A303 Amesbury to Berwick Down

Applicant's provision of technical reports supporting the Environmental Information Review

Ground Investigation - Phase 6 & 7 Factual Report

Document reference: Redetermination 2.12

Planning Act 2008

The Infrastructure Planning (Examination Procedure) Rules 2010

February 2022

A303 Stonehenge - Phase 6 & 7 Ground Investigation

Final Factual Report on Ground Investigation

Project No: 733442

Client: Highways England

APRIL 2019

STRUCTURAL SOILS LTD

DOCUMENT ISSUE RECORD

Project No.:	733442
Report No.:	733442-1(01)
Project Name:	A303 Stonehenge - Phase 6 & 7 Ground Investigation
Document Title	Final Factual Report on Ground Investigation
Client:	Highways England
Engineer:	AECOM
Status:	Final

Author	[redacted]	A Dingle BSc (Hons) FGS
Author		I Foster MSci (Hons)
Draft approved by		L Llewellyn BSc (Hons) CGeol FGS
Final approved by		M Addinall BSc (Hons) MSc FGS
Report Issue Date		12 April 2019

REVISION RECORD

Revision	Date	Description of revisions	Prepared by
00	20/12/18	Minus on-going geotechnical testing	AD
01	12/04/19	Final Report Incorporating AECOM comments	MA

STRUCTURAL SOILS LIMITED
The Old School
Stillhouse Lane
Bedminster
BRISTOL
BS3 4EB
Tel: 0117 947 1000
Email: ask@soils.co.uk
[redacted]

CONTENTS

1 INTRODUCTION

This investigation was carried out by Structural Soils Ltd (SSL) on the instructions of AECOM (the Engineer) on behalf of Highways England (the Client) to the west of the town of Amesbury, in Wiltshire. The purpose of the work was to obtain geotechnical and geoenvironmental information, and to conduct hydrological testing for the proposed A303 improvements including a tunnel at Stonehenge. This investigation is required to inform the scheme design to mitigate any impacts which relate to the uncertainties, mainly regarding the phosphatic chalk properties and hydrogeological characteristics.

The investigation included the completion of the remaining boreholes from the Early Phase Ground Investigation, which was curtailed due to land access issues in spring 2017, together with a number of catchment area monitoring boreholes.

The work included an intrusive investigation, hydrological testing, laboratory testing and the preparation of this report. The report contains a description of the site and the works carried out, the exploratory hole logs, in-situ and laboratory testing results.

The ground investigation has been carried out in accordance with the contract specification, and the general requirements of BS 5930:2015, BS 10175:2011+A2:2017, BS EN 1997-2 (2007), BS EN ISO 22475-1 (2006) and other relevant standards as identified below.

SSL have undertaken other investigations at this site, which are detailed in our report A303 Amesbury to Berwick Down 2017 report referenced 731823: (see References).

This report presents the factual records of the fieldwork carried out and laboratory testing. Whilst every attempt is made to record full details of the strata encountered in the exploratory holes, techniques of hole formation and sampling will inevitably lead to disturbance, mixing or loss of material in some soils and rocks. All information given in this report is based on the ground conditions encountered during the site work, and on the results of laboratory and field tests performed during the investigation. However, there may be conditions at the site that have not been taken into account, such as unpredictable soil strata, contaminant concentrations, and water conditions between or below exploratory holes.

This report was prepared by SSL for the sole and exclusive use of Highways England in response to particular instructions. Any other parties using the information contained in this report do so at their own risk and any duty of care to those parties is excluded. No liability will be accepted after a period of 6 years from the date of the report.

2 SITE DESCRIPTION

2.1 Location and Topography

The site is located around a central point approximately 3 km west of the town of Amesbury, Wiltshire (see Site Location Map in Appendix A). The British National Grid Reference of the centre of the site is approximately SU 125417.

The overall extents of the site is approximately 9 km east to west; from the Countess Roundabout to Winterbourne Stoke, and 7 km north to south from Lark Hill Camp to Devils Hand Farm, with the main concentration of boreholes within the farmland to the south of the A303 near the centre of the site. The site topography is undulating, with elevation ranging from ~75 m AOD to ~115 m AOD.

All the exploratory holes were undertaken within arable and pastoral farmland, with the exception of the two most northerly positions which were located within land associated with the Ministry of Defence Lark Hill Army Barracks.

The site lies within the Avebury and Stonehenge World Heritage Site (WHS) between Amesbury and Berwick Down. The site has significant cultural heritage, archaeological and ecological value.

For the purposes of reporting the results of this investigation the exploratory hole locations have been split into the following areas:

2.1.1 R142 Cluster

This area is located within the centre of the site, with the boreholes being centred around a historic borehole R142; the location was selected to provide more information on the phosphatic chalk where it was previously encountered (in R142) at its greatest thickness.

2.1.2 Tunnel Alignment of Stonehenge Bottom

The 18 no. boreholes (both rotary cored and rotary open-holed) are aligned east-west within the central section of the site, directly adjacent to the southern side of the existing A303. A further cluster of 6 no. boreholes are also located on Coneybury Hill, to the south of the proposed tunnel alignment

2.1.3 South of Alignment (Coneybury Hill)

A further cluster of 6 no. boreholes are also located on Coneybury Hill, to the south of the proposed tunnel alignment

2.1.4 Hydrogeology Boreholes

The 6 no. hydrogeology boreholes were located to provide additional groundwater information, in addition to the boreholes that were drilled and installed in the 2017 investigation. The provisional additional groundwater level monitoring boreholes are located near Cherry Lodge in Parsonage Down Valley, south of the Longbarrow roundabout in the vicinity of Druids Lodge, north of the Longbarrow roundabout in the

vicinity of Rollestone Camp, and within the fields adjacent to the south of the existing A303.

