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High Speed Rail in the Chilterns: Feasibility Study of an Alternative Tunnelling Option

Final Report Rev AC

Project Ref: 30067|Rev 0| Date: February 2015

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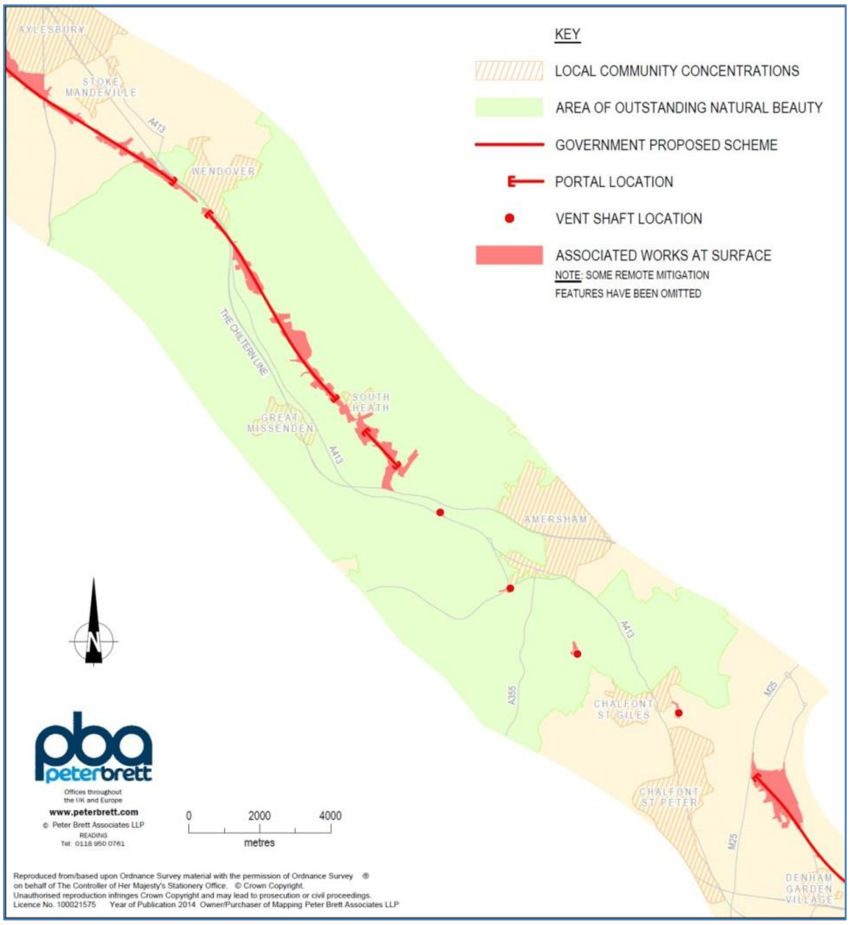
Report Summary

Peter Brett Associates LLP (PBA) was commissioned by Chiltern District Council, in association with its statutory partners Aylesbury Vale District Council, Buckinghamshire County Council and Chilterns Conservation Board, to consider options for proposing alternative solutions to that being promoted by HS2 Ltd for the section of the proposed High Speed Railway between London and Birmingham where it crosses the Chilterns AONB. PBA worked together with OTB Engineering Ltd on tunnelling and Beazley Sharpe (Railwise) Ltd on rail alignment and systems to develop alternative tunnel alignments and prepare the study.

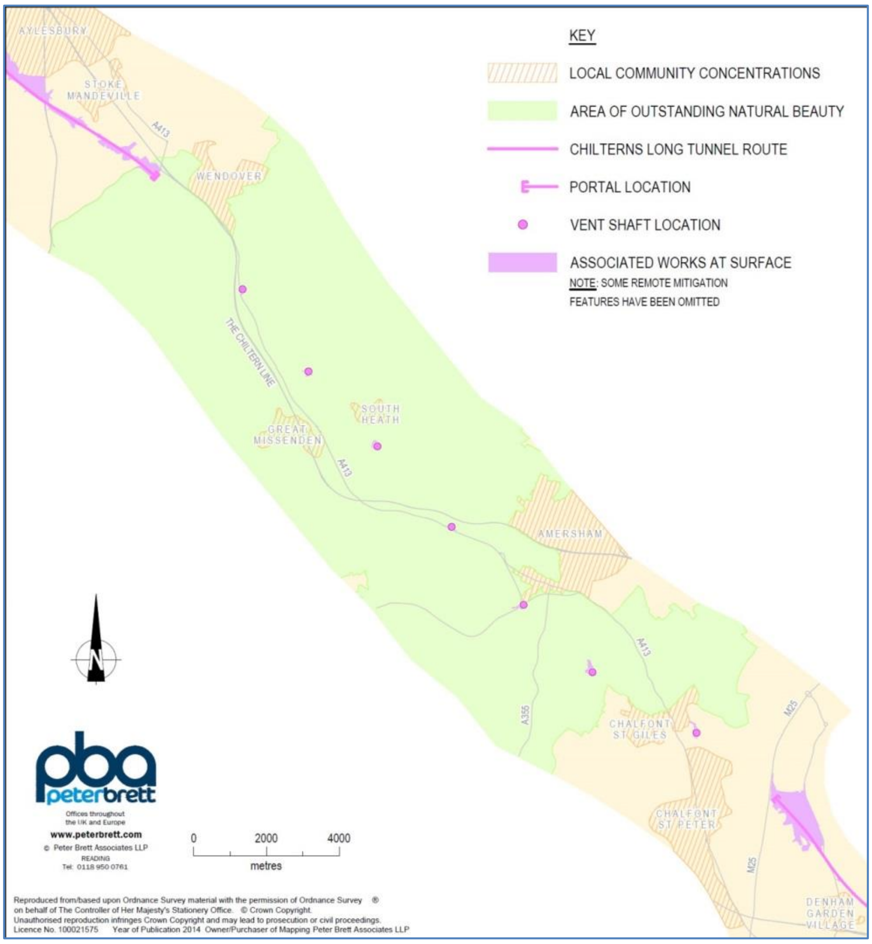
The main conclusion from this study is that a long tunnel for the transit of the Chilterns by HS2 is technically feasible and protects the designated landscape of the Chilterns AONB and Green Belt where appropriate. The second conclusion is that it is a better alignment.

The proposed route of HS2 bisects the county of Buckinghamshire diagonally across its length for 60km from south east north-west; about one third of the total route between London and Birmingham. Bucks is the county most adversely affected by HS2 and the route crosses under and over the Chilterns AONB, nationally designated for its outstanding natural beauty and one of England's finest landscapes. The route of HS2 cuts across this beautiful and distinctive Chilterns landscape: it severs irreplaceable ancient woodland, dissects nationally important historic landscape, detaches heritage assets from their rural setting and disrupts intact medieval landscape and areas of great biodiversity value. The HS2 has no tangible benefits for people or place in Bucks. The proposals presented in the HS2's Environmental Statement are generic, and fail to respond to the unique pattern and subtlety of the Chilterns AONB landscape and the six designation criteria. In contrast, this report demonstrates how HS2 can be integrated into and not imposed on this protected landscape.



The design of the government's Proposed Scheme, illustrated above, takes no obvious account of the designated landscape of the Chilterns AONB and the application of the six designation criteria.

The protection to the AONB and the Green Belt afforded by the Chilterns Long Tunnel Route illustrated below extends almost to the northern boundary with only minor interruptions for ventilation shafts and other access arrangements. The position of the north portal, which ideally should be situated north of Nash Lee Road is dictated by the topography and the levels needed to cross man-made and natural physical features further north. However, it can be seen that not only does the proposed Chilterns Long Tunnel Route offer a more balanced vertical alignment and avoid impacts upon Great Missenden, South Heath and Wendover but also provides a slightly smoother horizontal alignment, taking advantage of being a specific tunnel route alignment, rather than a suppressed surface alignment in the vicinity of Wendover, which is far more determined by surface features, habitation and interfaces with other infrastructure.



Between the divergence point at Little Missenden and the re-convergence north of the Chiltern scarp, the proposed Chilterns Long Tunnel Route is marginally shorter than the government's Proposed Scheme (approximately 100 m) and the smoother horizontal alignment, requiring less cant to sustain the operational speeds, should provide a more economical operational and maintenance railway.

There is further capacity to improve and modify this proposed Chilterns Long Tunnel Route, during design development to Approval in Principle, at which stage detailed transitions will be confirmed and minor alignment adjustments inserted to address any environmental noise and vibration impacts upon potentially sensitive receptors. This will ensure that the least impact and optimized alignment is identified and developed. Particular benefits can be gained by introducing slight variations to the two tunnel alignments, such that they provide convergence into the fire fighting point and significantly reduce the overall width of these elements. A similar 'wineglass' effect was used to manipulate Crossrail tunnel alignments to avoid conflicts with other infrastructure around the Royal Oak Portal and although the rate of convergence and re-divergence will be much flatter than was applied to Crossrail, the benefits of closing the tunnel centres in this way are that there is very limited length over which the bores have less than one diameter separation.

