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Concerns arising from the Geology and Hydrology of the ground underlying the High Speed (HS2) routes through the Chilterns

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INTRODUCTION

This study deals initially with the "preferred" route (Route 3) for the high speed rail line from London Birmingham as it passes through the Chiltern area. Additional comments will also be made concerning the alternative routes (Route 4 trough Berkhamsted and Route 2.5 through Princes Risborough).

The proposed HS2 Route 3 runs north westwards through the valley of the River Misbourne from Denham to Wendover. It starts as a tunnel under the M25 at Denham and then continues under Chalfont St Peter, Chalfont St Giles and Amersham before emerging just west of Amersham Old Town at Mantles Farm, a total distance of about 9km. The route then continues up the Misbourne Valley through a series of six cuttings, six embankments and across two viaducts past Little Missenden and Great Missenden through to Wendover.

In order to understand the impact of constructing a tunnel along this route, a brief description of the underlying geology is presented below. The regional geology was recently remapped by the British Geological Survey and a more detailed description is provided in the explanatory report which accompanies the published map for the Beaconsfield district (Morigi *et al*., 2005).

It should also be understood that due to persistence of distinct layers within the underlying Chalk of the Chiltern region, many of the descriptions, comments and discussion regarding HS2 Route 3 can also be directly applied to the HS2 Routes 2.5 and 4.

THE GEOLOGICAL SETTING OF THE CHILTERNS

The Misbourne river valley is underlain by a thin veneer of periglacial river sands and gravels overlying, at shallow depth, the White Chalk Subgroup which has a very weathered upper section, often recorded to a depth of c.16 metres in local borehole logs.

The Chalk of the Beaconsfield area (as recorded on the BGS geological map Sheet 255) is divided into three lithostratigraphic units (See Figure 1); these are the New Pit Formation, the Lewes Nodular Chalk Formation and the Seaford and Newhaven Chalks. This latter unit has not been subdivided into its two constituent formations as they cannot be separated in this area, but to all intents and purposes for the area of interest, we are considering the Seaford Formation.

Despite all being "chalks", the New Pit, Lewes and Seaford Formations have very different lithological characteristics which will impact on engineering quality and water flow, the latter both above and below the surface.

The **New Pit Chalk Formation** is described by Morigi *et al*. (2005) as a "massively bedded, non-nodular chalk, with fairly regularly developed marl seams and sporadic flints". It is the presence of the marl seams which characterises this unit, as these argillaceous clay seams, often less than 1cm thick, are extremely widespread, being recognised across the whole of southern England and in a number of cases even across to Germany.

The New Pit Formation underlies the Misbourne valley below Amersham Old Town and continues to subcrop to the southeast as far as the disused Quarrendon Mill. The BGS interpretation places the boundary between the New Pit Chalk and the younger (overlying) Lewes Chalk just to the southeast of the mill (SU978960).

The **Lewes Nodular Chalk** has very different characteristics to those described for the underlying (older) New Pit chalk. The Lewes Formation comprises “a hard nodular chalk, with conspicuous regularly developed flints, thin marls and hardgrounds” (Morigi *et al, op.cit*.). The hard nodular chalks occur as a series of condensed mineralised hardgrounds, principally the Chalk Rock and the slightly higher (younger) Top Rock, both of which occur throughout the Chiltern area. Both these beds are extremely hard and were often used as quarry floors in old quarry workings regionally. The typical Chalk Rock of the Chilterns is described well from the working quarry at Kensworth, Bedfordshire where this “chalkstone is penetrated by an extensive *Thalassinoides* burrow system, mostly filled by either friable, granular chalk or else empty of sediment.” (Mortimore *et al*., 2001). Whilst the younger Top Rock hardground lacks the open tubular burrows described from the Chalk Rock, it is also penetrated by burrowing back filled with soft granular chalk sediments. The indurated character of the Lewes Chalk makes it much more liable to fracturing when compared with the underlying New Pit marly chalk.

The Lewes Chalk outcrops beneath the Misbourne valley from just south east of Quarrendon Mill to the village centre of Chalfont St. Giles. From this point southwards to Denham the river valley overlies chalk of the Seaford Formation.

