

**National Highways: A303 Amesbury to
Berwick Down Project, Development
Consent Order Application**

Scheme Reference: TR010025

**Geology, Ground Investigation
and
Groundwater Monitoring**

**Response to Secretary of State's call for further
representations on his Statement of Matters
Bullet Point 4 (Sections 7 and 8)**

**and on relevant Technical Reports submitted by National
Highways**

for

**The Stonehenge Alliance
(Reference No. 2001870)**

Prepared by:

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April 2022

A303 Stonehenge Redetermination of DCO Application

Submission on Geological, Geotechnical and Hydrogeological Reports issued by National Highways (formerly Highways England) in response to the Secretary of State's Statement of Matters

**By Dr George M Reeves CGeol PhD MSc BSc FGS
for the Stonehenge Alliance**

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1. Introduction

The documents detailed below were finally made available to the Stonehenge Alliance by National Highways (NH) in January 2022, following repeated requests for the information at the 2019 Examination and under FoI (for example, [REP2a-003](#), [AS-035](#), and [AS-074](#)). Since 2019, the Examining Authority has recommended that the scheme does not go ahead (January 2020), and there was a successful Judicial Review challenge by Save Stonehenge World Heritage Site Ltd. in June 2021.

All of the fourteen packages of documents sent to us in January and described herein were added to the Infrastructure Planning Inspectorate website documentation, with a publication date of 23rd February 2022, some under different titles. Only the 2003 Soil Mechanics SI data (for the original Balfour Beatty Costain Joint Venture, covering the Phase 1A site investigation work – Item 3, below) is omitted. In addition, a report (Technical Note, dated February 2022) on “2.18 Flood Risk Modelling Climate Change Update Redetermination” is included in the published documents which falls outside the scope of this current assessment of new SI data released to SA in January 2022. Work on the documents for the Alliance was started immediately and is based on the 14 reports issued to us in January which were not cross-referenced to the published reports.

PINS (The Planning Inspectorate for England) Library reference numbers and links are added to this report, where possible, to ease access to the relevant documents.

The Secretary of State has indicated his intention to redetermine the scheme and requested submissions on his Statement of Matters with no change to the proposal and plans submitted to the 2019 Examination. This submission forms part of that response.

2. The Documents

Fourteen packages of site investigation (SI) data were released by National Highways in January 2022 (some dating back to 2003, comprising a total of 3.1Gb of digital data), following the initial request in a letter from the Alliance to NH on 17 April 2019 ([REP2a-003](#)), and many subsequent repeats of this request for complete ground investigation data both during the Examination (e.g., [AS-035](#), [AS-074](#)) and afterwards under FoI requests, along with mention of incomplete data (e.g., [REP2-131](#), [REP3-064](#) and [REP9-045](#)).

Much of the most recent investigations reported post-date the closure of the Examination in October 2019.

The documents in summary are:-

- i. The Countess Roundabout Factual Site Investigation Report (and associated .ags (Association of Geotechnical and Geoenvironmental Specialists)) borehole data files: see below). This work was carried out in November and December 2019. The report is dated January 2020. (PINS Library ref. [Redetermination 2.22](#))
- ii. Groundwater Monitoring Data: Borehole logger water levels for whole scheme up to January 2022, plus Westfield Farm Boreholes A & B water levels from 21st October 2020 to 11 April 2021. (PINS Library: presented as multiple separate files under ref. [Redetermination 2.24](#))
- iii. Historic SI data (Report No. 21762) from before the first A303 Stonehenge Public Inquiry held in 2004. This data was not released then to the Stonehenge Alliance, on whose behalf the author gave evidence to that Inquiry. It dates from May 2003 and was carried out by Soil Mechanics Ltd. for the original Balfour Beatty Costain Joint Venture. It covers the Phase 1A site investigation work and is presented only in .ags file format. (PINS Library: apparently not listed)
- iv. A more recent report (No. 29779) is also only available in .ags file format and covers investigations and analyses of contaminants found in SI work carried out for Highways England in 2017 by Structural Soils Ltd. (PINS Library ref. [Redetermination 2.17](#))
- v. A report on work carried out as the 2019 Examination was drawing to a close in August and September 2019, is included, along with accompanying .ags files in the report "A303 Amesbury to Berwick Down- Phase 7A (ii)" report, dated November 2019. (PINS Library ref. [Redetermination 2.14](#))

This report covers a 6km. section of the A303, with 26 rotary core drilled boreholes which were also geophysically logged with caliper and optical televiewer tools. Two of these boreholes were then completed for long-term groundwater monitoring. The purpose of this drilling work was stated as "to investigate cuttings and embankments" (presumably for stability), along with "link roads and retaining walls".