For the northern portal, the natural alignment and a stagger in the curves assists this convergence. It is also considered feasible to use this stagger to facilitate a leaky portal structure, landscaped and masked from Wendover but able to create pressure relief openings in the south west face of both tunnels before solid separation structures are needed.

In railway design and operational terms, whilst new to the UK, underground intervention facilities with inclined road tunnel access are provided in other countries, where long tunnels are a necessary feature to penetrate natural mountainous barriers. Examples of such facilities can be found in new and under-construction Alpine tunnels and in the new railway tunnel providing a fast by-pass route into Oslo. The Chilterns Long Tunnel Route has been developed to support a suitable location for such underground intervention.

In the event that an underground fire fighting point is not accepted, the length of the alternative intervention gap, at approximately 1km, may also support the provision of sufficient length of parallel straight to offer a location for emergency cross-overs; such that maintenance or perturbation management would facilitate limited single-line working in any one of the four bored sections, and would mean that the impact of planned or emergency maintenance could be reduced from that incorporating full track occupation between access cross-over south of the M25 and cross-over provision in the Stoke Mandeville area.

Summary comparison table of routes within AONB

Aspects	**Government's Proposed Scheme**	**Chilterns Long Tunnel Route**
Tunnel	2 green tunnels (approx. 1km each) 1 bored tunnel (13.2km)	1 continuous bored twin tunnel of 24.2 km
Portals	6	2
Vent Shafts	4	7
Viaducts	2	0
Underground fire fighting point	0	1
Properties demolished	19	0
Length at Surface in AONB (21km)	8,870 m	405 m (Ventilation Shafts and North Portal)
Area of Surface Disturbance (including construction areas)	419 Ha	47 Ha

Aspects	Government's Proposed Scheme	Chilterns Long Tunnel Route
Total waste volumes for CFA9 and 10		
Excavation Arisings	12,082,769 tonnes (ES Vol 2 CFA9 and 10)	3,240,000 tonnes
% to Sustainable Placement / Landfill in AONB	1,930,000 tonnes (South Heath)	0
Demolition Waste	22,972 tonnes	0
% to Landfill	10% (2,297 tonnes) – assumed	0

The government's Proposed Scheme includes a Maintenance Loop to the north of the AONB boundary. This is deemed to be required to provide for operational maintenance trains, normally based at the proposed Calvert Infrastructure Maintenance Depot to be deployed in preceding closed periods to await access to the section southwards to London once the last train of the day has passed, or to return to before the first train comes through. The loop can also be used to hold failed passenger trains and transfer passengers to minimise journey disruptions. The Chilterns Long Tunnel Route retains this opportunity but it is noted that a tunnel based, slab-track format will generally require less maintenance and fewer, shorter trains than a ballast track system, in which case, the need for this maintenance facility could therefore be reviewed.

The flatter and smoother alignment also offers better operational conditions when considering power consumption and maintenance of infrastructure over the whole life of the scheme.

The government's Proposed Scheme will result in:

- The loss of extensive Ancient Woodland;
- Destruction of a Scheduled Ancient Monument;
- Severe impacts on the landscape and visual aspects;
- The loss, severance and degradation of biodiversity features;
- Extensive landtake around the route of approximately 400ha of land within the AONB;
- The use of a large tract of productive farmland for the disposal of over 1 Mm^3 (about 1.9 million tonnes) of surplus soil ('sustainable placement')
- The placement of about 0.5Mm^3 (about 1M tonnes) in the area of the South Heath Green Tunnel constitutes a further major landfill which is not required for engineering or landscape reasons; and
- A number of dwellings will be lost and many more will still be affected by the construction and operation of the railway with ongoing noise effects.

In contrast, the Chilterns Long Tunnel Route will result in:

- No houses demolished;
- No landfilling of surplus soil;
- Minimal disturbance to the irreplaceable and tranquil AONB;
- Minimal impacts on communities, businesses and residents.

It is estimated that the Chilterns Long Tunnel Route option would be broadly similar to the Governments proposed scheme in terms of construction programme.

The potential for selecting an alternative route more suited to tunnelling the whole length through the AONB has not previously been examined, other than by Arup in January 2012. This study considers alternative alignments for the railway should a tunnel solution be adopted.

It can be concluded therefore that the Chilterns Long Tunnel Route remains a viable alternative to the government's Proposed Scheme with little impact on programme and a cost difference which does not affect the business case for HS2.

1 Project Briefing

1.1 Introduction

1.1.1 Proposals for the construction of a High Speed Railway, known as HS2, between London and Birmingham and then to Manchester and Leeds have been developed by the government and its holding company HS2 Ltd, established for the purpose. These proposals have included route selection followed by further design of the preferred route. In 2013, the Environmental Statement was published and the Hybrid Bill prepared for construction of Phase One of the line on this route, incorporating the construction, operation and mitigation measures considered necessary at this stage.

1.1.2 During this period, which has included ongoing consultation with affected parties, the route through the Chilterns Area of Outstanding Natural Beauty (Chilterns AONB) has been promoted as including “extensive tunnelling” in mitigation of the effects of the proposals. However, the 13km bored tunnelling proposed by HS2 Ltd extends from inside the M25 for a distance of 9.5km into the Chilterns AONB. The following 11km within the AONB becomes a mixture of cuttings, embankments, cut and cover structures (“green” tunnels) and long viaducts through a landscape protected by statute.

1.1.3 The designation of the protected landscape of the Chilterns AONB rests on the unique characteristics of its landscape. The design of the government’s Proposed Scheme takes no obvious account of the designated landscape of the Chilterns AONB and the application of the six designation criteria, within the Guidance for Assessing Landscapes for Designation published by Natural England, or the protective provisions of Part IV of Countryside and Rights of Way Act 2000.

1.1.4 The section of HS2 not in tunnel in the Chilterns is also protected for most of its length by Green Belt designation – a strategically and nationally important policy. One of the purposes of Green Belt, highly relevant to consideration of HS2 in the Chilterns is “To assist in safeguarding the countryside from encroachment”. In addition Paragraph 81 of the National Planning Policy Framework goes on to set out examples of how local planning authorities (in this case government) should “plan positively to enhance the beneficial use of the Green Belt” and “retain and enhance landscapes, visual amenity and biodiversity”. This strategic government policy is highly relevant to how HS2 should be designed in this case. The National Planning Policy Framework at paragraph 115 states: “Great weight should be given to conserving landscape and scenic beauty in National Parks, the Broads and Areas of Outstanding Natural Beauty, which have the highest status of protection in relation to landscape and scenic beauty.” The impact of the scheme on the Chilterns AONB itself is especially important and a primary concern.

1.1.5 It has been a concern of Chiltern District Council (CDC) and its statutory partners in this study, Buckinghamshire County Council, the Chilterns Conservation Board and Aylesbury Vale District Council (the Stakeholders) that the bored tunnelling be extended through the whole AONB so that the impacts are almost entirely avoided, whilst recognising that such a tunnel is likely to require ventilation shafts at intervals through the landscape.

1.1.6 The feasibility of constructing the railway in a continuous tunnel through the AONB has been accepted by HS2 Ltd but, as reported in response to previous proposals for a full tunnel by Chiltern Ridges HS2 Action Group (CRAG) and Chiltern District Council they have rejected it on programme and cost grounds. The cost differential between the proposed scheme and a continuous tunnel is based on HS2 Ltd’s own published information; however, this has been questioned because the basis for the costs is unclear and do not take, for example, account of the economies of scale offered by more extensive similar activities. The programme issues can be resolved through more detailed analysis of the design and construction arrangements.

In the context of a major irreversible impact on the landscape relatively marginal differences in construction periods are insignificant.

1.1.7 The government's Proposed Scheme will result in the loss of extensive Ancient Woodland, destruction of a Scheduled Ancient Monument, severe impacts on the landscape and visual aspects, and the loss, severance and degradation of biodiversity features as described in the Report on Non-market Effects of the government's Proposed Scheme (PBA 2015) The works will require extensive landtake around the route of approximately 400ha of land within the AONB. This is for the railway and also for access, construction compounds, associated drainage infrastructure to drain the surface route, 'environmental mitigation' to offset environmental effects, and the use of a large tract of productive farmland for the disposal of over 1 million cubic metres (about 1.9 million tonnes) of surplus soil ('sustainable placement'); the spoil deposit of $0.5Mm^3$ at South Heath is in addition to this. A number of dwellings and other buildings (62 in total) will be lost and many more will still be affected by the construction and operation of the railway with ongoing noise effects, once the line has been constructed, in an area otherwise unaffected by such a major transport artery.

1.1.8 In addition, the potential for selecting an alternative route more suited to tunnelling the whole length through the AONB has not previously been examined, other than by Arup in January 2012. The proposals by others, notably Chiltern Ridges Action Group (CRAG) so far have all been on the published route which was originally designed to be a surface railway. This study considers alternative alignments for the railway should a tunnel solution be adopted to provide the most beneficial solution for construction and operation, free of many of the constraints imposed by a surface railway.