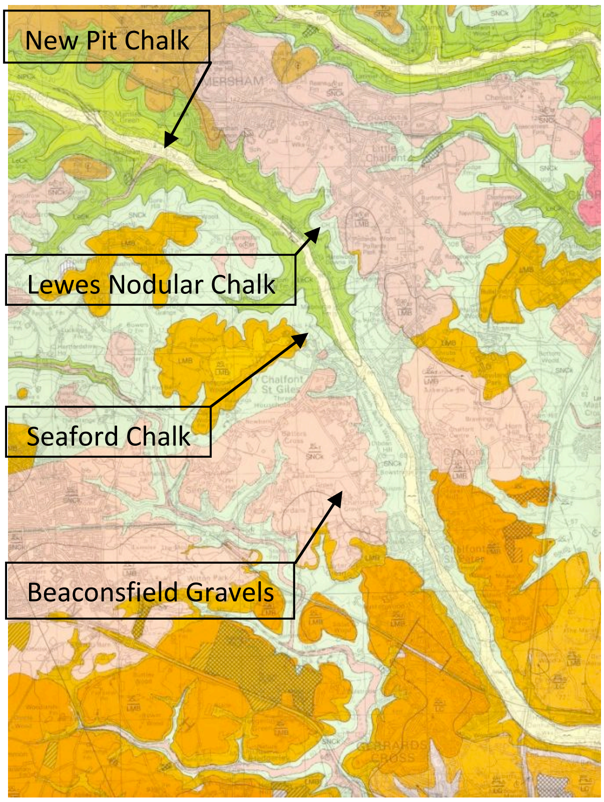

Figure 1: *Geological map of the Misbourne valley; BGS Beaconsfield Sheet 255, showing older chalk formations in the north west; also chalk overlain by pre-glacial Beaconsfield Gravels along the line of the proto-Thames.*

“The **Seaford Chalk** is typically a soft, flinty chalk with local shell rich horizons” according to Morigi *et al*. (*op.cit*.). The Seaford Formation comprises a uniform, very fine chalk, with a relatively high microporosity, making it a major aquifer through southern England (Mortimore *et al.,* 1990).

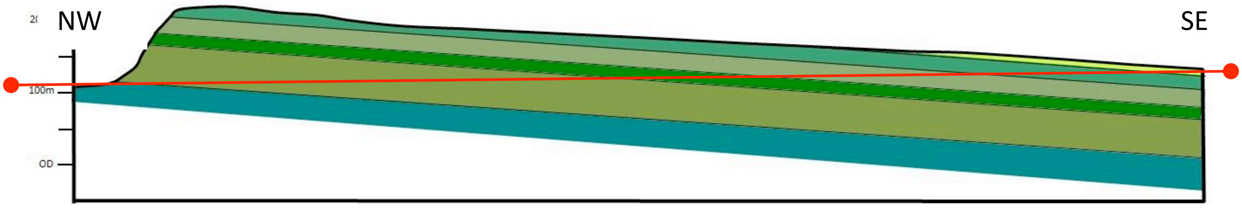

Figure 2: *Schematic geological cross section through the Chilterns. Different chalk formations dip gently to the south, forming the northern rim of the London Basin. The red line shows how any proposed rail route would tunnel/cut from younger to older chalk passing from the southeast to the northwest.*

Superficial deposits overlying the Chalk: Immediately overlying the Chalk of the Chiltern area there are extensive deposits of sands and gravels deposited approximately 450,000 years ago, during the Anglian ice advance. The recently published (2005) Beaconsfield geological map (Sheet 255) goes to some length to illustrate the complex history of the Thames valley, particularly during the Anglian ice age (see Figure 3). Prior to this time the proto-Thames flowed north eastwards across the district, roughly in a line running from Marlow through Beaconsfield and on to the north of Watford, along the line of the M25.

This major river deposited coarse clastic sediments (**Beaconsfield Gravel**) along its route which now occur as a series of terraces (Line A on Figure 3). The proto-Thames was dammed by the Anglian ice sheet in the Vale of St. Albans in the area of the present day M1/M25 junction. This glacial lake (B on Figure 3) eventually spilled out southwards through the present day Colne Valley and established the current Thames river valley from Marlow through Slough (C on Figure 3) and on to London.