2.1.5 Phase 7 Boreholes

The 14 no. Phase 7 boreholes (shown in blue on the Exploratory Hole Location Plan in Appendix A) were aligned roughly east-west across the width of the site. These boreholes lie on the southside of the A303 in the western section and cross to the north of the A303 in the eastern section of the site.

2.2 Geology

Information on the geology of the site was obtained from the following sources published by the British Geological Survey (BGS):

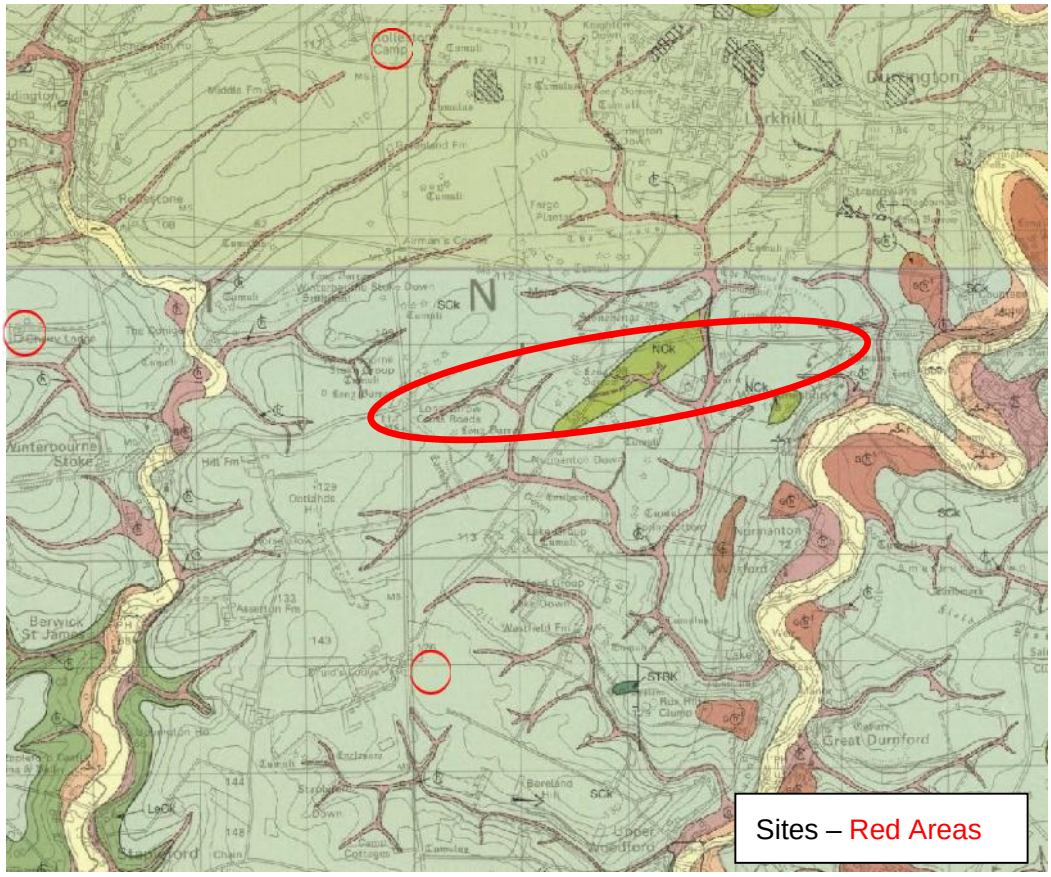
- BGS map (sheets 282 & 298, scale 1:50,000, published 2008 & 2005).
- The BGS digital geology map, which utilises the most up to date names for geological units [redacted].
- The BGS Lexicon of Named Rock Units, which provides typical descriptions for most geological units [redacted].

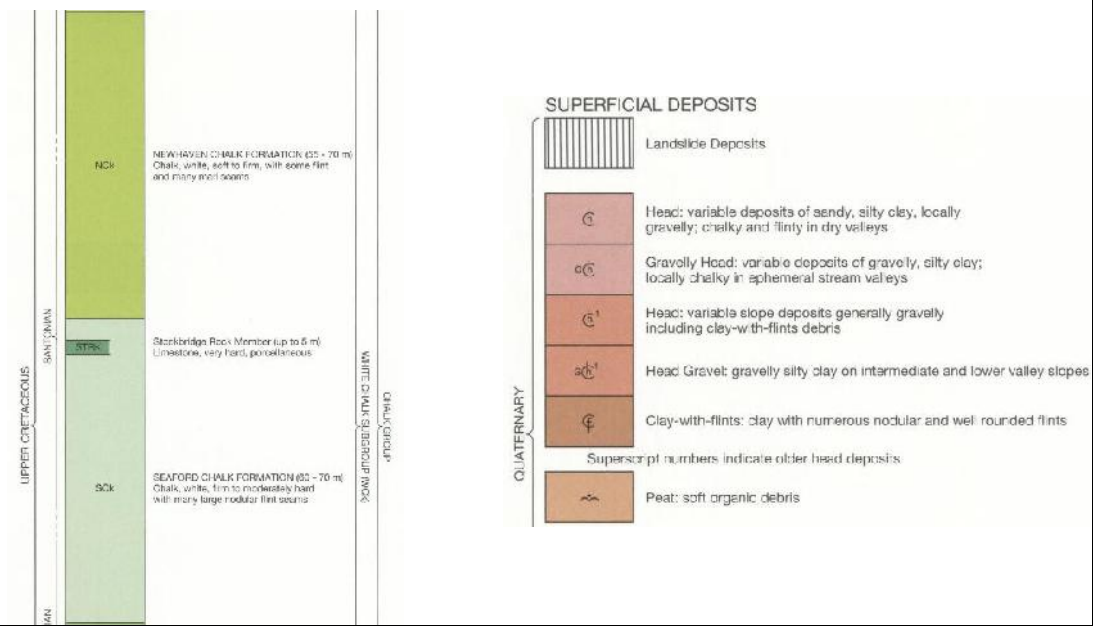
The site is shown to be underlain, in discrete areas, by a combination of the following descending sequence of strata:

TABLE 1 : SUMMARY OF EXPECTED SITE GEOLOGY	
Geological Unit Name	**Description**
DRIFT DEPOSITS	
River Terrace Deposits	Sand and gravel
Head Deposits	Clay, silt, sand and gravel
SOLID GEOLOGY	
Newhaven Chalk Formation	Chalk, white, soft to firm, with some flint and many marl seams.
Seaford Chalk Formation	Chalk, white, firm to moderately hard with many large nodular flint seams.