1.2 The reasons for undertaking this study

1.2.1 Most infrastructure programmes or projects impact on the urban or rural landscape in which they are placed and on the people within them. Linear, dispersed or single location programmes or projects all have impacts but in different ways. Linear ones, for example railways, will always impact more because the perimeter length in proportion to the whole is greater than in the case of those in a single location.

1.2.2 The Stakeholders have not accepted the role of commissioning this study lightly. It has done so because the government is considering the imposition of a major linear infrastructure project across the widest part of the Chilterns AONB. The basis of the Stakeholders' argument is that the current government proposals militate rather than mitigate the impact. It is not the purpose of this report to pass judgment on either of these approaches but to draw attention in an evidence-based and objective way to the consequences of the Government's approach in this case and to provide what the Stakeholders consider as being a better proposal.

1.2.3 The report serves three purposes. They are:

- to confirm to the Stakeholders that the Chilterns Long Tunnel is a sound practical proposition which mitigates the effects of the government's Proposed Scheme and to illustrate its main characteristics;
- to provide the Hybrid Bill Select Committee, government and HS2 Ltd with the technical details of the Chiltern Long Tunnel, the genesis of its development, and the nature of the underlying geology and hydrogeology, as well as the manner of construction; and
- to encourage a much wider debate, including environmental considerations, to support these alternatives.

1.2.4 The need for considering an alternative has been the result of concerns about the appropriateness of the route proposed by HS2 Ltd, whether a continuous tunnel should be adopted and whether an alignment for a tunnel could be developed that was better than the government's Proposed Scheme, considering all the various factors that will influence its design. The options presented in this report take these into account.

1.3 Scope

1.3.1 In the initial feasibility report High Speed Rail in the Chilterns: Feasibility Study of Alternative Tunnelling Options (Peter Brett Associates, April 2014) (PBA, April 2014), two alternative horizontal alignments, out of four considered, to that currently proposed by Government of the route of High Speed 2 across the Chilterns AONB were initially presented for comparison to three reference alignments based on the government's Proposed Scheme. This was done in terms of railway functionality/operability, broad environmental impact, and constructability. One of the alternative alignments (the 'Green Route') was then considered in more detail.

1.3.2 This is the final report on a feasibility study to establish the engineering and economic case for a continuous tunnel through the Chilterns AONB to carry the proposed high speed railway. Peter Brett Associates LLP (PBA) was commissioned by Chiltern District Council to consider options for proposing alternative solutions to that being promoted by HS2 Ltd. PBA worked together with OTB Engineering Ltd on tunnelling and Beazley Sharpe (Railwise) Ltd on rail alignment and systems to develop alternative tunnel alignments taking account of environmental factors and prepare the study.

1.3.3 Most importantly this study takes account of the proposed changes to the safety requirements of long railway tunnels requiring an accessible firefighting Point (at 20km intervals rather than an Intervention Gap open to air. This fire fighting point can be underground with emergency surface access points and evacuation of passengers to a safe area.

1.3.4 In avoiding those impacts it considers further options closer to the government's Proposed Scheme. The Chilterns Long Tunnel Route was developed as a clear preference given its low impacts on landscape and previously unaffected residential properties and commercial business operations.

1.4 Reference options

1.4.1 In this study the government's and HS2 Ltd's proposed railway alignment, which is part tunnel and part surface route, is referred to as the 'government's Proposed Scheme'.

1.4.2 The alternative railway alignments considered in the previous feasibility report (PBA, April 2014) have been discarded as a result of this work, and the relative route lengths of the railway through the Chilterns affected by this study are set out in Table 1.1, representing the distance between the points on which the alignments deviate from the government's Proposed Scheme.

Table 1.1 Railway routes considered in this study

Route	Start (Southern Portal)	Finish	Route Length
Government's Proposed Scheme	M25	North of Stoke Mandeville	25.9 km
Chilterns Long Tunnel Route	M25	North of Stoke Mandeville	25.8 km

1.4.3 This feasibility study adopts a balanced engineering based approach to evaluating new alternative railway alignments for a continuous tunnel through the Chilterns AONB close to the government's Proposed Scheme, with a southern portal at the same location as the London Portal and a northern one near a location at the northern end on the government's Proposed Scheme at Nash Lee Lane, Wendover.

2 Study Programme

2.1.1 The initial feasibility study for considering route alternatives was commissioned in February 2014 by Chiltern District Council, supported by Aylesbury Vale District Council, Buckinghamshire County Council and the Chilterns Conservation Board. Collectively these bodies are the Employer in terms of this report. A report, High Speed Rail in the Chilterns: Feasibility Study of Alternative Tunnelling Options (Peter Brett Associates, April 2014) proposing the Green Route was issued in April 2014.

2.1.2 This report is for a revised feasibility study was commissioned in September 2014, by the same Employer, and describes the results of the updated work undertaken, describing the alternative alignments examined and evaluates it against the government's Proposed Scheme and the preferred option identified from the initial feasibility study.

Progress of the Study

2.1.3 Meetings and communication have been held with the Employer's Agent at regular intervals and other feedback from the Employer during the study period has assisted in determining the optimum railway alignment.

2.1.4 The drawings included in this report reflect this feedback and other design developments as the scheme assessment progressed.

3 Route Selection

3.1 Introduction

3.1.1 In developing the railway alignment for a continuous tunnel solution, consideration has been given to the applicable railway alignment standards and system requirements in the context of:

- Operation of the railway;
- Construction methods and logistics;
- Topography and landscape;
- geology;
- hydrogeology; and
- suitability.

3.1.2 Furthermore, the built environment has also been taken into account, recognising:

- the large and small urban and rural settlements distributed along the valley and at each end and also individual but important properties and businesses;
- the A413 highway; and
- the Chiltern Line railway.

3.1.3 In considering some of the details of the route design, the location of Ancient Woodland and Listed Buildings that could be affected by the selected route were determined and these have influenced some of the refinements to the route as it has been developed.

3.1.4 The initial assessment (PBA April 2014) considered four different routes to the Government Proposed Scheme. This report considers a further option. Particular elements in the design of the initial routes were the intervention gap required to satisfy safety requirements and the location of the north portal near Wendover.

3.1.5 This report considers the location of a fire fighting Point which is required as a result of the recently adopted change to the TSI requirement for some form of safety measure if the tunnel extends beyond 20 km between portals. Therefore, in order to satisfy the safety requirements in a long tunnel as proposed by the Chilterns Long Tunnel Route, an option for an underground emergency facility as the necessary fire fighting point has been proposed. The need for a safety measure is described further in Section 4 - Railway Alignment and Systems.

3.1.6 In addition, the tunnel will also require ventilation shafts to the surface at nominally 3km intervals. The position of these shafts is influenced by topography, surface features and the road network, and setting in the landscape.

3.1.7 The broad environmental impacts associated with the construction of a major linear infrastructure project, and, in particular noise and vibration during construction and operation, have been taken in to account in selecting a preferred route as well as considering the more specific impacts of the route where it runs on the surface to rejoin the published HS2 alignment.

3.2 Railway route alignment description

3.2.1 The evaluation undertaken during the initial feasibility study process and the response to that study reduced the options for further consideration and comparison to the one alternative route alignment, called in this report the Chilterns Long Tunnel Route. The alternative railway alignments considered and the key elements of those alignments are set out in Appendix E. Key features at the surface and below ground on the alignment of the Chiltern Long Tunnel Route are shown on PBA Drawing 30067/001/017 & 018.

3.2.2 In summary, it can be described as follows: Chilterns Long Tunnel Route – following the government's Proposed Scheme under the River Misbourne through Chalfont St Giles and under Shardloes Lake. While following the horizontal alignment of the government's Proposed Scheme to the north of South Heath it runs at a flatter gradient (less than 1%) and hence at a greater depth (up to 88m) and reaching a summit level of 118m AOD near the A413 near The Firecrest in Wendover Dean before descending to the North Portal near Nash Lee Road and rejoining the government's Proposed Scheme horizontal alignment about 1km south of, and the vertical alignment about 1km north of, Stoke Mandeville.

3.2.3 This route alignment has been the subject of a more detailed evaluation compared to the government's Proposed Scheme.

4 Railway alignment and systems

4.1 Geometry

4.1.1 The horizontal and vertical alignment of the alternative Chilterns Long Tunnel Route meets the requirements for the design of tunnels and high speed railways as set out in the relevant EU Technical Specifications for Interoperability (TSI) and other applicable standards.

4.1.2 Some further refinement will be needed on the selected route alignment to confirm adherence to specific standards related to transition curves, interaction between curves and lengths of gradient, where the gradients approach the recommended maximum. These refinements will not change the fundamental locations of the indicated routes significantly and for the Chilterns Long Tunnel Route there will be few, if any, necessary changes to the outline vertical alignments.