The report includes good photographs of all the cores obtained (showing considerably weak rock and core loss in some holes). There are 1159 pages in the report, together with a considerable amount of further data in .ags format.

- vi. Factual Report: Structural Soils Ltd. A303 Stonehenge Phases 6 &7 Ground Investigation, Project No. 733442. Published April 2019. (PINS Library ref: [Redetermination 2.12](#) (multiple))

The main stated aim of this work (page 1, Introduction to Report) is that "This investigation is required to inform the scheme design to mitigate any impacts which relate to the uncertainties mainly regarding the phosphatic chalk (sic) properties and hydrogeological characteristics".

In his evidence to the Examination on numerous occasions in June, July and August 2019, this author (GMR) gave multiple warnings concerning these uncertainties.

- vii. Factual Report: A303 – Amesbury to Berwick Down Stage 4 – Ground Investigations Phase 7A(i) Factual Report HE551506-HE-VSS-ZZ_GN_ZZ_Z-RP-KK-0167 S4 FOR STAGE APPROVAL 05/11/2019. (PINS Library ref. [Redetermination 2.13](#))

This report, again by Structural Soils, covers drilling and ground investigation work carried out in June and July 2019, involving the drilling of ten percussion (“shell and auger”) boreholes and fourteen rotary core drilled boreholes. Numerous other field testing was carried out, including trial pits, plate load tests, CBR tests, dynamic cone and in-situ permeability tests, as well as an extensive programme of down-the-hole geophysics (wireline logging). A total of 1102 pages are included in this report, as well as 2.9Mb of .ags file data. (47Mb of digital data in total). None of this data was available for assessment as part of Stonehenge Alliance’s submissions as evidence to the 2019 Examination.

- viii. A major pumping test in Borehole W617 was carried out by Stuart Wells Ltd during March 2021. The report, 288 pages in length, is a very comprehensive document covering this major and important groundwater response test in the Stonehenge Bottom area 300 metres South of the Stonehenge Monument, in the first field just South of the A303. (PINS Library ref. [Redetermination 2.23](#))

The aim of the work was to “collect additional hydrogeological information of the Chalk South of Stonehenge to aid design for the proposed tunnel. This pumping test was undertaken in an existing well W617, installed as part of Phase 6 A303 Ground Investigation in 2018 (BH log within Appendix), with abstracted groundwater discharged through a 200mm Ø pipeline to ground a nominal 800 metres south of the pumping well”. It demonstrates the considerable lack of knowledge that Highways England held, at the Examination stage in 2019, considering that this very important and extensive groundwater response test was not carried out until the Spring of 2021. (See additional discussion, following.)

- ix. HAGDMS Borehole ID: This large Excel Spreadsheet file lists all the details, NGR locations etc. of all the boreholes, trial pits etc. investigated during all phases of the various investigations for the proposed A303 Stonehenge tunnel and roads improvement schemes. (PINS Library ref. [Redetermination 2.21](#))

- x. Report No. HE551506-AA-EHR-SWI-RP-YE-000003, prepared for the Arup-Atkins Joint Venture in May 2017, was carried out by Wessex Archaeology. It is entitled “Geophysical Survey Report Stage 1 Final Stage 1”. (PINS Library ref. [Redetermination 2.19](#))

A detailed gradiometer survey and ground penetrating radar (GPR) survey was conducted over eight areas along the route of the A303. The survey (was stated as forming) 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. The site comprises a number of arable fields covering a total area of 227.8 ha.