Note: Information obtained from BGS digital records © NERC.

The BGS online maps portal provides access to scans of almost all maps produced by the BGS since 1932. An extract of the most recent available scanned map for the site is included below:





Note: Above images contain British Geological Survey materials ©NERC [2018].

3 FIELDWORK

3.1 General

The ground investigation was carried out by SSL between 21 March and 10 October 2018. The investigation was supervised by a team of engineers from SSL. The exploratory hole and in-situ test locations are shown on the Exploratory Hole Location Plans (Figures 2a and 2b) presented in Appendix A.

The scope of investigation, choice of rotary coring techniques, sampling and in-situ testing specification details all being determined by AECOM.

The positions were selected by AECOM, set out by SSL and adjusted where necessary to take account of any restrictions such as nesting birds.

Prior to the commencement of any exploratory hole or intrusive test a cable avoidance scan was carried out using a cable avoidance tool (CAT) and signal generator ('Genny').

Inspection pits were hand dug at all exploratory locations and noted on the relevant exploratory hole log or in-situ test results. Prior to the excavation by SSL staff, each exploratory hole inspection pit was commenced by an archaeologist (Wessex Archaeology) to allow an assessment and record any potential archaeological features encountered, and if required the exploratory hole location to be moved.

The exploratory holes were logged by an engineer in general accordance with the recommendations of BS 5930:2015 (which incorporates the requirements of BS EN ISO 14688-1, 14688-2 and 14689-1), and CIRIA Report C574 Engineering in Chalk. Detailed descriptions, together with relevant comments, are given in the logs included in Appendix B together with a summary of each borehole's discontinuity log and photographs of the core.

Prior to commencement of intrusive works at borehole RX630 (near to the Lark Hill Army Barracks), the hole location and the immediate vicinity were scanned by a specialist UXO (Unexploded Ordnance) Officer using a magnetometer to check for buried ferrous objects that could possibly be UXO.

On completion of the works, a survey of the exploratory hole locations was undertaken using specialist Global Positioning System (GPS) equipment. The coordinates of each exploratory hole were measured relative to British National Grid, and the level relative to Ordnance Datum. These are shown in tabular format in Appendix A and on the exploratory hole logs contained in Appendix B which have been printed with a reduced level column.

3.2 Exploratory Holes

The exploratory holes are listed in the following table grouped by section of works.

TABLE 2 :SCOPE OF INTRUSIVE WORKS		
Hole Number	**Exploratory Hole / Test Type**	**Drilled Depth (m)**
R142 Cluster		
GC605	Rotary Open Hole with Gamma CPT	15.00
SBP604	Rotary Open Hole and Cored with Self Boring Pressuremeter Tests	38.00
RZ603	Rotary Cored Borehole	34.90
R602	Rotary Cored Borehole	35.00
Tunnel Alignment West of Stonehenge Bottom		
W601	Rotary Open Hole with Pumping Test	61.00
R606	Rotary Cored Borehole	60.00
R607	Rotary Cored Borehole	60.00
R608	Rotary Cored Borehole	60.00
RX609	Rotary Open Hole	60.00
R610	Rotary Cored Borehole	53.00
R611	Rotary Cored Borehole	53.00
R612	Rotary Cored Borehole	55.50
R613	Rotary Cored Borehole	55.70
R614	Rotary Cored Borehole	56.00
R615	Rotary Cored Borehole	56.00
R616	Rotary Cored Borehole	55.90
W617	Rotary Open Hole with Pumping Test	48.80
R618	Rotary Cored Borehole	48.70
R619	Rotary Cored Borehole	48.10

TABLE 2 :SCOPE OF INTRUSIVE WORKS		
Hole Number	**Exploratory Hole / Test Type**	**Drilled Depth (m)**
R620	Rotary Cored Borehole	48.30
RX621	Rotary Open Hole	48.00
RX622	Rotary Open Hole	48.00
South of Alignment		
W623	Rotary Open Hole with Pumping Test	70.00
RX624	Rotary Open Hole	70.00
RX625	Rotary Open Hole	70.00
RX626	Rotary Open Hole	70.17
RX627	Rotary Open Hole	71.30
RX628	Rotary Open Hole	71.60
Hydrogeology Boreholes		
RX629	Rotary Open Hole	65.00
RX630	Rotary Open Hole	70.00
RX631	Rotary Open Hole	85.00
RX632	Rotary Open Hole	60.00
RX633	Rotary Open Hole	55.00
RX634	Rotary Open Hole	65.00
Phase 7 Boreholes		
R7801	Rotary Cored Borehole	51.50
R7805	Rotary Cored Borehole	46.10
R7809	Rotary Cored Borehole	45.50
R7813	Rotary Cored Borehole	46.00
R7817	Rotary Cored Borehole	46.00

TABLE 2 :SCOPE OF INTRUSIVE WORKS		
Hole Number	**Exploratory Hole / Test Type**	**Drilled Depth (m)**
R7821	Rotary Cored Borehole	45.50
R7822	Rotary Cored Borehole	50.20
R71906	Rotary Cored Borehole	53.65
R71907	Rotary Cored Borehole	66.80
R71909	Rotary Cored Borehole	70.60
R71911	Rotary Cored Borehole	67.50
R71913	Rotary Cored Borehole	50.50
R72002	Rotary Cored Borehole	61.00
R72003	Rotary Cored Borehole	45.45

3.2.1 Rotary Boreholes

The boreholes were drilled using a rotary drilling rig using rotary coring and rotary open holing techniques.