Speed

4.1.3 The requirement to provide a railway that allows train speeds of up to 320kph in tunnels and 400 kph on the surface imposes restrictions on both the vertical and horizontal alignments. The horizontal and vertical radii limits to achieve the necessary operational speed mean that the potential for avoiding every feature on any particular alignment constrains the options available. These requirements can be better delivered by the proposed Chilterns Long Tunnel Route.

Safety

4.1.4 The EU Decision: Technical Specification for Interoperability on safety in railway tunnels on conventional and high speed rail systems (TSI 2008/163/EC), required some form of safety measure if the tunnel extends beyond 20km between portals. A twin bored tunnel extending the full width of the Chilterns through the Misbourne Valley will be in the order of 25km long and, therefore, this safety measure will be required. This could take the form of a third bore for escape, as is provided in the Channel Tunnel for example. It has complex fire control measures and dedicated safety and rescue infrastructure or alternatively the form of an underground emergency station as in the Gotthard Base Tunnel. A simpler alternative option has been considered.

4.1.5 A stopping point within 20km of either portal with access to the surface from the full length of a train and accessibility for emergency vehicles may be deemed to be an acceptable form of safety measure. This is called an ‘intervention gap’ and is the solution adopted in the design of the alternative tunnel alignment referred to in paragraph 1.3.1. However, improved fire and emergency access, with passenger escape facilities may be sufficient even for tunnels over 20km. The current HS2 proposals incorporate specific fire service access at all shafts and cross-passages at frequent intervals. The vertical alignment proposed for the Chilterns Long Tunnel allow for 0.2% (1 in 500) gradients around the proposed alternative locations for an underground intervention point, located at a tunnel nadir, such that a failed train might coast to this location and the length of any adjacent escape chamber (located between the two bores) will facilitate rapid exit of all passengers from any failed train and concurrent access for emergency services.

4.1.6 However, TSI 2008/163/EC, which sets out these requirements, was superseded on 1st January 2015 by TSI 1303/2014 concerning the technical specification for interoperability relating to “safety in railway tunnels” of the rail system on the European Union. A requirement in the new TSI is to provide a fire fighting point at a maximum 20km interval. The fire fighting point can be underground with means of access for emergencies and egress to safe areas and to the surface for evacuation of passengers. It is this requirement which forms the basis of the proposed Chilterns Long Tunnel Route.

4.1.7 The Chilterns Long Tunnel Route provides two locations where a TSI compliant fire fighting point might be provided. These are at Little Missenden, at the location currently proposed as a vent shaft location by HS2 (Little Missenden Ventilation Shaft) at approximate chainage 43.000 km, or at the proposed Wendover Dean Ventilation Shaft at approximate chainage 51.750 km. The potential general arrangement of the fire fighting point and the specific location at Little Missenden is shown in Figures 4.1 - 4.2. This is discussed in detail at paragraph 5.4.33.

Figure 4.1 Illustrative Arrangements for fire fighting point

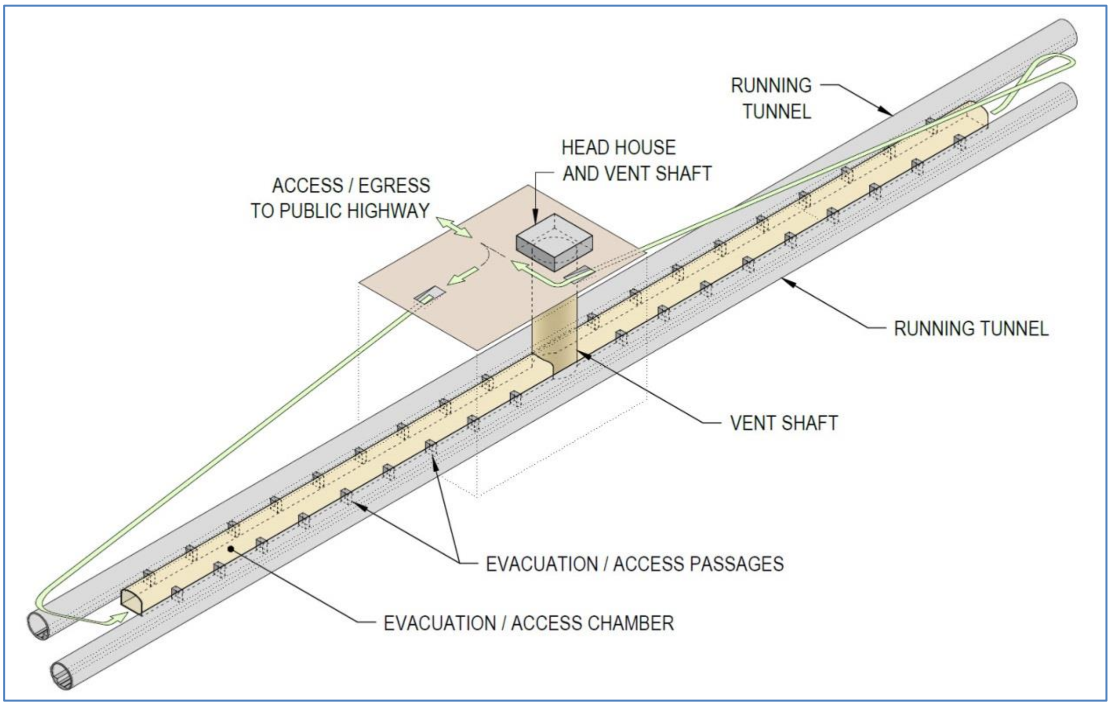
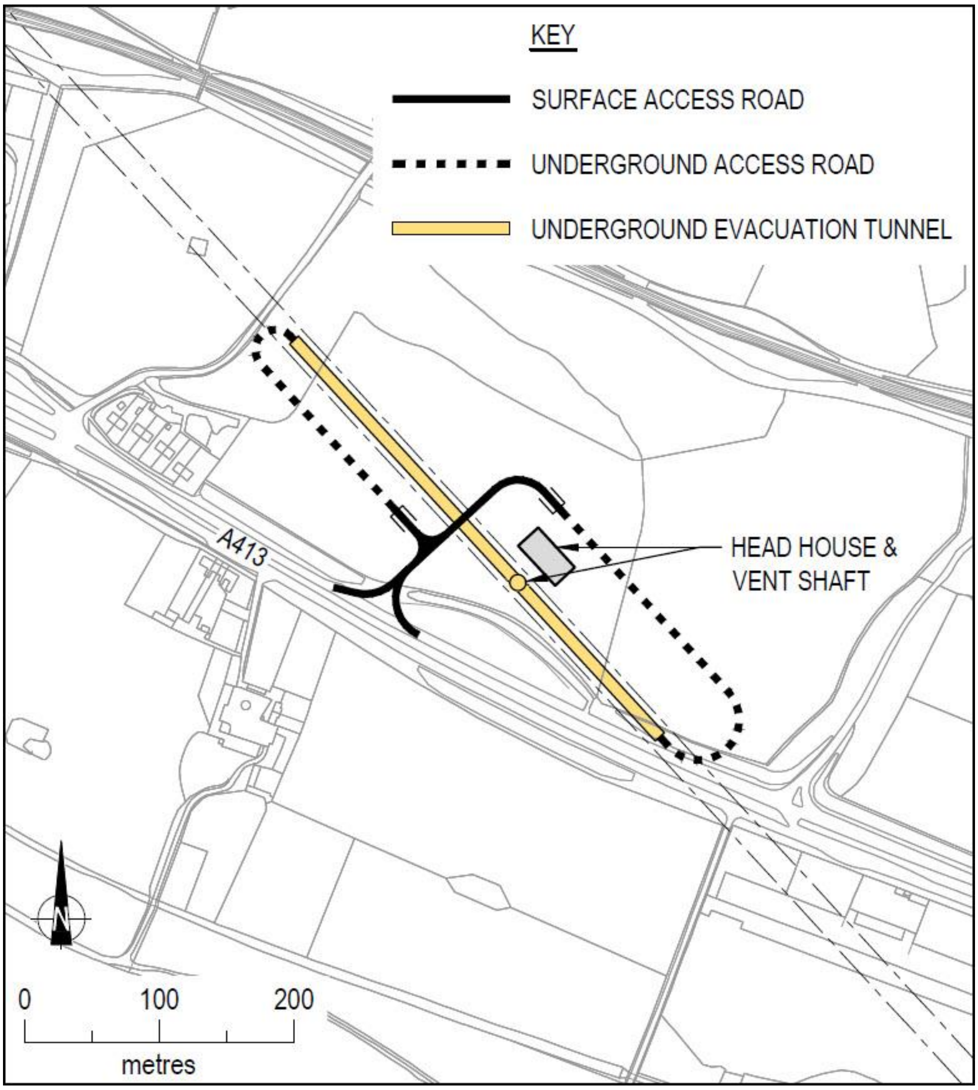


Figure 4.2 Indicative fire fighting point at Little Missenden Ventilation Shaft



4.1.8 Regular provision of cross passages and shafts in the tunnel clearly mitigates the evacuation risks and the plans for vent shafts to have sufficient equipment to be considered intervention shafts could make specific provision of a fire fighting point less necessary. The suggested layout also avoids the aerodynamic effects of widening the tunnel bore for this facility. The construction arrangements for this facility are described in paragraph 5.4.33 onwards.

