Dr. George M Reeves CGeol CEnv PhD MSc BSc FGS FIMMM,
HydroGEOtecH Consultants.
Lybster Caithness, Scotland **www.hydrogeotech.co.uk**

Submission to Planning Inspectorate, National Infrastructure Planning:
Ref. TR010025 **25 July 2019**

Prepared by Dr. G.M. Reeves for the **Stonehenge Alliance Ref No. 2001870**

Response to Planning Inspectorate: Examining Authority's second Written Questions arising from the draft Development Consent Order; Highways England proposed A303 Scheme.

Numbered references are as in Examining Authority's Questions arising from the draft DCO.

CH.2.6	Applicant All Interested Parties	**Geophysical techniques** **Discuss the reliability of the investigation results of different geophysical techniques and the need to compare data sets across different techniques.**

Response

Notwithstanding this question having been directed primarily towards the identification of archaeological remains, as detailed in previous submissions and evidence submitted by the Stonehenge Alliance, a thorough engineering geophysical assessment of the whole proposed A303 road and tunnel route would better inform the design, planning and understanding, in 3 dimensions, and to the critical depths of up to 100 metres for the proposed development.

In this writer's specific experience and professional opinion, this is an essential step prior to any granting of any DCO.

This would involve, inter alia, digitally based and recorded, engineering seismic surveying, deep ground probing radar, micro-magnetics, high resolution resistivity, electro-magnetics and gravity surveys.

Existing previously obtained, shallow, localised archaeological oriented geophysical survey data should be integrated and refined by this deeper, more engineering-directed survey work.

Integrated 3-D data analysis and presentation should be part of a comprehensive geological, geotechnical (rock property and structural), hydrogeological (on a chainage-scale basis, especially for the tunnel profile) and geophysical, detailed ground model of the proposed route and adjacent affected areas.

This integrated Ground Model would be over 5 kilometres in length (at least from West Amesbury to Longbarrow Roundabout), over 100 metres in depth, and cover at least the areas up to 1 kilometre north and south of the proposed route, i.e. 2 kilometres in N-S plan.

DCO.2.15	Environment Agency	**Article 7 – Limits of deviation** **In the light of the Applicant's DL4 written summary of oral submissions put at the DCO hearing on 4 June 2019 [REP4-029], are there any outstanding concerns as regards the interaction between the vertical LoD of the proposed tunnel and groundwater flows?**

Fg.2.23	Environment Agency	Groundwater i. **Can you confirm whether you are satisfied with the provision in the OEMP for the Groundwater Management Plan?** ii. **If this is inadequate, please specify why and what amendments do you consider to be necessary?**

Fg.2.26	Applicant Environment Agency	**Groundwater, Geology and detailed design** In its DL4 submission the Environment Agency has requested that it be consulted on any updated design to the proposed tunnel to consider any impact on groundwater flows [REP4-049]. Requirement 3 in the dDCO requires consultation with the planning authority on matters relating to its functions. i. **Should there be a Requirement to consult the Environment Agency where any changes are proposed to the tunnel? Please provide reasons.** ii. **If consultation is required, how should this be secured (for example by amending Requirement 3)?**

Fg.2.32	Applicant Environment Agency Wiltshire Council The Stonehenge Alliance	**Contamination and groundwater flow** In respect of the tunnel boring methodology and the potential for there to be a risk of pollution or impediment to groundwater flow the Environment Agency notes that OEMP: PW-G1, MW-G5, MW-G7, MW-WAT8, MW-WAT9, MW-WAT 10, MW WAT11, and MW-WAT14 provide **some** control of these activities (emphasis added) [REP4-020]. **Are the controls adequate and, if not, what additional controls are required to mitigate any risks appropriately?**
Fg.2.33	Applicant Environment Agency Wiltshire Council	**Dewatering** The OEMP now commits to the use of closed face tunnelling techniques. This should prevent the risk of large-scale dewatering being required [REP4-020]. i. **To what extent was small-scale dewatering assessed in the Environmental Statement and does it reflect the worst-case scenario in terms of dewatering?**

<u>Commentary and Combined Responses to all the above issues</u>

An adequate understanding of present groundwater conditions is significantly and fundamentally incomplete, in and around the route of the proposed A303 Stonehenge tunnel and associated highway works.