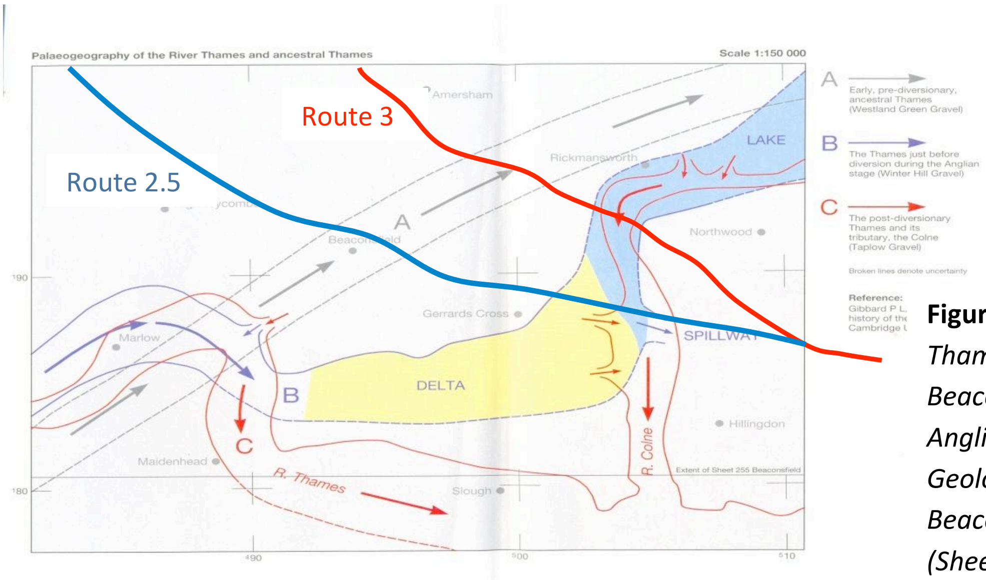

Figure 3: *The development of the Thames Valley across the Beaconsfield area during the Anglian ice age; from the Geological Survey 1:50 000 Beaconsfield Solid and Drift map (Sheet 255).*

The River Misbourne has cut through the Beaconsfield Gravels and now runs directly over the Chalk. However, it must be recognised that the complex ice age history outlined briefly above will have had a major impact on the water bearing qualities of the chalk immediately below the surface, with the flow of a major river over it and through it via karst pipes and fractures, combined with the action of freeze/thaw breakage and damage. Consequently the chalk underlying the present day Misbourne river valley between Chalfont St. Giles and Chalfont St. Peter has been deeply eroded by the proto-Thames river and disaggregated and shattered by later repeated freeze and thaw episodes.

Borehole data available to the Chiltern Society from along the Misbourne valley clearly reveal the depth to which the underlying chalk has been weathered and damaged by former river and ice action. In boreholes between Gerrards Cross and Chalfont St. Giles, weathered "Upper" Chalk (Lewes and Seaford formations) is recorded to a 16 m depth below the current ground surface. This will have a direct impact on the hydrogeology of the area and tunnelling, which is discussed below.

Current routes and the impact of the underlying geology

Route 3: This is the current preferred routing for HS2 and is indicated to pass through a 9 kilometre tunnel from the M25 crossing at Denham, directly beneath Chalfont St. Giles and exiting just to the north west of Old Amersham. Beyond this it runs through a series of cuttings, a small tunnel, over six embankments and two viaducts before it reaches Wendover.

This routing means that the main tunnel will pass initially (for approximately 1 kilometre) through the basal part of the Seaford Formation, but will then be within the Lewes Nodular Chalk for the rest of its length, approximately 8 kilometres. These two units are the principal aquifer formations of the area and the tunnel construction will be well within the water table (see figure 4), consequently the potential for damage to the aquifer and pollution of the water system cannot be underestimated or ignored.

It has already been calculated that the residents of the Misbourne valley above Gerrards Cross need approximately 30Ml/d of water to satisfy current requirements and it is up to the water companies to meet this demand. Between them Thames Water and Veolia are licensed to abstract a maximum of only 14 Ml/d. So already half of the water needs of the area have to derived from outside the Misbourne catchment area. Any damage to the aquifer will impact directly and immediately onto the water supply which is already under pressure. Veolia have five active groundwater sources in this river valley, one of which, at Amersham, is within 300 metres of the proposed route.