4.1.9 Whilst the location of the fire fighting point does not interfere with normal operations, the position is influenced by potential emergency procedures. It seems logical to assume that a more central location for the fire fighting point will offer the most flexibility and effectiveness rather than one which is situated nearer one end of a long tunnel. In this regard, the Little Missenden location appears preferable as it is also situated close to a major centre (Amersham) for emergency fire fighting teams and is adjacent to a dual carriageway with wide central reserve. Further consideration to this is given in Section 6 with respect to tunneling strategy and programme.

Portals

4.1.10 The proposal for the northern portal on the Chilterns Long Tunnel Route as shown in Figure 4.3 below falls close to the AONB boundary with a shallow cutting passing under Nash Lee Road.

Figure 4.3 Illustrative North Portal General Arrangement

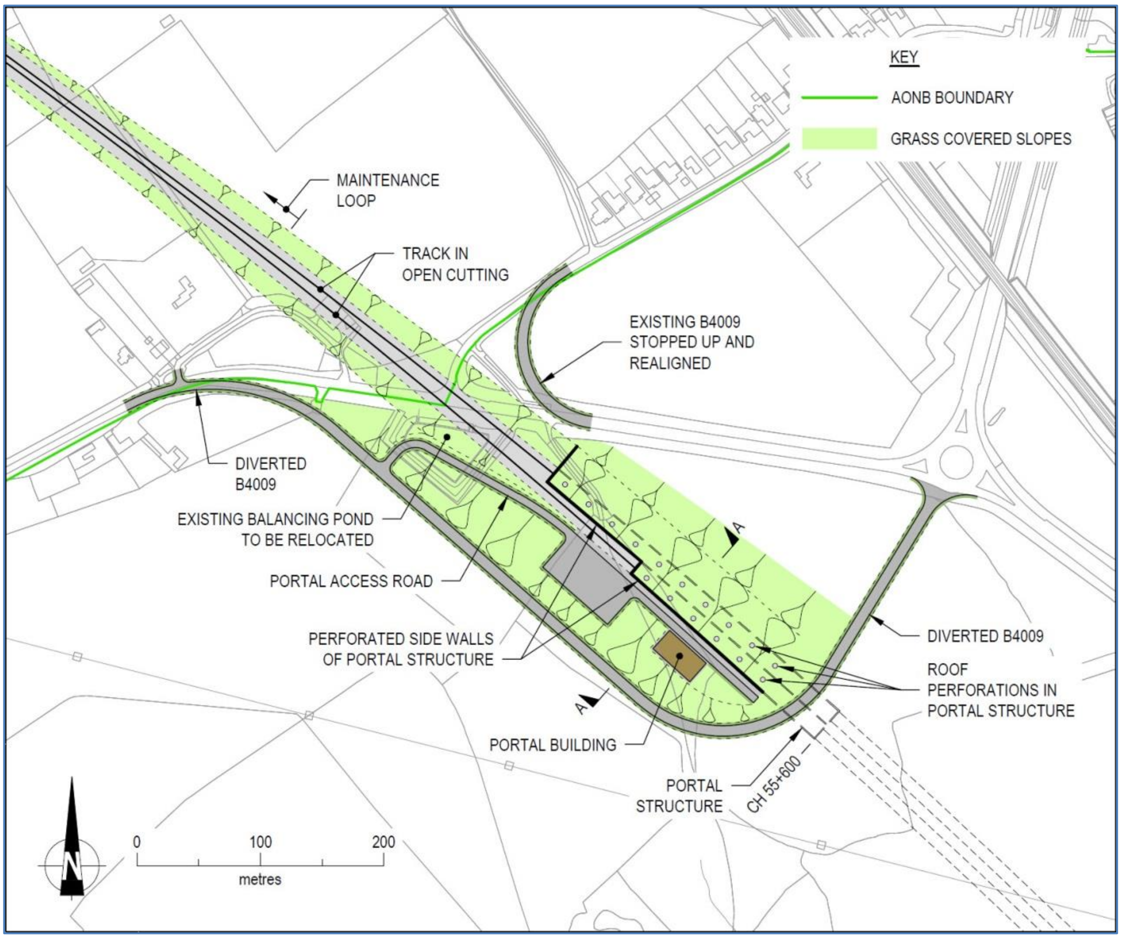
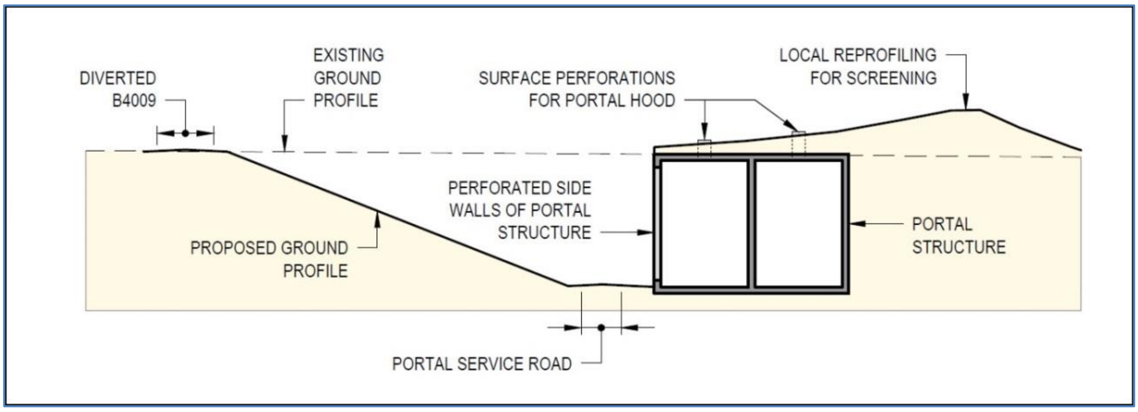


Figure 4.4 Illustrative North Portal Cross Section – facing north



4.1.11 The portal location allows the proposed Chilterns Long Tunnel Route alignment to tie into the government's Proposed Scheme north of Nash Lee Road, before entering the long straight of about 2km. The portal location has the potential to be masked and blended into the landscape by a short cut and cover tunnel, as shown by Fig 4.4, and such a design will also provide the necessary 'leaky portal' pressure and ventilation functions to mitigate noise and train speed issues. The alignments between the northern portal and current HS2 straight quickly converge to close the track centre spacing from the bored tunnel alignments to the 5 m track spacing used on the HS2 surface routes.

Track formation

4.1.12 The ‘ideal’ vertical alignment of one peak in the middle (i.e. a summit at Wendover Dean) and falling to both ends is not possible due to the approach level of the government’s Proposed Scheme (up to the south portal at chainage 31.500,) as it crosses the Colne Valley on viaduct, and having to pass under the River Misbourne at Chalfont St Giles and Shardloes Lake. Nevertheless, there are robust drainage reasons for incorporating slight undulations with nadir sumps situated at ventilation shafts. The introduction of an underground fire fighting point will most likely require a section of flat gradient (not exceeding 0.2%) at the fire fighting point but as this would be underground, it would remove the need to climb to surface for an open-to-air ‘intervention gap’.

4.1.13 Good slab track construction progress in tunnels need not take any longer to install than the conventional formation, drainage, sub-ballast and ballasted track construction along an end-fed section of ballasted track. All this work will take place through the tunnel rather than travelling on the surface roads in the Chilterns AONB, which will minimise environmental impacts along the route.

4.1.14 The government’s Proposed Scheme will revert to ballasted track outside of the tunnels and viaducts. This will result in isolated sections of ballasted track and the need to convey ballast maintenance plant and material through tunnels to reach these isolated sections and result in regular noise from overnight maintenance activities to maintain the necessary track line and level for the design speeds. The proposed longer tunnels will remove this requirement ensuring inspection and maintenance consistency and minimization throughout the Chilterns AONB and south of the South Portal on to the Colne Valley viaduct and Northolt Tunnel.

4.1.15 There is both empirical and some recorded evidence of maintenance cost benefits that result from installation of ballastless track (as in tunnels) and conventional ballasted track (as in the open). A properly designed ballastless track system will provide a much longer life than a ballast track system, particularly if the design follows engineering principles that are now being incorporated into new Eurocodes for ballastless track structures, which are currently in draft.