As a major example of this point, the Whitway Rock (known to the east of the Salisbury area and in the SW of the Devizes BGS 1:50,000 geological map as the Stockbridge Rock) has not been identified in either phase of the site investigation work for the proposed Highways England A303 road and tunnel scheme.

The Stockbridge Rock is referred to by Mortimore et al. (2017, page 8):

> *"It is also possible that the hardground equates with the British Geological Survey Stockbridge Rock Member mapped on the Salisbury Sheet (Hopson, 2005). The Stockbridge Rock Member is a hard bed several metres below Barrois' sponge bed. It is localised within a part of the*

Wessex basin controlled by syn-sedimentary faulting/folding along the line the Winchester-Dean Hill anticline (Fig. 2)."

It is highly likely that the Blick Mead and nearby Amesbury Abbey spring system occurs on a sub-crop of the Whitway/Stockbridge Rock to the west of Countess Roundabout. The Blick Mead/Amesbury Abbey major spring system arises at the stratigraphic level of the Whitway Rock in the Seaford Chalk i.e. at approximately 5 metres below the base of the Newhaven Chalk. It is described (Soley et al., 2012) as

> *"….an up to 5 metres thick hard porcellenous chalk layer near the boundary of the Seaford and Newhaven Chalk formations (the Stockbridge Rock/Whitway Rock Member, BGS Winchester Sheet, Booth 2002; Newbury Sheet 267, 2006). This latter hard layer is probably the lateral equivalent of Barrois' SpongeBed, a regionally important marker bed."*

There is therefore grave concern about long term effects due to potential changes in horizontal and vertical permeabilities of such zones as the Whitway Rock, the overlying Upper Seaford Chalk/Newhaven Beds, and fracture systems which control groundwater flow southwards below Stonehenge Bottom, respectively.
It is therefore essential that additional, deeper, targetted (and carefully cored) borehole drilling is carried out, especially to the east of Stonehenge Bottom, as far as Countess Roundabout. This would enable proper investigation of geological and hydrogeological conditions at depth, below the proposed tunnel soffit level.

Such boreholes would assess the presence or absence of the Whitway Rock in the area of the Scheme and if present, its hydrogeological significance, especially in the eastern section of the Chalk that is likely to be affected by tunnel construction and operations.

The background to the adopted Wessex Basin Groundwater Model, and associated work, is detailed by Soley et al. (2012). This paper extensively discusses the Chalk aquifer properties across the South of England, confirms the 250m spacing of nodes for all the models, including the Wessex Basin model, as adopted virtually without any refinements (and at a wholly inappropriate coarse scale by Highways England, with the approval of the EA and Wiltshire Council).
In this paper it is stated that the initial work carried out in advance of the Wessex Basin and associated groundwater modelling activities prior to 2012 was informed by a comprehensive 3-D ground model of all these areas, carried out by the British Geological Survey (BGS).

The Stonehenge Alliance continues to refute that Highways England groundwater modelling is "fit for purpose" for accurately modelling groundwater effects relevant to the proposed A303 tunnel.

If the combination of extensive vertical major fractures and fissuring in the Newhaven and Seaford Chalk horizons (particularly in Stonehenge Bottom and eastwards) are adversely affected by the tunnel construction, especially with extensive penetration of bentonite slurry/grout, nearby groundwater abstractions and springs could well be permanently derogated.
The creation of any degree of groundwater barrier, as a result of tunnel construction, could adversely affect local private abstractors, and even the discharge of the Blick Mead/Amesbury Abbey springs to the east.
Using groundwater modelling nodes (as utilised in ModFlow software, and similar) with 250m spacings, only about 15 data points are established to predict groundwater conditions along the tunnel line.

This poor level of detail is totally inappropriate and insufficient to investigate the complexity of groundwater movement, recharge, flow and discharges at the necessary scale and detail requirements of the 3.3km long tunnel.