As with all these reports, none of the included data was available to Stonehenge Alliance (or others giving evidence) during the 2019 Examination.

- xi. Report No. HE551506-AMW-HGT-SW_GN_000_Z-RP-CE-0005, published by AECOM, Mace, and WSP in August 2018. (PINS Library ref. within Redetermination 2.24 (multiple files))

This report is an attempt at an interpretative groundwater data-oriented report, prepared for Highways England by the AECOM-Mace-WSP consortium based on data collected up to the summer of 2018.

Again, as with all of the reports listed herein, this report was not available to any of the organisations giving evidence at the 2019 Examination until the January 2022 release of the 14 data packages to the Alliance only, under the FoI requests. (See below for further commentary on groundwater related aspects of this and associated data, including reporting of observations, factual data and interpretations by the author whilst giving evidence to the Examining Authority in June, July and August 2019.

- xii. Report by Public Health England on “Radiological assessment of tunnel arisings from A303 Amesbury to Berwick Down Stonehenge bypass”. Title: Methodology Vs. 1.2. (PINS Library ref. Redetermination 2.20)

This 4-page report, by Public Health England Radiation Protection section, concludes that there are no consequences or hazards from either uranium, radon or tritium, or any other radionuclides following excavation of spoil from any proposed tunnelling works.

- xiii. File pe181471v2 is an .ags file compiling geotechnical and chemical analytical data from the A303 Stonehenge scheme site investigation reports (72kb), dated 08/05/2018. (PINS Library: apparently not listed)

- xiv. Abstracted figure plus trial pit logs – from 2000 SI Report; SI15 dated May 2000 by Halcrow for the Highways Agency in May 2000: Countess Roundabout; Boreholes and Trial pits. (PINS Library ref. Redetermination 2.22)

3. Observations on January 2022 National Highways FoI data files

It is not intended to repeat many of the detailed points raised in evidence presented to the Examining Authority by the author during the 2019 Examination. However, it is intended to report issues highlighted by the release of the above data, as well as those key issues which remain unresolved by NH, despite the delayed and untimely release of this information.

References to all of the relevant Stonehenge Alliance submissions to the Examination are listed in an Appendix to this document and are referenced herein where relevant. We ask for these representations to be taken into account in the redetermination process.

4. Main Issues for Concern (as also detailed repeatedly in our evidence to the Examination)

4.1. Low Residual Strength in some horizons of (especially the Phosphatic) Chalk.

(REP2-131, REP3-064, AS-045, REP4-088, AS-098 and REP9-045)

From numerous boreholes drilled for this project, especially in the western area of proposed tunnelling to the west of Stonehenge Bottom, very weak, often heavily fractured or “non-intact” Chalk was encountered.

“Structureless Chalk” of the White Chalk stratigraphic group (of the Newhaven Chalk Formation) has been widely reported, generally at shallow (i.e., up to 5 metres) depths along the line of the proposed road and tunnel route. In addition, poor quality rock (RQD ratings of 20 or less) can be identified deeper in many boreholes.

From both the original (2004) Stonehenge tunnel route ground investigations, and the more recently drilled boreholes, highly fractured weak, poor quality chalk zones (CIRIA Rating Group C: with discontinuity spacing of less than 200mm; RQDs of 20 or less) are present commonly at shallow depths i.e., 0 to 10m BGL. However, such conditions have also been encountered mostly along the western section of the proposed tunnel line at greater depths (e.g. up to 26.92 metres in BH R503B, and 19.00 metres in BH R507A).

The results of unconfined compression tests (quoted by the Arup-Atkins Joint Venture report for Highways England, December 2016) gave intact compressive rock strengths mostly between 1 and 3MPa with an average of 2MPa, corresponding to the description of a ‘very weak’ rock. The poorest quality White Chalk in the Stonehenge area has been identified commonly and linked to the “dry valleys” (or combes) such as the Stonehenge Bottom valley.