4.1.16 Further to this, Dr Coenraad Esveld states in 'Modern Railway Track' 2nd Edition; 2001:

- Long term experience with slab track has shown that these requirements (Quality control requirements) result in a very good track quality directly after construction as well as over many years, as there is hardly any maintenance required.
- From the experience with ballastless track on high speed lines, it is obvious that slab track systems require hardly any maintenance and provide high availability.
- The lasting good track-quality throughout the periods observed does not only guarantee a minimum requirement for maintenance, the improved driving-comfort for the passengers as well as the highly available track have proven to be benefits of slab track.
- Experience with maintenance of slab track goes back to 1972 (in Germany).... in general the maintenance work was restricted to changing the synthetic rail pad.
- Compared to ballasted track, failures like dents near welds or near (insulated) rail joints will evolve considerably slower .... The cost of maintenance .... is approximately only 10% of the cost involved with ballasted track.
- Maintenance costs in Japanese experience amount to 20-30% of the costs involved in the case of ballasted track and yet had a better quality track geometry and alignment.

4.1.17 These are important aspects to consider in the whole life maintenance cost of HS2, particularly in this section through the Chilterns, where a slab track in tunnel will require fewer maintenance interventions.

Operation

4.1.18 Recent weather events have demonstrated that overhead line equipment in open, high ground is vulnerable to extreme winds. Prevailing winds are generally from the west, so the Chilterns Long Tunnel Route will replace some of the exposed areas of embankment and viaduct that are inherent in the government's Proposed Scheme. The tunnel route will also provide protection to overhead line equipment and also other railway systems infrastructure and provide a protected site whenever maintenance is required. Semi-automated video-based inspection methods are already deployed on HS1 (High Speed 1) and are well suited to standardized ballastless track systems, such as those that could be expected within the tunnels. These inspections can be carried out at higher speed than traditional inspections and will not be subjected to weather-related problems. Rail thermal stress variations will be significantly less within the tunnel and the risks of buckling and rail breaks due to excessive tensile stress will be greatly reduced.

4.1.19 Certain structures and fixtures are much smaller and simpler to install and maintain as the tunnel itself provides the structure upon which to fix equipment. A tunnel will also minimize the incidence of blown vegetation debris on to the line. Such debris is considered a risk and requires regular removal to keep the line safe and operable.

4.1.20 Tunnel tracks are no less safe than open tracks. Indeed, if slab track (where the track is cast into or fixed onto a concrete base rather than ballast) is used with any derailment protection and in a single bore, the removal of potential train-train impacts will remove such risks. The tunnel is designed for a slightly lower train speed with possible reduced risks and reasonably constant environment with no exposure to extreme weather or errant vehicles. Safety and security in a tunnel is thus better controlled than a surface railway.

4.2 Aerodynamic considerations and power consumption

4.2.1 Aerodynamic considerations that need to be taken into account in considering the effect of the tunnel include:

- Design line speeds of 320kph in bored tunnels, 360 kph in cut & cover structures and 400 kph through all other sections of the government's Proposed Scheme (although maximum operating speed is expected to be 360 kph).
- A free area of 56.0 m^2 in bored tunnels, leading to an internal diameter of 8.8 m;
- A tapering length of porous portal (hood) at each portal site to increase the local free area by 50% at the point of exit to the open area; and
- The current length of the portal structure is 100 m in the Interim Preliminary Design although for the Northolt Tunnel it is understood that 200m has been adopted.

4.2.2 These criteria are delivered by the railway designs and associated tunnel structures for the Chilterns Long Tunnel.

4.2.3 The exact location of ventilation shafts along the tunnel is dependent upon the criteria adopted by HS2 Ltd and the land form, other environmental considerations and access requirements.

4.2.4 These criteria have been addressed and met, or are capable of being met when the more detailed transition alignments are developed, for the Chilterns Long Tunnel Route.

4.2.5 The introduction of any additional underground caverns might have significant impacts on the aerodynamics within the tunnels which need to be considered in detail design. The Chilterns Long Tunnel proposal anticipates that any underground intervention will be more likely achieved by minor adjustments to the horizontal alignment, to slightly increase the spacing of the bores to allow for a common intervention chamber, between the two bores and connected by conventional cross-passages at close centres, as indicated in Figure 4.1 above. There will be no widening of the tunnel to accommodate a wide platform, thus avoiding aerodynamic effects.

4.2.6 There has been concern that the energy consumption in a tunnel is significantly more than that in the open, due to both head and tail resistance and the skin-friction drag within the bore. It is true that aerodynamic resistance is a major factor in determining the traction power requirement. In total, overcoming the combined aerodynamic resistance (on a level gradient in the open) requires approximately 75% of the traction energy consumed by the train. This increases by approximately 10% in tunnels. The generally selected tunnel diameter is sized for the trains to mitigate aerodynamic effects and the magnitude of transient pressures for the design speed proposed.

4.2.7 In contrast on the surface the effects of wind speed have to also be considered, especially in open, exposed situations such as embankments and viaducts across the Chilterns. These wind effects, especially cross winds, which do not occur in the tunnels, also put overhead electrification wiring at risk, where vehicle drag, sway and wind effect drag on the catenary and traction wires and can lead to accidental de-wirement (removal of electrified and/or catenary wires) .

4.2.8 Where significant gradients are encountered, a substantial proportion of the increased energy demand is required to raise the mass of the train up the total height gained. Energy is also lost due to wheel slippage and this is more likely to be a feature of exposed track, with steeper gradients than the tunnel track clear of the portal zones, where weather and debris effects can also impact upon traction.

4.2.9 Therefore, with a maximum grade of only 1% rather than 3% and in stable tunnel atmosphere, the traction effort is likely to be far more efficient in the Chilterns Long Tunnel than in the open sections of steep gradient on the government's Proposed Scheme. It is also probable that the power consumption to gain the necessary rise to the summit of the Chilterns Long Tunnel route (approximately half that of the government's Proposed Scheme), will be approximately 50% of that consumed on the government's Proposed Scheme over this section of track.

4.2.10 Steep gradients involved in the government's Proposed Scheme are partially within the tunnel but largely in the open air and green tunnels. The steepest, at 3%, which is a steep gradient for a railway, also requires additional braking effort. These gradients will generally exceed the balance gradient down which a train can coast (that is free-wheeling without requiring additional traction energy). To avoid over-speeding it is necessary for the train to brake and whilst some of the braking energy can be re-captured if regenerative braking systems are employed, in the tunnel section the heat generated will increase the tunnel temperature and therefore there is an increased demand on the ventilation requirement to cool the tunnel. The steepest gradient also passes through the tunnel portal area and will therefore also create additional risk of contamination being drawn into the bore and increasing the risk of wheel slippage, further increasing the energy requirement to climb this gradient on the government's Proposed Scheme.

4.2.11 For the Chilterns Long Tunnel Route, the up and down gradients are much shallower and the steepest gradients are not located at the portals. This, coupled with the greatly reduced demand to reach the summit and shallower down gradients that will not require the same braking demand, is likely to outweigh any additional energy demand from aerodynamic drag in order to maintain line speed. This is also referred to in paragraph 4.2.6.

4.3 Maintenance sidings

4.3.1 Should the proposed Chiltern Long Tunnel be adopted, then the total length of non-ballasted track between the northern portal structure at Nash Lee Road and the London terminus at Euston will increase significantly and given that the remaining areas of ballasted track will be relatively short, interrupted by the Colne Valley Viaduct and therefore isolated, it may be more economical in the long-term (considering the whole life of the railway), to construct all track south of the Stoke Mandeville Maintenance Loop (chainage 57+000) as non-ballasted track. In that case and possibly even with some ballast track located south of Stoke Mandeville, it is questionable whether a full maintenance siding loop, which is based upon conventional ballast track maintenance demands, is actually best located so far south on the HS2 route. The need for such regular maintenance will be much reduced. The secondary need, using the loop to stable a defective train would also be accommodated on this potentially shorter length as the trains are a maximum of 400m long

4.3.2 Based upon the routine maintenance of High Speed One, maintenance inspections and some intervention maintenance is carried out with Multi-purpose Vehicles (MPV) that can rapidly inspect, record and identify defects along the track and catenary sections. Also, for slab-track systems there is only rare requirement to carry out major structural replenishment and maintenance tasks tend to be routine inspection, grinding and replacement of worn sections of rail. The MPVs and rail grinders require much less extensive sidings than ballast trains, ballast tampers and conventional track maintenance re-laying trains.

4.3.3 Even if the full Stoke Mandeville siding loop is required, such as to avoid the need for maintenance trains or MPVs to travel past settlements south of Calvert Infrastructure Maintenance Depot (IMD) late at night, the transition designs and adjustment to the horizontal alignment to achieve the closer track separation, along with appropriate turnout designs, could accommodate the anticipated 850 m length of loop shown on the scheme plans. Whilst straight track is a normal requirement for the location of the turnouts, if this cannot be achieved and the full length of siding loop is required, it is not impossible to accommodate the turnouts on curves and it is also possible to accommodate relatively flat curves within the plain line length of the siding, between the switches; this will be a matter of detailed design.

4.4 Track and tunnel alignment comparisons

4.4.1 Referring to drawing 30067/001/18 at Appendix D, comparison is made here between the government's Proposed Scheme, shown red, and the alternative Chilterns Long Tunnel Route alignment, shown pink, with the corresponding vertical alignment for each route.