If the crown of the tunnel is located below the Stockbridge Rock, i.e. at approx. 50m BGL (55mAOD), with the road level in the tunnel at 36.3m AOD, the tunnel would be approximately 15m deeper than is currently shown in Highways England drawings. The current levels shown in the drawings (HEng. DCO Application: Documents 2.7- Engineering Section Drawings; No.7 of 24) show the crown level of the tunnel below Stonehenge Bottom at 70m AOD, and the road level at 51.3mAOD.

Therefore, if tunnelling goes deeper than proposed to the west and east of Stonehenge Bottom, the Stockbridge/Whitway Rock high permeability zone is likely to be intercepted, but not in the major fracture zone below Stonehenge Bottom.

The consequence of any such variations to the published Limits of Deviation has not been investigated, neither by site investigation drilling nor groundwater monitoring and testing, and consequently has not been part of any detailed and relevant groundwater modelling.

Fg.2.40	Applicant The Stonehenge Alliance	**Geology and soils** **i. Are you aware of any examples where an integrated 3D model (as suggested by Dr Reeves at ISH4 on behalf of the Stonehenge Alliance) has been considered to be necessary at the pre-consent stage?** **ii. If so, please provide details of any examples and set out whether these can be considered reasonably comparable with the Proposed Development?**

Response

The Planning Inspectorate (PI) files and the PI Public Records are the best and most accurate source of information as to the dates and details of hearings and approvals for such projects and we have not accessed them to give specific answers to the ExA's Questions.

Numerous applications of 3-D geological ground modelling showing geotechnical and hydrogeological features as they change throughout a block of ground in which excavations (especially tunnels) are intended to pass, have been used increasingly over the past 10 to 15 years.

It is now a natural logical step for integrating complex ground information, to assist in the understanding of complex, varying and inter-related geoscientific data pertinent to a major civil engineering excavation project.

These techniques and approaches have been used in the UK as follows:

1. Central and Greater London areas: Major infrastructure, Crossrail and London Underground tunnelling and sewer drainage planning. (Report: nora.nerc.ac.uk/507607/) - Includes Thames Gateway and HS2 projects.
2. Central Glasgow – major infrastructure developments; tunnels and roads.
3. Wylfa, Sizewell C and Hinkley Point C Newbuild Nuclear Power Stations as well as the Dounreay and Drigg (LLWR) nuclear decommissioning/radwaste disposal sites. Radioactive Waste Management Ltd. - Geological Screening
4. The London Basin- Superficial and Bedrock Lithoframe 50 model used in projects as listed in 1, above- Burke et al., 2014)

5. CrossRail and HS2 specific rail tunnel projects, including Farringdon Station, East London.
6. Tata Steel –Leeds to York Electrification
7. Arup/Yorkshire Water - Doncaster
8. Environment Agency: National Geological Model –UK 3D; Aquifers and Shales; Manchester; Knowsley; Holderness; Chichester; Doncaster; North Kent; London Chalk Model
9. Glasgow City Council – ASK Network.
10. British Waterways – Monmouthshire and Brecon Canal
11. Forres-Moray (Moray Council) – Flood Prevention
12. CO2storage - CASSEM
13. Dept Energy and Climate Change – Shale Study Midland Valley (Scotland)
14. Oil and Gas Authority – Bowland Shale Gas
15. Jurassic Shale of the Weald Basin
16. Scottish Government - Geothermal Energy
17. Ordnance Survey – 3D workshops/Project Iceberg
18. University of Newcastle – Groundwater Flooding
19. University of East Anglia DTCs-Wensum
20. Kingston University - Visualisation Training

Overseas Applications include:

1. Singapore (Building and Construction Agency) – 3D geological Model
2. Arup – UAE Offshore
3. Ministry of Energy (Abu Dhabi) –Abu Dhabi Geological model
4. Vale/Coffey Mining –Mineral Exploration
5. Wardell Armstrong –TELLUS HOW
6. Anglo American –Visualisation Training
7. SGU (Sweden) –Esker Pilot Study
8. Illinois –Visualisation and Modelling
9. GTK (Finland) –Groundhog Desktop Development
10. Chile –Digital Mapping Workflow
11. Volcano Research –STREVA
12. UNITEN (Malaysia) –Visualisation Capability and Training
13. European 3D Geological Modelling Community-
    Sub-Urban–Consortium of GSOs, Cities and Research partners - Management of ground beneath cities.