In addition to surprisingly weak rock, the occurrence of a previously unknown (pre-2000) sub-crop of highly phosphatic Chalk (i.e., very weak Chalk rock altered and enriched with phosphate) has been identified mostly in the western half of the tunnel route. These are the thickest such deposits identified so far in the UK (Mortimore et al. 2017).¹ These materials are thought to have been deposited in scoured marine channels (“cuvettes”) in an organically rich environment on the Late Cretaceous seabed floor. Although laboratory leaching tests carried out for National Highways have not identified any groundwater contamination risks, it remains a concern that changes in groundwater flow patterns caused by the proposed tunnel construction, and/or changes in groundwater quality and chemistry may cause long term concerns. Disposal of tunnel spoil is likely to cause problems and concerns of induced phosphate contamination, especially when the status of the River Avon as a Special Area of Conservation (SAC), with existing unacceptable elevated levels of phosphate, is considered. Natural England in conjunction with Wiltshire County Council have implemented the River Avon Phosphate Management Plan (published in February 2016) to drastically reduce phosphate levels in the river. Similar materials to this Phosphatic Chalk are mined in Northern France for use in fertilisers and the chemical industry.

¹ Mortimore, R.N., L.T. Gallagher, J.T. Gelder, I.R. Moore, R. Brooks and A.R. Farrant, “Stonehenge—a unique Late Cretaceous phosphatic Chalk geology: implications for sea-level, climate and tectonics and impact on engineering and archaeology” in Proceedings of the Geologists Association Vol. 128, Issue 4 (August 2017), pp.511–682.

As a consequence of the above information on the occurrence of poor quality rock along the line of the proposed tunnel, and the relatively shallow depth of the middle portion of the tunnel route in the Stonehenge Bottom area, it has been proposed by National Highways that a “slurry shield” method of closed-faced tunnelling would be the most likely tunnelling method to be adopted.

This depends on a full-face tunnel boring machine (TBM) with a bentonite-mud based slurry forming external additional long-term grout support to the strata surrounding the tunnel face and sides. Grout stabilisation, either from the tunnelling process, and/or the probable necessity for surface grouting via an array of specially constructed grouting boreholes will, together with the ground affected by the tunnelling, form an underground barrier to the existing predominant NW/SE groundwater flow regime.

It is inevitable that such a major sub-surface “groundwater cutoff” or “sub-surface dam” will therefore considerably affect groundwater movement, flow paths, recharge and abstraction well yields, causing extensive disruption to the existing groundwater conditions.

4.2. Groundwater Disruptions

(REP2-131, REP3-064, AS-045, REP6-064, REP6-065, AS-090, AS-098, REP8-051, REP8-053, REP8-054, and REP9-045)

As stated above, the requirement for ground stabilisation of numerous sections of the very weak Chalk bedrock (especially in the Newhaven Chalk Formation and the zones of Phosphatic Chalk, will undoubtedly adversely affect existing groundwater movement patterns, especially in the western tunnel section. Similar effects, simply due to the effects on sub-surface drainage by tunnel and road drainage construction in the eastern tunnel section are also very likely to affect groundwater flow patterns, recharge and seasonal springline resurgences.

The most significant locations where these adverse effects are likely to occur are in the Blick Mead and Amesbury Abbey locations. (AS-090). At Blick Mead, waterlogged peat deposits and shallow saturation of bedrock have resulted in a unique preservation of archaeological deposits from one of the encampments considered to have been used (adjacent to the springs at Amesbury Abbey and the River Avon) during the Mesolithic period. Loss of or damage to these deposits could occur from a prolonged period of drying-out.

A sub-horizontal zone of higher permeability Chalk (at the level of the Whitway or Stockbridge Rock, which results in a number of spring resurgences or springlines on the west banks of the River Avon) has resulted in the spring pool feature known as Amesbury Abbey Spring, adjacent to Blick Mead and Vespasian’s Camp (AS-098). This spring system and set of gas generating bubbling pools, is recharged from the Chalk aquifer to the northwest of the River Avon, into which it flows.