4.4.2 Further detail describing the alternative alignments is discussed in Appendix E.

4.4.3 In operational terms, the Chilterns Long Tunnel Route offers a much more attractive operational alignment than the government's Proposed Scheme, both vertically and horizontally. The vertical alignment in particular, will reduce the power requirements to achieve the summit and allow more coasting as trains pass through the Chilterns, rather than the considerable power to achieve the summit of the government's Proposed Scheme. Furthermore, the actual speeds achieved on the government's Proposed Scheme due to the gradients will make the lower design speed of the extended length of tunnel irrelevant in the context of overall journey time. It is likely that the maximum operational speed of 360km/h on the surface section is unlikely to be achieved whereas the tunnel design speed of 320km/hr can be achieved. The actual differential in transit time between the two will in practice therefore be minimal.

4.4.4 There are some features of the government's Proposed Scheme that push vertical curves and horizontal transitions close together, with the risk that these will actually overlap during detail design or cause speed constraints in order to maintain separation or require the use of maxima design criteria to reduce optimal transition lengths. The alignments of the proposed

Chilterns Long Tunnel Route reduce this risk and it is not envisaged that maxima design criteria or non-compliant overlapping design elements will be necessary to support this route

4.4.5 The loop immediately to the north of the study area, where maintenance trains will be held in readiness for accessing the section of the government Proposed Scheme south into London, enables deployment of maintenance teams as soon as possible once the last train of the day has passed through. The loop is located on a relatively level stretch of line about 1.2 km in length and comprises a pair of lines adjacent to the through lines to allow maintenance trains to stand. It can also be used to hold passenger trains for operational reasons such as a breakdown. However, we note that the current vertical alignment of the loop does not actually meet the HS2 standard, as the gradient exceeds 0.2% (1 in 500).

4.4.6 The alignment of the Chilterns Long Tunnel Route converges with and rejoins the government's Proposed Scheme south of the straight and will therefore allow such a facility to be created. The vertical alignment of the Chilterns Long Tunnel Route has been adjusted to provide the required gradient for any such sidings or loop.

4.4.7 In summary, it can be seen from the proposed alignments, that the Chilterns Long Tunnel Route offers a more balanced vertical alignment and avoids permanent impacts upon Great Missenden, South Heath and Wendover. It also removes the requirement and significant impacts associated with the construction and future operation of the viaducts and green tunnel, by relocating further from Wendover, whilst maintaining a smooth horizontal alignment that emerges close to the existing transport corridor, without compromising the proposed Stoke Mandeville by-pass road. These advantages are achieved by developing a specific tunnel route alignment, rather than adopting a depressed surface alignment.

5 Tunnel Design

5.1 Introduction

5.1.1 This section initially sets out the options available for tunnelling on the Chiltern Long Tunnel Route as well as the construction methods for some of the principal structures for the government's Proposed Scheme. It describes ground movement issues and methods of handling spoil, particularly at the northern portal for the Chilterns Long Tunnel Route. It is expected that issues associated with the southern portal site are accepted and understood by HS2 Ltd.

5.1.2 The section continues with consideration of some of the issues which should be taken into account when evaluating the constructability and durability of the government's Proposed Scheme.

5.2 Anticipated tunnelling conditions

5.2.1 The government's Proposed Scheme and the Chilterns Long Tunnel will encounter broadly the same solid chalk geology. However, the geology will vary considerably according to vertical alignment and to a lesser extent by horizontal alignment and the proportion of each geology type will therefore vary.

5.2.2 The type of Chalk varies with stratigraphy, the broad geotechnical properties of which are described in Appendix B. The tunnels will encounter chalk of varying type and quality. TBMs working from the southern portal will commence their drives in Seaford Chalk and cut down sequence, whereas those working from the northern portal will commence their drives in the West Melbury Marly Chalk and Zig Zag Chalk and cut up sequence.

5.2.3 Those commencing at the southern portal will be in very pure white chalk with flints whereas those commencing at the northern portal will be in calcareous mudstone and limestone with no flints.

5.2.4 The quality of the chalk (C574D - Engineering in chalk: CIRIA 2002; A Lord, C.R.A. Clayton, R.N. Mortimer) will vary according to the lithostratigraphy, depth of weathering (the presence of Palaeogene cover) and the proximity to fault/fracture zones and solution features. The geological sections in Drawings 021 & 022 indicate the likely variation. A wide variety of chalk quality for each chalk type is to be anticipated and this should be planned for in the specification of the tunnel boring machine and materials handling arrangements.

5.2.5 Groundwater occurrence will vary according to the relative elevation of the groundwater table which does vary according to season and rainfall, as well as permeability and transmissivity of the fracture zones. At the northern end the close proximity of the groundwater divide, variability at the interface between strata, weathering and surface topography will influence local groundwater levels and the position of springs.

5.2.6 The type of chalk will vary and will affect how the chalk is processed. The majority of the chalk in any of the tunnels will breakdown to silt due to the application of mechanical action since the majority of the drives are in low to medium density chalk. However, high density chalks will not always be broken down and these will form chips and lumps that will require separation from the slurry using screens.

5.2.7 In summary therefore, at the southern end of the government's Proposed Scheme and Chilterns Long Tunnel Route the geological conditions for tunnelling are the same between the southern portal and the second crossing of the Misbourne Valley at Shardloes Park (in the vicinity of the Little Missenden Ventilation Shaft). However northwards the routes depart in level and also in plan between South Heath and Stoke Mandeville areas. It is the case that the government's Proposed Scheme continues at a shallower level than for the Chilterns Long Tunnel Route. As a result of these departures the Chilterns Long Tunnel Route passes through better and more consistent ground conditions below the water table. This is characterized by relatively flint-free chalk, reduced permeability chalk, mostly below the deeply weathered zones underlying the dry valleys, zones containing solution features and chalk mines and, at the northern portal, avoids extensive unstable slopes. Consequently taking account of the potential for geohazards, the linked impacts upon the surface and the engineering challenges posed, the Chilterns Long Tunnel Route offers many advantages over the government's Proposed Scheme.

5.3 Tunnelling methods

5.3.1 The Chalk, since it is weak rock, is a very good material within which to build tunnels having sufficient strength to stand-up unsupported and soft enough to be easily dug. Bored tunnels have subsequently been constructed with a very wide variety of methods in the UK since the Industrial Revolution. Today, two methods dominate for this type of project and these are discussed below.

Tunnelling Boring Machine (TBM)

5.3.2 Construction of a long tunnel in the Chalk lends itself admirably to the use of a tunnel boring machine. The selection of the type of tunnelling machine depends on the permeability of the chalk, the likely groundwater pressures at the level of the tunnel and the strength/density/ behaviour of the Chalk. For the large diameter running tunnels (ca. 8 to 9 m diameter) it will be appropriate to construct these using closed face slurry tunnel boring machines (slurry-TBM). The feature of these machines is that machine itself is isolated from the ground enabling the tunnel lining to be erected within it and that the chalk is excavated and transported as pumped slurry via a pipeline. It is particularly suited to use in chalk because the rock will tend to break down very easily upon the application of mechanical action as a result of the excavation process (cutting action of the cutterhead, rotation of the cutterhead and slurry transportation). The advantages of such a system are the reduced mechanical wear on the machine due to use of a fluid and parts and the simple transportation system via pipeline, both highly important for a long tunnel. Being isolated from the ground means that any groundwater present in fractured zones is controlled by and contained within the slurry system.

5.3.3 This form of tunnel construction requires the installation of a precast concrete segmental lining that is erected within the skin of the TBM shield and extruded behind as the TBM moves forward. The annulus left between the cut profile and the extrados of the lining is fully grouted and the installed lining acts as a resistance against which the TBM is jacked forwards to penetrate the ground ahead.

Sprayed Concrete Lining (SCL) method

5.3.4 Originally developed in Austria, where it is known as the New Austrian Tunnelling Method (NATM) and in Norway where it is referred to as the Norwegian Method of Tunnelling (NMT) these methods have been adapted to forms of contract and construction practice in the UK where it is referred to as the Sprayed Concrete Lining (SCL) method. As implied by the title the form of construction places the tunnel support in the form of sprayed concrete in a controlled sequential excavation using purpose-built and conventional mechanical excavators and loaders. The sprayed concrete is installed using semi-robotic concrete spraying equipment fed by specially formulated concrete that can be either batched on site or supplied pre-mixed. The initial sprayed concrete support may be followed by a further, sprayed concrete or cast-in-situ concrete permanent lining.

5.3.5 Compared to a TBM the rate of progress is relatively slow and more labour intensive but the method has a number of key advantages. It involves a relatively low capital and operating cost and is much quicker to set up. In addition, it requires far less operational and logistical back-up during construction, consequently a number of tunnelling faces can progress simultaneously and cost-effectively. However, its most attractive feature is its flexibility, which allows the construction of variable size and shapes of tunnel and complex interconnections.

