat Assessment: Amesbury Project, 2016.

Appendices

Appendix A Magnetic survey equipment and data processing

A.1 Survey methods and equipment

A.1.1.1 The magnetic data for this project was acquired using a Bartington 601-2 dual magnetic gradiometer system. This instrument has two sensor assemblies fixed horizontally 1m apart allowing two traverses to be recorded simultaneously. Each sensor contains two fluxgate magnetometers arranged vertically with a 1m separation, and measures the difference between the vertical components of the total magnetic field within each sensor array. This arrangement of magnetometers suppresses any diurnal or low frequency effects.

A.1.1.2 The gradiometers have an effective resolution of 0.03nT over a ±100nT range, and measurements from each sensor are logged at intervals of 0.25m. All of the data are then relayed to a Leica Viva CS35 tablet, running the MLgrad601 program, which is used to record the survey data from the array of Grad601 probes at a rate of 8Hz. The program also receives measurements from a GPS system, which is fixed to the cart at a measured distance from the sensors, providing real time locational data for each data point.

A.1.1.3 The gradiometers have an effective resolution of 0.03nT over a ±100nT range, and measurements from each sensor are logged at intervals of 0.25m.

A.1.1.4 The cart-based system relies upon accurate GPS location data which is collected using a Leica Viva system with rover and base station. This receives corrections from a network of reference stations operated by the Ordnance Survey and Leica Geosystems, allowing positions to be determined with a precision of 0.02m in real-time and therefore exceed the level of accuracy recommended by Historic England (English Heritage 2008) for geophysical surveys.

A.1.1.5 Data may be collected with a higher sample density where complex archaeological anomalies are encountered, to aid the detection and characterisation of small and ephemeral features. Data may be collected at up to 0.125m intervals along traverses spaced up to 0.25m apart exceeding recommendation by Historic England [4] for characterisation surveys.

A.2 Post-processing

A.2.1.1 The magnetic data collected during the detail survey are downloaded from the Bartington cart system for processing and analysis using both commercial and in-house software. This software allows for both the data and the images to be processed in order to enhance the results for analysis; however, it should be noted that minimal data processing is conducted so as not to distort the anomalies.

A.2.1.2 The cart-based system generally requires a lesser amount of post-processing than the handheld Bartington Grad 601-2 fluxgate gradiometer instrument. This is largely because mounting the gradiometers on the cart reduces the occurrence of operator error; caused by inconsistent walking speeds and deviation in traverse position due to varying ground cover and topography.

A.2.1.3 Typical data and image processing steps may include:

- GPS Destripe – Determines the median of each transect and then subtracts that value from each datapoint in the transect. May be used to remove the striping effect seen within a survey caused by directional effects, drift, etc.
- GPS Base Interpolation – Sets the X & Y interval of the interpolated data and the track radius (area around each datapoint that is included in the nterpolated result).
- Discard Overlaps - Intended to eliminate a track(s) that have been collected too close to one another. Without this, the results of the interpolation process can be distorted as it tries to accommodate very close points with potentially differing values.

A.2.1.4 Typical displays of the data used during processing and analysis:

- XY Plot – Presents the data as a trace or graph line for each traverse. Each traverse is displaced down the image to produce a stacked profile effect. This type of image is useful as it shows the full range of individual anomalies.
- Greyscale – Presents the data in plan view using a greyscale to indicate the relative strength of the signal at each measurement point. These plots can be produced in colour to highlight certain features but generally greyscale plots are used during analysis of the data.

Appendix B GPR equipment and data processing

B.1 Survey Methods and Equipment

B.1.1.1 The ground penetrating radar (GPR) data were collected using a cart-based shielded antenna with central frequencies suitable for the types of target being investigated. Lower frequency antennae are able to acquire data from deeper below the surface, whereas higher frequencies allow high resolution imaging of near-surface targets at the expense of deep penetration. The exact make and model of equipment varies.

B.1.1.2 The depth of penetration of GPR systems is determined by the central frequency of the antenna and the relative dielectric permittivity (RDP) of the material through which the GPR signal passes. In general, soils in floodplain settings may have a wide range of RDPs, although around 8 may be considered average, resulting in a maximum depth of penetration c. 2.5m with the GPR signal having a velocity of approximately 0.1m/ns.