Some trial boreholes, groundwater investigations and groundwater level monitoring have been carried out on the Blick Mead site. A short technical note describing the observed water levels in 2018 and 2019 in boreholes at Blick Mead has been published by Highways England (AS-015). A letter correcting various misconceptions of the Blick Mead/Avebury springs situation and expressing concerns that the proposed scheme will inevitably have a significant deleterious effect on groundwater at these locations has also been submitted to the Inspectorate. (AS-071)

It is highly likely that this higher permeability zone persists along the line of the proposed tunnel at the Whitway/Stockbridge Rock level, almost coincident with the soffit level (at approximately 50 m AOD) of the proposed tunnel in its mid-section across the Stonehenge Cottages to Stonehenge Bottom areas. (AS-090). Considerable dewatering and/or extensive grouting are likely to be required to advance tunnels through these groundwater conditions.

4.3. Subsidence and potential damage to undiscovered archaeology

([REP2-131](#), [REP4-056](#), [REP8-052](#))

The 2017 geophysical survey work was carried out by Wessex Geophysics for Highways England between August and October 2016, but only made available to us in January 2022 (Report No. HE551506-AA-EHR-SWI-RP-YE-000003, prepared for the Arup-Atkins Joint Venture in May 2017, entitled “Geophysical Survey Report Stage 1 Final Stage 1” ([Redetermination 2.19](#))). The work involved both gradiometer (magnetometer) surveys and ground probing radar (GPR) over eight individual survey areas, selected by Highways England from the detailed gradiometer data. A complete geophysical survey of the whole Stonehenge WHS has yet to be carried out. As demonstrated by the discovery of the “Durrington pits” in 2021, there is much to be discovered regarding as yet unknown archaeological features in the Stonehenge and district landscape.

A number of features throughout the Chalk bedrock landscape of the Stonehenge World Heritage Site (WHS) have been identified in the past as potential “sinkholes” or karstic bedrock subsidence features (probably of a periglacial Quaternary age). This is thought to include archaeological features such as the Wilsford Shaft, as well as the recently discovered “Durrington Pits” features where sinkholes may have been re-used.

As stated by the author to the Examination in 2019 and still the case today:

‘During tunnelling, vibration may cause induced fracture migration and settlement in overlying strata transmitted upwards towards the surface. In the extreme, subsidence could migrate to surface levels, resulting in sinkholes and/or compaction. Grout migration from the TBM systems could lead to extensive permanent areas of Chalk with lowered permeability. The potential loss of fissures, fractures, void spaces, burial features, galleries, tunnels and shafts, at present undiscovered and unidentified, either by grout injection, settlement or the combined effects of both processes, could lead to the permanent loss of potentially important archaeological features. Similar detrimental effects of settlement and grout migration may also cause problems in land drainage and surface/shallow subsurface drainage systems.’ ([REP4-056](#), ‘General and Cross-topic’: 17.1, p.23 of 35)

5. Conclusions and Recommendations

As can be seen from the extensive geological, hydrogeological and geotechnical details submitted by the Stonehenge Alliance at the 2019 Examination (see Appendix, below), there are still many significant uncertainties as to the expected ground and especially groundwater conditions along the proposed A303 Stonehenge tunnel and road improvement Scheme route (see, [AS-045](#) and [AS-098](#)).

It should also be further emphasised, despite these uncertainties and such an additional wealth of detailed ground investigation data produced recently and described and listed herein, that no changes have been made by National Highways to the design, plans, layout and configuration of the proposed scheme from those proposed at the 2019 Examination. Furthermore, the information obtained in the lately-published reports gives no confidence that the uncertainties and difficulties we believe would be encountered in tunnelling through part of the World Heritage Site can be overcome. Detailed discussion of the findings in these reports in relation to earlier reports and evidence to the Examination is absent from NH's submission on Statement of Matters bullet point 4 – Environmental Information Review (Section 7: Geology and Soils); indeed, the matter is hardly raised, except in a land contamination context.

In respect of groundwater, NH states that groundwater monitoring is continuing (NH Redetermination 1.4, Section 8: Road Drainage and the Water Environment, para. 8.3.9). Further Blick Mead monitoring data has not been published. Although references to recent monitoring and changes in groundwater level are as predictable (paras. 8.3.12–19), they do not assist in demonstrating the certain uncertainties of the effects of groundwater movement arising from tunnelling in construction and operation.