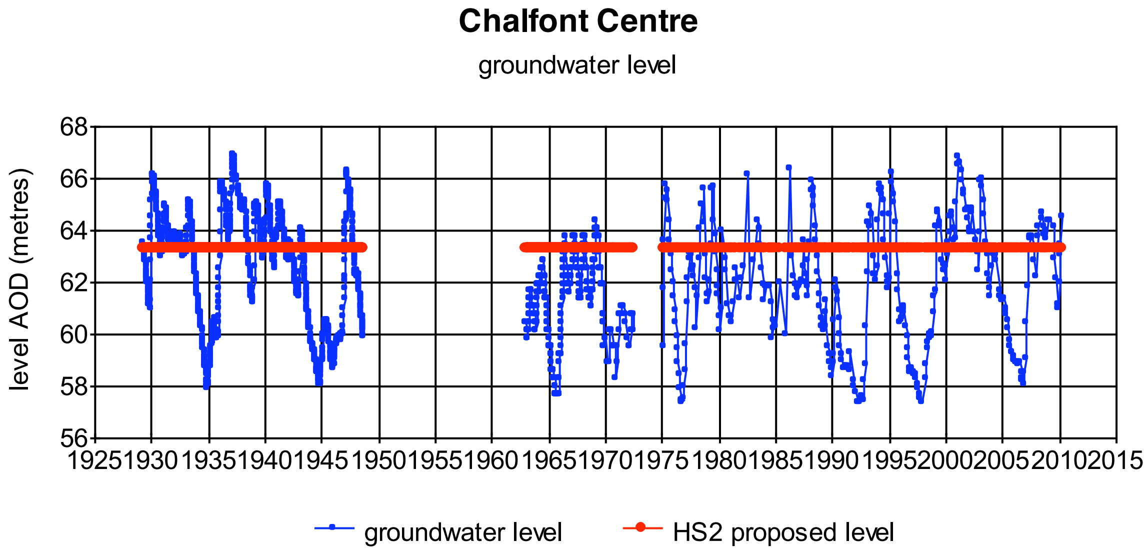

Figure 4: *Graph showing groundwater levels measured at the Chalfont Centre (the Epilepsy Centre/Colony at Chalfont St Peter) borehole from 1929 to the present; it shows that most of the tunnel will be in contact with groundwater for most of the time if previous levels are maintained.*

The 2007 Catchment Abstraction Management Strategies (CAMS) exercise concluded that the Colne catchment, which includes the Misbourne, Chess, Gade, and Bulbourne chalk streams (an internationally scarce and protected habitat) was already "over-abstracted". Should public supplies to the Misbourne catchment be compromised by HS2 construction, then the loss would have to be made good by imports of water from beyond the Colne catchment. It is difficult to imagine over what distance water would have to be transported or piped in, but places like Rutland water or even Wales might have to be considered.

The chalk itself is highly porous (<40% microporosity) but of low inherent permeability; however the presence of vertical joints and fractures within the chalk provide major water conduits throughout the underground aquifer system. The precise locations of such joints are highly unpredictable meaning that tunnelling operations could easily breach the aquifer causing long term damage. The Lewes and Seaford chalk formations underlie the whole of the London Basin and have, in the past, provided the capital with much of its water supply. Any pollution within the aquifer in the Chiltern area, unless isolated rapidly by complex ground engineering, could potentially cause long term damage to London's long term water supply. Mather *et al*. (1973) using isotope studies proved that groundwater circulation at depth within the chalk could take hundreds of years to pass through the aquifer. If damage was caused into the underlying Upper Greensand, then a circulation period of 24,000 years was calculated.

Between Chalfont St. Peter and Chalfont St. Giles the proposed tunnel will pass below the area most affected by the original route of the proto-Thames river as described above. The chalk in this zone is extremely weathered with clay filled pipes and swallow holes eroded deep into the chalk surface. The chalk in this area is clearly described in a borehole log from the Misbourne valley adjacent to Chalfont St. Peter (TQ001911) as "firm brownish white putty chalk with some gravel size pieces of moderately weak white chalk ....(weathered

Upper Chalk)" to a depth of 16 metres. Given that the depth of the tunnel crown in some locations in this area is within 22 metres of the surface (e.g. close to Misbourne Farm) then less than 6 metres of unweathered chalk exists above the tunnel in several places. The potential for ground surface collapse at such locations cannot be underestimated. Collapse structures in chalk areas are very well documented (see Plate 1) and extreme caution is advised in planning any excavation through such an area of unstable ground conditions.