The exploratory hole logs are presented in Appendix B. These provide information including the equipment and methods used, samples taken, tests carried out, water observations and descriptions of the strata encountered. Explanation of the terms and abbreviations used on the logs is given in the Key to Exploratory Hole Records in Appendix B, together with other explanatory information.

3.2.2 Rotary Cored Holes

The rotary cored drilling consisted of a GeoBore S wireline system with a combination of Geocube core bit and PCD GeoBore bit together with an air-mist flush to produce a hole of 146 mm diameter and a core of 102 mm diameter, recovered within plastic core liner. The flush was passed through a ‘stuffing box’ into catchment tanks, contained, and stored prior to disposal. The boreholes were drilled to depths of up to 60 m by this method.

All core samples were extruded horizontally, laid out sequentially in wooden coreboxes. Photographs of the samples, and features of interest were then taken and are appended to the exploratory hole logs contained in Appendix B. Disturbed (D) and undisturbed rock subsamples (U) were taken from the core samples where shown on the borehole logs.

3.2.3 Rotary Open Holes

Rotary open hole drilling was undertaken using tri-cone rock roller to produce a hole of nominally 146 mm diameter. Air-mist and water was used as a flush medium. The boreholes were drilled to depths of up to 85 m by this method. Steel casing was inserted where necessary to offer temporary support to the boreholes.

3.2.4 Hand Dug Inspection Pits

The hand dug inspection pits were approximately 0.40 m by 0.40 m in plan and were up to 1.20 m depth. For the larger diameter boreholes the inspection pits were extended to 0.75 m by 0.75 m. Environmental soil samples were taken from the inspection pits at regular intervals or as instructed by AECOM.

3.3 Backfill, Monitoring Wells and Installations

On completion 50 mm diameter groundwater monitoring wells were installed in selected exploratory holes the design having been decided by AECOM, as summarised in Table 3 below. The installation details are shown on the exploratory hole logs in Appendix B.

The well details are summarised below:

TABLE 3 : SUMMARY OF MONITORING WELL INSTALLATIONS

Location	Well Diameter (mm)	Well Depth (m bgl)	Well Response Zone (m bgl)	Type of Protective Cover	Notes
R142 Cluster					
R602	50	34.00	33.00 – 18.00	Upstanding	Monitoring
Tunnel Alignment West of Stonehenge Bottom					
W601	305	60.00	57.00 – 15.00	Upstanding	Pumping test
R606	50	60.00	56.00 – 20.00	Upstanding	Monitoring
R607	50	60.00	56.00 – 20.00	Upstanding	Monitoring
R608	50	60.00	56.00 – 20.00	Upstanding	Monitoring
RX609	50	59.00	56.00 – 20.00	Upstanding	Monitoring
R610	50	52.00	48.00 – 19.00	Upstanding	Monitoring
R612	50	55.00	53.00 – 18.00	Upstanding	Monitoring
W617	305	47.00	45.50 – 6.00	Upstanding	Pumping test
R618	50	47.00	44.00 – 8.00	Upstanding	Monitoring
R619	50	47.00	44.00 – 8.00	Upstanding	Monitoring

TABLE 3 : SUMMARY OF MONITORING WELL INSTALLATIONS					
Location	**Well Diameter (mm)**	**Well Depth (m bgl)**	**Well Response Zone (m bgl)**	**Type of Protective Cover**	**Notes**
R620	50	47.00	44.00 – 8.00	Upstanding	Monitoring
RX621	50	47.00	44.00 – 8.00	Upstanding	Monitoring
RX622	50	47.00	44.00 – 8.00	Upstanding	Monitoring
South of Alignment					
W623	305	70.00	67.00 – 40.00	Upstanding	Pumping test
RX624	50	70.00	67.00 – 40.00	Upstanding	Monitoring
RX625	50	70.00	67.00 – 40.00	Upstanding	Monitoring
RX626	50	70.00	67.00 – 40.00	Upstanding	Monitoring
RX627	50	68.00	65.00 – 40.00	Upstanding	Monitoring
RX628	50	70.00	67.00 – 40.00	Upstanding	Monitoring
Hydrogeology Boreholes					
RX629	50	64.00	61.00 – 20.00	Upstanding	Monitoring
RX630	50	70.00	67.00 – 9.00	Upstanding	Monitoring
RX631	50	81.00	78.00 – 9.00	Upstanding	Monitoring
RX632	50	60.00	56.00 – 9.00	Upstanding	Monitoring
RX633	50	54.00	51.00 – 6.00	Upstanding	Monitoring
Phase 7 Boreholes					
R17801	50	50.50	50.50-10.50	Upstanding	Monitoring
R71805	50	46.10	46.10-15.00	Upstanding	Monitoring
R71813	50	46.00	46.00-12.50	Upstanding	Monitoring
R71817	50	45.90	45.90-10.50	Upstanding	Monitoring
R71907	50	62.00	62.00-15.00	Upstanding	Monitoring
R71909	50	52.00	52.00-22.00	Upstanding	Monitoring

TABLE 3 : SUMMARY OF MONITORING WELL INSTALLATIONS					
Location	**Well Diameter (mm)**	**Well Depth (m bgl)**	**Well Response Zone (m bgl)**	**Type of Protective Cover**	**Notes**
R71911	50	57.00	57.00-27.00	Upstanding	Monitoring
R71913	50	49.50	49.50-46.50	Upstanding	Monitoring

In addition, AECOM specified continuous data logging equipment (Vibrating Wire Piezometers (VWP)) installed into certain boreholes in order for continuous long-term fluctuations in groundwater levels to be monitored. The details of the boreholes, and depths of the instrument installations are reported elsewhere.