B.1.1.3 The GPR beam is conical in shape, however, and whilst most of the energy is concentrated in the centre of the cone, the GPR signal illuminates a horizontal footprint which becomes wider with increasing depth. At the maximum depth of the antenna, it becomes impossible to resolve any feature smaller than the horizontal footprint for the corresponding depth. The size of the footprint is dependent upon central frequency, and its size increases as the central frequency decreases.

B.1.1.4 The vertical resolution is similarly dependent upon the central frequency; for the 500MHz antenna, features of the order of 0.05m may be resolved vertically. Antennae with lower frequencies can therefore penetrate more deeply but are less resolute in both horizontal and vertical directions. Choice of antenna frequency is guided largely by the anticipated depth to the target and the required resolution.

B.1.1.5 GPR data for detailed surveys are collected along traverses of varying length separated by 0.5m with cross lines collected running perpendicular to these traverses at wider separations. The data sampling resolution is governed by the data logger and a minimum separation of 0.05m between traces is collected for all surveys.

B.2 Post-Processing

B.2.1.1 The radar data collected during the detail survey are downloaded from the GPR system for processing and analysis using commercial software (GPR Slice). This software allows for both the data and the images to be processed in order to enhance the results for analysis; however, it should be noted that minimal data processing is conducted so as not to distort the anomalies.

B.2.1.2 Typical data and image processing steps may include:

- Gain – Amplifies GPR data based upon its position in the profile, which boosts the contrast between anomalies and background. A wobble correction is also applied during this step;

- Background Filter - is used to remove banding noises that are seen across the radargrams
- Bandpass – Removes GPR data lying outside a specified range, which removes high- and low-frequency noise.

B.2.1.3 Typical displays of the data used during processing and analysis:

- Timeslice – Presents the data as a series of successive plan views of the variation of reflector energy from the surface to the deepest recorded response. The variation in amplitude is represented using a colour scale with red indicating high amplitude and blue indicating low amplitude responses.
- Radargram – Presents each radar profile in a vertical view with distance along the profile expressed along the x axis and depth along the y axis. The amplitude variation is expressed using a greyscale.

Appendix C Geophysical interpretation

C.1.1.1 The interpretation methodology used by Wessex Archaeology separates the anomalies into four main categories: archaeological, modern, agricultural and uncertain origin/geological.

C.1.1.2 The archaeological category is used for features when the form, nature and pattern of the anomaly are indicative of archaeological material. Further sources of information such as aerial photographs may also have been incorporated in providing the final interpretation. This category is further sub-divided into three groups, implying a decreasing level of confidence:

- Archaeology – used when there is a clear geophysical response and anthropogenic pattern.
- Possible archaeology – used for features which give a response but which form no discernible pattern or trend.

C.1.1.3 For the interpretation of GPR datasets two additional categories are also employed:

- High Amplitude – used for features which give a notably high amplitude response but display no discernible patterns.
- Low Amplitude – used for features which give a notably low amplitude response but display no discernible patterns.

C.1.1.4 The modern category is used for anomalies that are presumed to be relatively modern in date:

- Ferrous – used for responses caused by ferrous material. These anomalies are likely to be of modern origin.
- Coherent ferrous – used for anomalies caused by ferrous material that can be directly linked to a specific or known modern origin.
- Modern service – used for responses considered relating to cables and pipes; most are composed of ferrous/ceramic material although services made from non-magnetic material can sometimes be observed.

C.1.1.5 The agricultural category is used for the following:

- Former field boundaries – used for ditch sections that correspond to the position of boundaries marked on earlier mapping.
- Ridge and furrow – used for broad and diffuse linear anomalies that are considered to indicate areas of former ridge and furrow.
- Ploughing – used for well-defined narrow linear responses, usually aligned parallel to existing field boundaries.
- Drainage – used to define the course of ceramic field drains that are visible in the data as a series of repeating bipolar (black and white) responses.

C.1.1.6 The uncertain origin/geological category is used for features when the form, nature and pattern of the anomaly are not sufficient to warrant a classification as an archaeological feature. This category is further sub-divided into:

- Increased magnetic response – used for areas dominated by indistinct anomalies which may have some archaeological potential.
- Trend – used for low amplitude or indistinct linear anomalies.
- Superficial geology – used for diffuse edged spreads considered to relate to shallow geological deposits. They can be distinguished as areas of positive, negative or broad bipolar (positive and negative) anomalies.

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