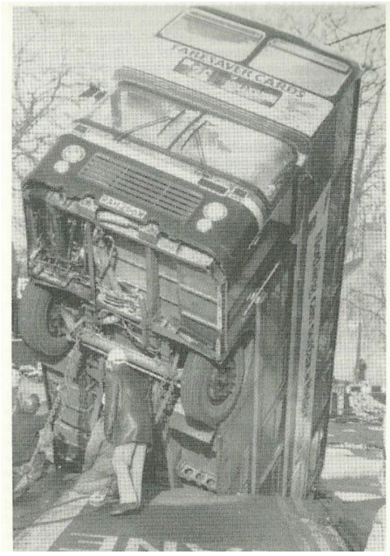

Plate 1: *Bus disappearing into a collapsed chalk mine, Earlham Road, Norwich, 4th March, 1988. Chalk collapses are not uncommon, with local examples existing in Hatfield, Hertfordshire and Reading, Berkshire.*

Groundwater levels recorded along the Misbourne valley throughout the period 1991 to the present day from stand pipes installed in the boreholes along the valley show annual/seasonal fluctuations over the 20 year period. The water table is at ground level from Great Missenden to Amersham Mill, but depressed over the remaining stretch of the valley to Chalfont St Peter. There are cones of depression in the vicinity of pumping stations along the valley showing that the water table is in direct contact with the underlying chalk aquifer. The problems of maintaining river flow in the Misbourne valley are well documented elsewhere. The Chiltern Society is currently in the process of developing a river bed lining scheme between Old Amersham and Chalfont St. Giles for the aesthetic and environmental value of maintaining river flow through the valley. In reality such measures will be of little value if tunnelling takes place, as the ground water flow is likely to be lost and the Misbourne valley will remain permanently dry for most of its length.

In conclusion, the tunnelled section of Route 3 gives rise to concerns geologically for the following reasons:

- Potential damage to the aquifer system
- Pollution of the main water supply system for the north western Home Counties area
- Potential for long term damage for part of London's water supply

- The serious potential of ground collapse in areas of deep sections of weathered chalk

- The total loss of surface water flow in the Misbourne river system, causing destruction of the adjacent habitats

- The aesthetic loss caused by the replacement of the existing river by a permanent dry valley.

To the north west of the tunnelled section, Route 3 is shown passing through a series of six cuttings, a small tunnel, over six embankments and two viaducts before it reaches Wendover. Research on the HS1 route through Kent indicates that maximum noise generation occurs at those places where the rail track passes from running over one medium and onto another, e.g. from the concrete of a viaduct to the hard core below the track in a cutting. On the current route map for Route 3, seventeen changes in the underlying medium are illustrated for the section from Old Amersham to Wendover. With the number of trains per hour projected running in each direction, the potential noise generation in the immediate vicinity of the track along this section of the route is difficult to envisage, but it is highly likely that noise alleviation measures will have to be seriously considered. This may mean the construction of artificial bunds and high security fencing along the length of the route leading to the loss of visual amenity over a thirteen kilometre belt of land through the Chilterns.

Route 2.5 runs north westwards through the Chilterns from Denham, just to the east of Beaconsfield and High Wycombe through to Princes Risborough immediately to the north west of the main chalk escarpment. Given that this route is placed at a level 110m above OD at Princes Risborough station (SP800028), whilst just 3 kilometres to the south of this at Redland End (SP834019) the escarpment reaches a height of 229m above OD, then a considerable amount of tunnelling will be required along this route. In order to achieve an acceptable gradient from a suitable location at a height above OD comparable to that at Princes Risborough then tunnelling and cutting construction will have to commence in the area west of Seer Green (SU955928). This is a distance of 13.5 kilometres of tunnel with a further 5 kilometres of cuttings.

Should this route be followed then again the potential impact on groundwater supplies will be considerable. The route runs through the interfluve area between the Misbourne to the east and the River Wye to the west, thereby affecting the catchment area of two of the major water systems in the area. Despite the water table being naturally depressed in this region to approximately 20 metres below ground surface, it will still be crossed by the tunnelling route given the length of the tunnel section to be cut. This being the case then all the concerns raised over Route 3 can equally be applied to this route giving the potential for both short term and long term damage to the aquifer system. Thames Water has four ground water sources in the area through which Route 2.5 will be cut.

Route 4 closely parallels the West Coast Main Line route through 27 kilometres of tunnels under North London to Watford and re-emerges just to the west of Kings Langley. From this point it follows a series of cuttings past Hemel Hempstead, passing through the Chilterns between Berkhamsted and Tring. This initially appears as a potentially viable route having least affect on the Chiltern AONB. However, this transport corridor is extremely narrow and it already supports the main rail line to the Midlands and beyond, the Grand Union canal, together with the A41 dual carriageway and the A4251 main road servicing the town listed above. Any additional rail construction will inevitably cause major disruption to the existing transport infrastructure.

If it were to be built along the route currently projected then the potential for noise generation within what is a relatively enclosed valley system would be very significant. In this area there is an existing population estimated at a quarter of a million people living in the towns between Watford and Tring.