On completion the remaining boreholes were backfilled with bentonite cement grout as instructed by AECOM.

All standpipes were purged using airlifting techniques until groundwater ran clear or three well volumes had been removed from the borehole.

3.4 In-Situ Testing

The in-situ tests are listed in the following table. The test methods used are detailed on the test result sheets included in Appendix C, unless otherwise noted.

TABLE 4 :SCOPE OF IN-SITU TESTING		
Quantity	**In-situ Test**	**Hole / Test Numbers**
70	Standard Penetration Tests (SPT).	2 no. In R608, 2 no. In R619, 14 no. In R71805, 14 no. In R71809, 15 no. In R71817, 14 no. In R71822, 9 no. In R72003
3	Falling head Permeability Tests.	3 no. in R616
22	Single Packer Permeability Tests	7 no. In R607, 4 no. In R619, 1 no. In RX627, 3 no. In R71907, 3 no. In R71909, 3 no. In R71911, 1 no. In R71913
5	Double Packer Permeability Tests	2 no. In RX624, 3 no. In RX627
1	Gamma Cone Penetration Test (GCPT)	GC605
3	Constant Rate Pumping Tests	W601, W617, W623
7	Pressuremeter Tests	SBP604

3.4.1 Standard Penetration Test

Standard Penetration Tests (SPT) were carried out 7 no. boreholes (R608, R619, R71805, R71809, R71817, R71822 and R72003) as instructed by AECOM, in accordance with BS EN ISO 22476-3 using hammers which have been calibrated for efficiency. The calibration certificates are included in Appendix F. Seating drives have been recorded in increments of 75 mm in accordance with recommended UK practice.

The SPT N-values are reported on the exploratory hole logs, on which the calibration number of the hammers used is recorded. The full results are presented in tabular format on a Summary of Standard Penetration Tests per borehole location in Appendix C. Plots showing N values versus depth and elevation per borehole location are also included.

3.4.2 Falling Head Permeability Testing

Three number falling head permeability tests were undertaken in R616 in general accordance with BS EN ISO 22282-2 (2012). The depths were scheduled by AECOM at depths of between 22.43 m to 26.73 m, 25.20 m to 38.40 m and 25.62 m to 38.82 m. The test results are present in tabular and graphical format in Appendix C.

3.4.3 Packer Tests

Double and single packer tests were carried out in general accordance with BS EN ISO 22282-3 (2012). The interval of testing was chosen by AECOM. The analysis of packer test data was carried out by SSL and calculated using Modified Lugeon values for each run (or “stage”). A summary of the packer testing can be seen in Table 5 below. Full test results including the plots are included in Appendix C.

TABLE 5 :SUMMARY OF PACKER TESTING

Borehole	Test Type and Number	Depth (m)	Over Pressure (bar)
R607	7 no. Single Packer	24.00 m – 28.90 m	Flow rate too high to achieve test pressure
		26.40 m – 28.90 m	Flow rate too high to achieve test pressure.
		23.90 m – 28.90 m	1/2/3/2/1
		32.40 m – 34.90 m	1/2/3/2/1
		39.90 m – 42.40 m	1/2/3/2/1
		47.40 m – 49.90 m	1/2/3/2/1
		55.00 m – 60.00 m	1/2/3/2/1
R619	4 no. Single	36.00 m – 39.00 m	1/2/3/4

TABLE 5 :SUMMARY OF PACKER TESTING			
Borehole	**Test Type and Number**	**Depth (m)**	**Over Pressure (bar)**
	packer	39.00 m – 42.00 m	1/1.8 flow rate too high to achieve test pressure
		42.00 m – 45.00 m	1/1.5 flow rate too high to achieve test pressure
		45.00 m – 48.00 m	1/2/3/2/1
RX624	2 no. Double Packer	43.00 m – 46.00 m	Flow rate too high to achieve test pressure
		53.00 m – 56.00 m	Flow rate too high to achieve test pressure
RX627	1 no. Single Packer, 3 no. Double Packer	62.00 m – 70.00 m	1/2/3/2/1
		46.00 m – 61.00 m	1/2/3/2/1
		46.00 m - 51.00 m	1/2/3/3 Unable to continue test due to possible 3D flow.
		48.00 m – 53.00 m	1/2/3 Unable to continue test due to possible 3D flow.
R71907	3 no. Single Packer	36.80 m – 39.80 m	1/2/3
		42.80 m – 45.80 m	Zero flow recorded (up to 4 bar pressure)
		48.80 m – 51.80 m	1/2/3/2/1
R71909	3 no. Single Packer	42.00 m – 45.00 m	1/2/3/2/1
		48.00 m – 51.00 m	Zero flow recorded
		54.00 m – 57.00 m	1/2/3/2/1
R71911	3 no. Single Packer	46.50 m – 49.50 m	1/2/3/2/1
		52.50 m – 55.50 m	Zero flow recorded
		58.50m – 61.50m	1/2/3/2/1
R71913	1 no. Single Packer	43.00m – 46.00m	Flow rate too high to achieve test pressure

Calibration certificates for the flow meters and transducers are included in Appendix F.

3.4.4 Gamma Cone Penetration Testing (GCPT)

SSL commissioned In-Situ Site Investigation Limited (ISSI) to carry out a Gamma Cone Penetration test which was conducted in borehole SBP604 at the base of an open hole (15.00 m) as instructed by AECOM. The measured parameters were to include, cone resistance, sleeve friction, pore water pressure and inclination for X and Y axis however the test refused at 15.13 m. The test results are presented in Appendix C.

3.4.5 Pressuremeter Tests

The pressuremeter tests were carried out Cambridge Insitu at borehole SBP604 at various depths as requested by AECOM. A separate pressuremeter test report produced by Cambridge Insitu is included in Appendix C which also contains the calibration register for the test equipment.