From the above referred-to reports, it can be seen that a vast amount of ground and groundwater investigation work was being carried out as the Examination drew to a close in October 2019. Subsequent to that date, additional investigations (therefore not submitted then or available until now) have taken place without the benefit of examination and interrogation by the Examining Authority. The full data which is available to NH should be released to consultees (including Natural England and the Environment Agency), interested parties and to the Secretary of State. This includes the monitoring data at Blick Mead so as to ensure that all environmental information is consulted upon and taken into account. Further, a full appropriate assessment should be made of the impact of potential phosphates leaching into the River Avon SAC.-We consider it essential that the Scheme is re-examined so that the enormous volume of new data on such critical elements of the project may be formally scrutinised by an appointed Examining Authority to enable the Secretary of State to receive its independent specialist advice.

In any event, it should be borne in mind, as cautioned numerous times by the Alliance and especially the current author in his evidence, that it remains highly likely, should the scheme go ahead in its current configurations, there will be both considerable cost and time over-runs in completing the works proposed.

gmr 02.04.22

Appendix

Representations by Dr George M Reeves to the 2019 Examination on behalf of the Stonehenge Alliance

REP2-131. Deadline 2 Submission - Written Representation on Flood Risk groundwater protection

REP2a-003. Deadline 2a Submission - Response to Deadline 2a (letter requesting missing information, 17.4.19)

AS-035. Additional Submission accepted at the discretion of the Examining Authority (letter re missing information, 17.5.19)

REP3-064. Deadline 3 Submission - Comments on Written Representations and Additional Submissions to the Examining Authority submitted by Deadline 2 (part)

AS-045. Additional Submission accepted at the discretion of the Examining Authority - Supporting Evidence for Hearings (slide show)

REP4-087. Deadline 4 Submission - Summary of oral presentation and submissions to ISH 4 on water, geology etc. and ISH 5 on noise, vibration etc. by Dr George Reeves. FINAL - Late Submission accepted at the discretion of the Examining Authority

REP4-088. Deadline 4 Submission - Appendix 1 Presentation by Dr. GM Reeves to Session 4 A303 Stonehenge Examination, Tuesday 11th June 2019 - Late Submission accepted at the discretion of the Examining Authority. Slide show.

REP4-056. Deadline 4 Submission - Comments on any further information requested by the ExA and received to Deadline 3 (part)

REP5-024. Deadline 5 Submission - Dr George Reeves Comments on Highways England Deadline 4 Submission REP4-036- 8.31 Comments on any further information requested by the ExA and received to Deadline 3

REP6-065. Deadline 6 Submission - Response to Examining Authority's Second Round of Written Questions and information sought on various topics (part)

REP6-064. Deadline 6 Submission - Response to Examining Authority's Second Round of Written Questions and information sought on geological and groundwater issues by Dr George Reeves

REP6-086. Deadline 6 Submission - Late Submission accepted at the discretion of the Examining Authority - Response by Dr George Reeves to Applicants Comments on any further Information Requested by the Examining Authority and Received at Deadline 4.

AS-074. Additional Submission accepted at the discretion of the Examining Authority - Requests for Information (letter re missing information, 14.8.19)

AS-090. Additional Submission accepted at the discretion of the Examining Authority - Slide deck concerning groundwater to inform Issue Specific Hearing 8/Issue Specific Hearing 10 - Original version published on 21 August 2019 - Superseded version published on 22 August 2019

AS-098. Additional Submission accepted at the discretion of the Examining Authority - Written note and finalised slide deck to inform presentation at ISH10

REP8-051. Deadline 8 Submission - Slides for presentation by Dr Reeves at Issue Specific Hearing 10

REP8-053. Deadline 8 Submission - Written Summaries of oral submissions at Issue Specific Hearing 10

REP8-052. Deadline 8 Submission - Written Summaries of oral submissions at Issue Specific Hearing 8

REP8-054. Deadline 8 Submission - Comments on Deadline 7 Document - REP7-021 (part)

REP9-046. Deadline 9 Submission - Summary of Case (part)

REP9-045. Deadline 9 Submission - Response to Highways England Deadline 8 Documents by Dr George Reeves.