The proposed routing for Route 4 has it running to the immediate west of Hemel Hempstead where the A41 has already cut through a Biological/Geological SSSI (Roughdown Common) which could be further damaged by HS2 railway construction. Likewise, to the south west of Berkhamsted the HS2 route passes through the dry valley of the Bourne Gutter which has recently (2009) been designated a RIGS (Regionally Important Geological Site) on the basis of its delicately balanced hydrological status. The Bourne stream flows following periods of high rainfall on an approximate 7 – 8 year cycle and during the intervening years all groundwater flow is below the surface. This balanced water table would be damaged irreparably should the rail route be placed along this valley.

The geology underlying the Bourne Gutter is directly comparable to that described along the line of the Misbourne River, the only difference being that the Bourne Gutter lies too far to the north to have been affected by the proto-Thames. The weathering of the chalk surface in this area is restricted to the development of pipes and swallow holes covered by a thin veneer of clay with flints. This being the case, then any rail line construction along this route following cuttings, as indicated, could give rise to the same potential damage to the chalk aquifer and possible pollution of important water resources, drawn from boreholes at 2 groundwater sources along the Bulbourne valley (there are a further 3 groundwater sources in the adjacent Gade valley).

Route 4 follows the corridor already created by the A41 trunk road and in places the HS2 route displaces the A41 which will have to be re-routed, causing further damage to the water table in this restricted valley area. The route continues through the Chilterns via the Tring gap, cutting through a further area designated as a Biological SSSI (Tring Woods). Such areas are supposed to have statutory protection to prevent their progressive destruction as the result of urban development. It would appear from this routing that little or no attention has been given to any protected site.

Conclusions

The Chalk which constitutes the core of the Chiltern hills is between 100 and 84 million years old. It provides the foundations onto which the surface habitats, landscapes and ecosystems which comprise the Chilterns Area of Outstanding Natural Beauty have developed.

This landscape was last modified naturally about four hundred and fifty thousand years ago during the Anglian ice age. The ice sheets formed at this time reached as far south as the Vale of St. Albans, dammed the proto-Thames river which was, until then, flowing eastwards towards the North Sea and depositing the sand and gravel terraces which we see exposed today in road cuttings (e.g. M25) and gravel pits across the region.

This geological history has directly impacted onto the underlying rock succession which is a critically important but vulnerable aquifer in an area of high and still growing population density. The HS2 construction will cut through this underlying foundation, which ever route is followed.

All the routes indicated will require extensive construction via tunnels and deep cuttings in order to cross the Chilterns and access the Vale of Aylesbury to the north. It will be impossible to do this without:

- Potentially causing long term damage to the Chalk aquifer system (this applies to all three proposed routes).

- Causing pollution of the main water supply system for the north western Home Counties area and potentially further into north London – with the subsequent need to source water from other, much more distant parts of the country.

- Running the risk of serious ground collapse in areas with deep sections of weathered chalk.

- Depressing the water table in the Misbourne valley, resulting in -

- the total loss of surface flow in the Misbourne River system and the destruction of the adjacent habitats........

- and the aesthetic loss of the Misbourne River and its replacement by a dry valley.

- Causing the loss of both biological and geological SSSI's and a Regionally Important Geological Site should Route 4 be selected.

A final thought – the construction of the M3 through the chalk at Winchester (Twyford Down) and the construction of the M40 through the Aston Rowant cutting through the Chilterns have left permanent scars on the landscape. As a result, when the A505 Baldock

Bypass was constructed in 2003 (see photograph on the front cover of this report) a cut and fill tunnelling system was used to return the landscape to something approaching its original form.

The construction of this short (<1km) tunnel was delayed by the discovery of a WW2 bomb, the discovery and subsequent excavation of a Saxon graveyard and, more critically, for half a year, by a family of badgers who were raising a litter of young under a hedgerow which had to be lifted en masse before the cutting could be excavated. Given the tunnel and cutting lengths envisaged during the construction of the HS2 through the special environment of the Chilterns AONB, the potential for delay and disruption on targeted construction times could be considerable.

The construction phase of any such project cutting across chalk is bound to cause extensive short to medium term disruption and long term damage to precious ancient Chiltern landscapes. A project of this magnitude also has the potential to disrupt the underlying geological foundations of the region for the long term. The hydrogeology of the region is a vital but vulnerable resource which could easily be damaged by the construction of HS2 through the Chilterns.

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