Initiation of many of the UK examples where such 3-D ground models have proven useful pre-date the new NSIP processes introduced by the Planning Inspectorate by way of The Planning Act 2008.

It should also be noted that a 3-D geological model, developed by the British Geological Survey, was the basis for the development of the Wessex Basin and associated groundwater models of the Southern English Chalk aquifers, as described by Soley et al. (2012).

Since the proposed A303 road and tunnel project are being assessed under the new NSIP process, the Infrastructure Conditions of Contract and/or the Institution of Civil Engineers (ICE) “New Engineering Contracts”, NEC 3 and NEC 4, Terms of Contract and conditions must apply.

In these systems and procedures there are two highly relevant protocols. These are the Unexpected Ground Conditions clauses (ICE 7 Clause 12 et seq.) and the principle of using “Best Available Technology Not Entailing Excessive Cost”.

In addition, the recently adopted Building Information Modelling approach, now used on most major projects in the UK, would predicate the use of 3-D Ground modelling, prior to the tendering stage especially where complex ground conditions are expected.

Failure to follow the above systems could not only result in inflated costs of such a project due to extensive claims against the proponent/client but also considerable delays when these "unexpected conditions" result in costly remedial measures, and indeed could draw any proponent/client into massive legal costs for not having complied with the requirement of presenting all known available data to prospective tenderers, and especially the successful bidding contractor, in the best and most complete format so as to enable an accurate and economic bid (in both fiscal and project management terms), especially when the Client is the UK Government/The Public Purse.

Conclusions

The following comments on the shortcomings of Highways England ground investigations and characterisation of the block of ground likely to be affected by the proposed road and tunnelling works, can therefore be made:

1. 3-Dimensional ground modelling is an essential element of the site investigation data presentation.
2. Groundwater modelling, on a scale appropriate to the dimensions of the area likely to be affected by any changes in groundwater conditions which may result from and/or be caused by construction, is vital, and has not been achieved.
3. Grouting trials, in similar fractured Chalk bedrock should be undertaken to assess the expected extent of penetration due to both closed face slurry/bentonite tunnelling and possible emergency surface or tunnel-based grouting.

Finally it is strongly suggested that the Examining Authority might wish to invite Professor Rory N. Mortimore, who is the acknowledged expert on the Chalk Rock of Britain and Europe, to address and be questioned by the Panel, to their undoubted benefit, on the geological and geotechnical details of the proposed scheme, especially with respect to the immediate necessity of Ground Modelling information, now that the tendering process has commenced.

Dr. GM Reeves 25.07.19

References

Burke, H., Mathers, S.J., Williamson, J.P., Thorpe, S., Ford, J. and Terrington, R.L. (2014). "The London Basin superficial and bedrock LithoFrame 50 Model". Nottingham, UK, British Geological Survey, 27pp. (OR/14/029) (Unpublished; http://nora.nerc.ac.uk/id/eprint/507607/)

Mortimore et al. (2017). "Stonehenge—a unique Late Cretaceous phosphatic Chalk geology: implications for sea level, climate and tectonics and impact on engineering and archaeology", Proc. Geol. Assoc. 128 (4), 564–98.

Soley et al. (2012). Modelling the hydrogeology and managed aquifer system of the Chalk across Southern England. R. W. N. Soley, T. Power, R. N. Mortimore, P. Shaw, J. Dottridge G. Bryan and I. Colley. Geological Society, London, Special Publications, 364, 129-154, 23 April 2012. https://doi.org/10.1144/SP364.10

Entwistle, D. and BGS staff (2019). 3D geological modelling at the British Geological Survey (BGS). Slides presented at workshop January 2019.
http://nora.nerc.ac.uk/id/eprint/522402/1/3D%20geological%20modelling%20at%20the%20British%20Geological%20Survey_pdf_Final.pdf