3.4.6 Optical Televiewer and Down-hole Geologging

SSL commissioned Robertson Geologging to carry out the optical televiewer and geologging in the scheduled completed rotary boreholes. The boreholes were flushed with clean water and left to settle before optical televiewer logging was undertaken. The logging was carried out either from the base of the temporary casing or from the bottom of the hole depending on which suite was scheduled.

SSL reviewed all the data submitted by Robertson Geologging before inclusion in the report. All the logs and images are included on the logs presented in Appendix C.

Down-hole geologging suites of various tests were undertaken with the results presented in Appendix C. The various suites of test are summarised below:

- **Suite A:**
  - Caliper
  - Natural gamma
  - Optical televiewer
  - Flow logging (ambient and pumped conditions)
  - Fluid conductivity
  - Fluid temperature
  - P and S wave velocity (sonic probe)
- **Suite B:**
  - Caliper
  - Natural gamma
  - Optical televiewer
  - P and S wave velocity (sonic)
- **Suite C:**
  - Caliper
  - Natural gamma
  - Optical televiewer
  - Flow logging (ambient and pumped conditions)
  - Fluid conductivity

- Fluid temperature

Suite D:

- Caliper
- Natural gamma
- P and S wave velocity (sonic)

A summary table of the boreholes in which optical televiewer and down-hole geologging was undertaken is presented in Table 6 below.

TABLE 6 : SUMMARY OF DOWN-HOLE GEOLOGGING			
BH No.	**Date Logged**	**Depth (m)**	**Suit Logged**
R142 Cluster			
R602	16/05/2018	2.50 m – 34.79 m	Suite B
Tunnel Alignment West of Stonehenge Bottom			
W601	01/06/2018	1.60 m – 60.10 m	Suite A
R606	23/05/2018	2.40 m – 56.70 m	Suite D
R607	23/05/2018	2.37 m – 60.09 m	Suite D
R608	16/05/2018	0.00 m – 59.90 m	Suite D
RX609	16/05/2018	0.00 m – 59.83 m	Suite D
R610	23/05/2018	2.46 m – 49.00 m	Suite D
R611	31/05/2018	2.42 m – 52.74 m	Suite D
R612	31/05/2018	2.42 m – 54.40 m	Suite D
R613	31/05/2018	1.60 m – 55.64 m	Suite A
R614	07/06/2018	2.30 m – 53.00 m	Suite D
R615	07/06/2018	2.40 m – 55.60 m	Suite D
R616	19/06/2018	2.44 m – 55.29 m	Suite D
W617	09/07/2018	2.60 m – 45.00 m	Suite C
R618	02/05/2018	0.65 m – 48.00 m	Suite A
R620	02/05/2018	2.40 m – 48.00 m	Suite C

TABLE 6 : SUMMARY OF DOWN-HOLE GEOLOGGING			
BH No.	**Date Logged**	**Depth (m)**	**Suit Logged**
South of Alignment			
W623	08/05/2018	8.60 m – 66.20 m	Suite C
RX624	18/04/2018	2.40 m - 68.00 m	Suite C
RX627	19/04/2018	4.60 m – 69.00 m	Suite C
Phase 7 Boreholes			
R71801	27/09/2018	1.60 m - 51.50 m	Suite A
R71805	19/10/2018	1.60 m - 46.10 m	Suite A
R71809	19/10/2018	1.60 m - 45.50 m	Suite A
R71813	16/10/2018	1.80 m - 46.00 m	Suite A
R71817	12/10/2018	1.60 m - 45.90 m	Suite A
R71822	12/10/2018	1.60 m - 50.20 m	Suite A
R71906	05/09/2018	1.60 m - 53.75 m	Suite A
R71907	23/08/2018	1.60 m - 66.80 m	Suite A
R71909	14/09/2018	1.60 m - 70.60 m	Suite A
R71911	14/09/2018	1.80 m - 67.00 m	Suite A
R71913	19/09/2018	1.60 m - 149.00 m	Suite A
R72003	20/09/2018	1.60 m - 45.00 m	Suite A

3.4.7 Constant Rate Pumping Tests

SSL commissioned Stuart Wells Limited to carry out three constant rate pumping tests in W601, W617 and W623 for 7 no. days each in general accordance with BS ISO 14686:2003 and BS EN ISO22282-1:2012 Parts 1 and 4. Integrated inline digital flowmeters, with a V-notch weir as backup, were used to record discharge rates. Borehole groundwater levels, barometric pressure and rainfall were also monitored for the duration of each test at intervals specified by AECOM.

Prior to each constant rate pumping test an equipment test and a subsequent step drawdown test were carried out to provide data to allow AECOM to establish the discharge rates required for each location. Recharge rates were also monitored at the end of each pumping phase until at least 95% recovery had been achieved.

A separate report detailing the site work, results and calibration documentation is included in Appendix C.

3.5 Geoenvironmental Sampling

Samples for contamination testing were taken from the exploratory holes where indicated on the exploratory hole logs and recorded as ES samples for soil and EW for water.

All samples were placed in appropriate contamination sample containers that were supplied by the geoenvironmental laboratory. Soil sample containers for potential volatile testing were filled to capacity. Similarly, any water sample containers (*with preservatives where required) were filled to capacity to minimise volatilisation. All samples were then kept in cool boxes with ice packs and were transported to the laboratories under Chain of Custody documentation, as promptly as possible to maintain sample integrity.

4 LABORATORY TESTING

Samples for potential geotechnical testing were returned to one of the Company's UKAS accredited laboratories, and those for potential geoenvironmental testing were sent to a sister company Envirolab Limited, a MCERTS and UKAS accredited testing laboratory. Laboratory tests were scheduled by AECOM. Tests carried out in accordance with MCERTS/UKAS standards where noted on the results sheets.

4.1 Geotechnical Laboratory Testing

Geotechnical laboratory testing was generally carried out in accordance with the relevant part of BS1377: 1990, *Methods of Test for Soils for Civil Engineering Purposes*, or, where superseded, by the relevant part of BS EN ISO 17892:2014+ *Geotechnical investigation and testing – Laboratory Testing of Soil*.

The number of tests completed and the test methods used are summarised below. Where non-standard procedures have been undertaken, this is recorded on the report sheet. The results are reported in tabular and/or graphical form and included as Appendix D of this report.

TABLE 7 : SUMMARY OF GEOTECHNICAL TESTING

Number of tests	Test	Remarks
Classification Tests		
34	Water content.	
414	Saturation moisture content of chalk (SMC).	
34	Intact Dry Density including Porosity of chalk.	
1	Particle size distribution by sieving.	
1	Particle size distribution by sedimentation.	
Shear Stress – Effective Stress		
7	Single stage consolidation undrained triaxial compression tests with the measurement of pore water pressure.	
24	Direct shear strength of rock	
Rock Tests		
155	Uniaxial compressive strength tests.	
51	Deformability of Rock in uniaxial Compression	
7	Point Load Index.	The natural ('as received') water content of the samples was determined.
49	Slake Durability	
Chemical Tests: Soil*		
17	Water soluble sulphate content and pH.	

TABLE 7 : SUMMARY OF GEOTECHNICAL TESTING		
Number of tests	**Test**	**Remarks**
2	Total (acid soluble) sulphate and pH.	

Note:* Test(s) carried out to method approved in BRE Special Digest 1.

4.2 Geoenvironmental Laboratory Testing

The geoenvironmental testing carried out is summarised in the following table. The results are included as Appendix E of this report, and include details of the test method.

TABLE 8 : SUMMARY OF GEOENVIRONMENTAL LABORATORY TESTING		
Numbers of tests	**Description**	**Notes**
SOIL		
1	AECOM Soil Test Suite E1 (modified)	Comprises antimony, arsenic, barium, beryllium, boron, cadmium, copper, chromium (total, hexavalent, trivalent), lead, manganese, mercury, molybdenum, nickel, selenium, vanadium, zinc, speciated polycyclic aromatic hydrocarbons (PAH), total petroleum hydrocarbons (TPHCWG (speciated)), phosphate, sulphate (water soluble), sulphur (total), sulphide, cyanide (free), cyanide (total), phenols (total), organic matter, total organic carbon, pH.
1	AECOM Soil Test Suite E1	Comprises antimony, arsenic, barium, beryllium, boron, cadmium, copper, chromium (total, hexavalent, trivalent), lead, manganese, mercury, molybdenum, nickel, selenium, vanadium, zinc, speciated polycyclic aromatic hydrocarbons (PAH), total petroleum hydrocarbons (TPHCWG (speciated)), phosphate, sulphate (water soluble), sulphur (total), sulphide, cyanide (free), cyanide (total), phenols (total), organic matter, total organic carbon, pH, intestinal enterococci, e-coli, coliforms, and asbestos in soil.
1	SSL Human Health Suite B	Comprises arsenic, cadmium, copper, chromium (total), lead, mercury, nickel, selenium, zinc, speciated polycyclic aromatic hydrocarbons (PAH), total petroleum hydrocarbons (TPHCWG (speciated)), sulphate (water soluble), organic matter, and pH.
8	Soil Agricultural Phosphorus Suite (AECOM Suite E2)	Moisture content (0.1%), Total Phosphorus (10mg/kg), Neutral Ammonium Citrate soluble P (0.1%), Total Neutralising Value CaCO3 equivalent (0.1%).
18	Soil Leachate phosphorus suite (AECOM Suite F3)	Orthophosphate (0.05mg/l), Phosphorous dissolved and total as a metal (1mg/l), Chloride dissolved (1mg/l), Sulphate dissolved (0.05mg/l), Calcium dissolved (0.1mg/l), Magnesium dissolved (0.1mg/l), Potassium dissolved (0.1mg/l), Sodium dissolved (0.1mg/l), Bicarbonate alkalinity HCO3 (10mg/l), Carbonate alkalinity CaCO3 (10mg/l).

5 REFERENCES

5.1 BS 5930:2015 *Code of practice for ground investigations*

5.2 BS EN 1997-1:2004 *Eurocode 7 — Geotechnical Design Part 1 - General Rules* incorporating corrigendum Feb 2009 and Amemdment A1 2013

5.3 BS EN 1997-2:2007 Eurocode 7 — *Geotechnical design Part 2: Ground Investigation and testing*

5.4 BS 10175:2011 *Investigation of potentially contaminated sites: Code of practice*, including amendment A2 2017

5.5 SSL Report 731823: *A303 Amesbury to Berwick Down* 2017

5.6 British Geological Survey sheet 282 & 298 scale 1:50,000, published 2008 & 2005

5.7 British Geological Survey online digital geological map, [redacted]

5.8 British Geological Survey Lexicon of Named Rock Units, [redacted]

5.9 BS EN ISO 14688-1:2002 *Geotechnical investigation and testing – Identification and classification of soil: Part 1: Identification and description*, including Amendment A1 2013

5.10 BS EN ISO 14688-2:2004 *Geotechnical investigation and testing – Identification and classification of soil: Part 2: Principles for a classification*, including Amendment A1 2013

5.11 BS EN ISO 14689-1:2003 *Geotechnical investigation and testing – Identification and classification of rock: Part 1: Identification and description*

5.12 CIRIA Report C574 (2002) *Engineering in Chalk*

5.13 BS EN ISO 22475-1:2006 *Geotechnical Investigation and Testing – Sampling methods and groundwater measurements, Part 1 Technical principals for execution*

5.14 BS EN ISO 22476-1:2012 *Geotechnical investigation and testing - Field Testing - Electrical Cone and piezocone penetration test*, incorporating corrigendum January 2013

5.15 BS EN ISO 22476-3:2005 (updated February 2007) *Geotechnical Investigation and Testing – Field Testing Part 3: Standard Penetration Test*, including Amendment A1 (2011)

5.16 CIRIA Report R143 (1995) *The Standard Penetration Test (SPT) - Methods and Use*

5.17 BS ISO 14686:2003 *Hydrometric determinations – Pumping tests for water wells – Considerations and guidelines for design, performance and use (supersedes BS6316:1992).*

5.18 BS EN ISO 22282-1:2012 *Geotechnical investigation and testing – Geohydraulic testing Part 1: General Rules;*

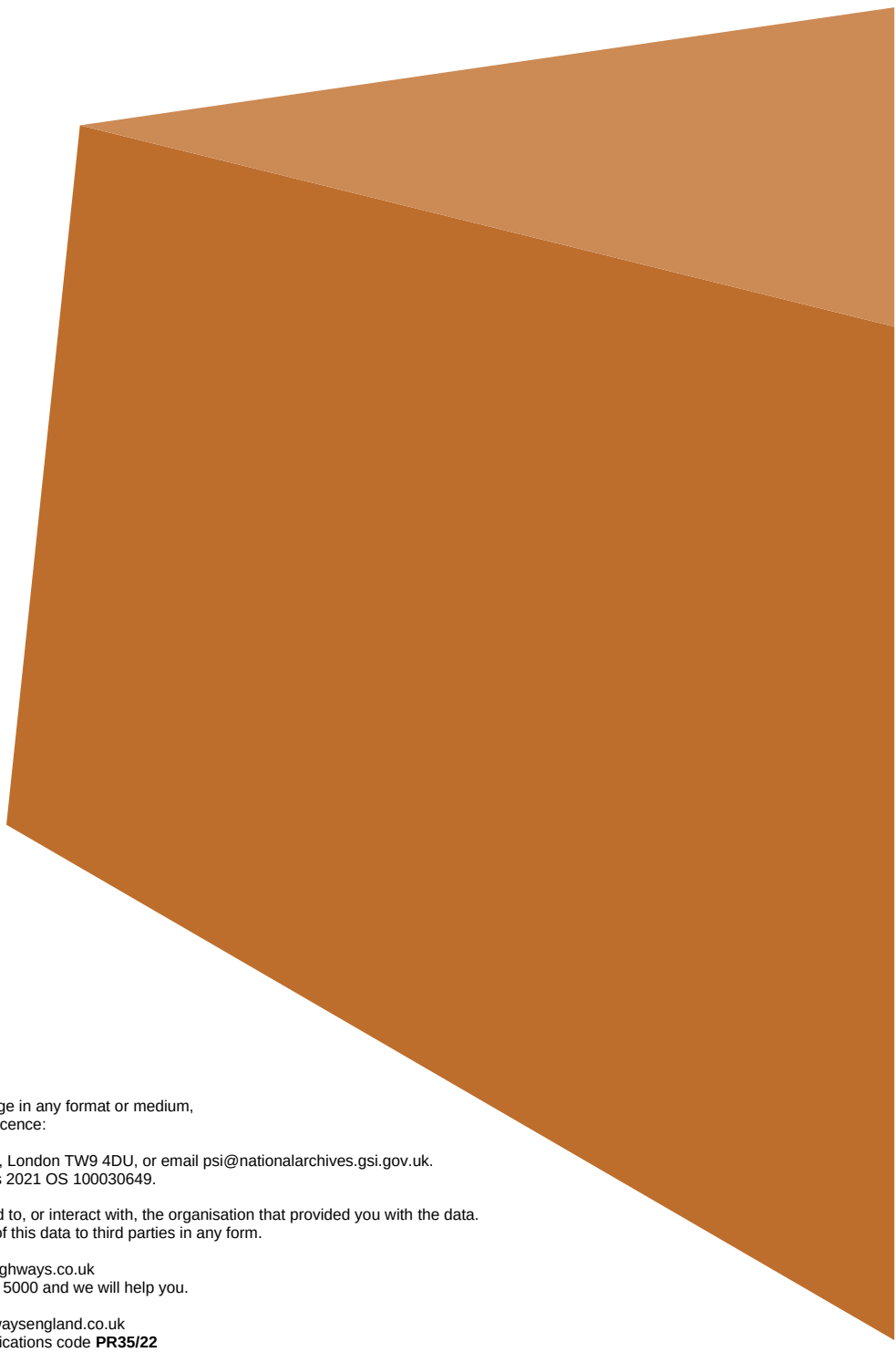
5.19 BS EN ISO 22282-1:2012 *Geotechnical investigation and testing – Geohydraulic testing Part 4: Pumping tests.*

5.20 BS EN ISO 22282-2:2012 *Geotechnical investigation and testing. Geohydraulic testing. Water permeability tests in a borehole using open systems*

5.21 BS EN ISO 22282-3:2012 *Geotechnical investigation and testing. Geohydraulic testing. Water pressure tests in rock*

5.22 BS 1377:1990 *Method of Test for Soils for Civil Engineering Purposes*

5.23 BS EN ISO 17892:2014 *Geotechnical investigation and testing – Laboratory Testing of Soil*



This document is also available on our website at www.nationalhighways.co.uk
For an accessible version of this publication please call 0300 123 5000 and we will help you.

If you have any enquiries about this publication email info@highwaysengland.co.uk
or call 0300 123 5000*. Please quote the National Highways publications code **PR35/22**
National Highways creative job number **BRS17_0027**

*Calls to 03 numbers cost no more than a national rate call to an 01 or 02 number and must count towards any inclusive minutes in the same way as 01 and 02 calls.
These rules apply to calls from any type of line including mobile, BT, other fixed line or payphone. Calls may be recorded or monitored.
Printed on paper from well-managed forests and other controlled sources when issued directly by National Highways.
Registered office Bridge House, 1 Walnut Tree Close, Guildford GU1 4LZ
National Highways Limited registered in England and Wales number 09346363