5.3.6 For tunnel lengths of only several kilometres in length SCL can be more cost effective than TBM tunnelling. Recent examples include the 3.2km long, 12m diameter HS1 North Downs Tunnel and the twin bore 1.8km long, 11m diameter A3 Hindhead tunnels. The use of SCL does depend on the degree of fissure groundwater flow in the locality and the extensive use of this technique will need to take the conditions into account. Consideration has been given to use of SCL for the tunnels from the North Portal at Nash Lee Road towards Wendover Dean to provide flexibility and reduce the quantity of arisings at this location. It has been concluded however that the consequent 20km TBM drive from the South Portal would significantly increase the programme and the volume of arisings at this portal which therefore significantly reduces the viability of this option..

5.3.7 SCL is often used as a supporting method to the main TBM tunnel construction where it can cost-effectively form a number of key features such as TBM launch and reception chambers cross passages, turnouts, sumps and caverns. The method is also widely used for shaft sinking. SCL was used extensively on the Heathrow Rail Link, Jubilee Line Extension and Crossrail and continues to be considered in the planning of future railway schemes such as Crossrail 2.

5.4 Tunnel layout and dimensions

Running tunnels

5.4.1 As currently planned the circular running tunnels will be twin, uni-directional, 8.9 m internal finished diameter TBM bores. This is similar to recently planned and constructed high-speed long railway tunnels in Europe such as the Alpine Base Tunnels. The tunnel size is dictated by the clearances required by the trains, overhead electrification, track bed and walkways together with the aerodynamic (transient pressure) criteria required by the high speed rail traffic. The tunnel lining thickness is indicated as being 400 mm.

5.4.2 On the Channel Tunnel 2 m diameter pressure relief ducts connect the running tunnels at 250m intervals enabling a reduction in tunnel size to 7.6 m internal diameter. This approach could also be considered for HS2 although the planned train running speed is higher and therefore suitability will need to be checked along with a number of other parameters which influence tunnel diameter.

5.4.3 It is advantageous not only from a railway operational point of view but in construction to align the running tunnels as straight and at as constant a gradient as possible. Vertical and horizontal curves require the use of tapered precast lining segmental rings that can be offset rotated as they are erected inside the TBM to enable the installed lining to negotiate the curve. Straight tunnels or tunnels with only very gentle curves can utilise non-tapered rings, the slight offset being taken up by the compression of the gaskets between adjacent rings. However, as this degree of straightness is uncommon, the use of tapered rings has become the norm, with variable orientation of the taper used to produce the necessary vertical or horizontal curvature.

5.4.4 Modern TBMs have little difficulty in maintaining exact alignment; utilising state-of-the art laser guided steering systems. However, in order to steer the TBM around a curve it must exert greater thrust force on one side of the ring than the other, which if not carefully controlled can damage the concrete segment.

5.4.5 The Chilterns Long Tunnel Route offers a more direct and straighter alignment both horizontally and vertically than the government's Proposed Scheme or even just suppressing that route into tunnel and will therefore make tunnel lining manufacture and TBM operation easier, potentially offering programme and cost benefits.

Tunnel lining

5.4.6 The running tunnels will be lined with pre-cast concrete segments that are assembled to form a ring attached to the previous constructed rings forming the tunnel within the TBM.

5.4.7 The segmental lining design would be bespoke to the particular project and takes into account the geological and hydrogeological environment, spatial and operational requirements of the railway, internal structures and fixings. In addition, it should take account of stresses applied during manufacturing, handling, storage, transportation and installation as well as the forces exerted by the forward thrust of the TBM. Consequently the product must be of the highest quality and manufactured to exacting tolerances.

5.4.8 The 400mm thick lining indicated in the HS2 information implies that the segmental lining will be steel fibre reinforced rather than using steel rebar cages. At 8.8m internal diameter it is probably within, though at the upper end of the economical range for this type of lining. The use of rebar cages has certain disadvantages in terms of material cost and manufacture but has a significant advantage in terms of its structural performance, which can significantly reduce its thickness by as much as 100mm. This in turn reduces tunnel diameter by 200mm thereby reducing the size and power consumption of the TBM and the volume of spoil to be removed as well as a number of lesser economic benefits such as reduced transportation cost, grout volumes etc. Over the tunnel lengths being proposed this alternative option should be considered carefully.

5.4.9 Construction of short portions of tunnel using Sprayed Concrete Lining (SCL) would be performed with a roadheader in top heading and a road planer to remove much of the remaining material to the tunnel invert. This has the added advantage of producing engineering fill at source for use locally. In this case the primary tunnel lining would comprise sprayed concrete whilst the secondary or permanent lining may comprise either sprayed concrete or cast-in-situ concrete.

5.4.10 Very effective fire resistance can be provided for all forms of concrete tunnel linings by the inclusion of a small amount of fine plastic fibres in the mix. This adds little to the cost and does not affect the concrete performance. It will, however, enable the tunnel linings to withstand fire loads of up to 1,300º C and should be considered.

Tunnel separation

5.4.11 In low-stress rock environments there are no technical criteria for tunnel separation despite the generally accepted 'rule of thumb' that this should be not less than one tunnel diameter. This is traditionally based on the concept of tunnels potentially interfering with or destabilising each other during construction but this is only true in high rock stress environments such as through the high Alps. The tunnel separations shown in the HS2 proposals are at least 19.4 m centre to centre and appear to follow this rule.

5.4.12 It is true, however, that if the tunnels are too close together an intervening rock pillar in weak rock can become overstressed but since the tunnels will be driven by TBM and structurally lined immediately, this has little consequence. For example, many large segmental (cast iron and concrete) and SCL lined London Underground tunnels in clay are extremely close together and, in some cases, actually touching.

Tunnel cover at the portal

5.4.13 In a similar approach to tunnel separation, a commonly used 'rule of thumb' to define the minimum cover to the tunnel at the portals is that this should be not less than one tunnel diameter. Again, unless there are specific geotechnical, environmental or constructional reasons for this there are no general requirements relating to the portal depth, indeed the cover to the crown of the tunnel at the portal can be virtually zero. Whilst it may be convenient to cut or bench back unstable superficial deposits or weathered rock to expose rockhead there is usually no need to further excavate the face to establish the tunnel portal.

5.4.14 In order to accommodate TBM construction it will be necessary to form a temporary portal structure. This may comprise a shallow cutting. The cover of ground above the temporary tunnel portal can be much reduced, lessening the size and impact of this structure. It is, however, sometimes useful to excavate the initial portion of the tunnel in Sprayed Concrete Lining as a launch cavern for the TBM. This enables the shield section of the TBM to be initially advanced without thrusting off the lining rings, which can then be erected in the launch chamber behind the shield. Here the SCL launch chamber can be constructed almost entirely in the superficial deposits and weathered rock without need to excavate them back to expose the rockhead.

5.4.15 The final arrangements would be determined following the necessary geotechnical investigations and laboratory testing prior to finalising the design.

Portal arrangements

5.4.16 It is assumed that the southern portal has been fully assessed by HS2 Ltd as it forms part of the government Proposed Scheme and the relevant mitigation measures will apply, whichever route is selected.

5.4.17 The north portals will be constructed either as a retaining cutting in the case of the government's Proposed Scheme at Mantles Wood, or as a landscaped engineered cutting for the Chilterns Long Tunnel Route at Wendover. This will depend on the location and vertical alignment, although the final portal may probably contain a combination of the two solutions potentially incorporating the perforated acoustic hood. At the commencement of the tunnel drive the portal will temporarily be in cut, with the permanent engineered arrangements following to suit the programme.

5.4.18 As discussed with the tunnel separation there is no reason why the portals for each bore cannot be located closer together by incorporating a wineglass effect in the alignment of the bores, unless there are other overriding operational or acoustic criteria.

5.4.19 As illustrated in figures 4.3 and 4.4, the permanent portal will be an in-situ reinforced concrete structure located within the approach cutting, which is subsequently backfilled and landscaped. This structure may contain measures to control air-pressure phenomena associated with high-speed trains.

5.4.20 High speed rail portals are subject to air-pressure wave phenomena that mean that additional measures are required to dissipate air pressure as the train exits the tunnel. These measures include the following either singularly or in combination:

- Air-vents/ventilation shafts
- Porous portals
- Ballasted track
- Acoustic cladding (i.e. absorptive materials)

- Train speed
- Ducts and slots
- Flared portals

5.4.21 The optimum solution needs to consider the precise location of each portal and be suitably engineered to minimise land take and environmental impacts and integrate with the existing landscape. Figures 4.3 and 4.4 below indicate the potential arrangement at the proposed North Portal for the Chilterns Long Tunnel. Route in plan and then section across and along the line.

5.4.22 Clearly reducing the number of tunnels lessens the number of portals and consequently reduces their impact overall. The presence of portals within the AONB together with the associated accesses, headhouses, areas of hardstanding and security fencing in addition to the surface railway will distribute a form of industrial urbanisation throughout this landscape which is protected from such features. Importantly, the Chilterns Long Tunnel Route only has two portals, one located near the M25, as proposed by HS2 Ltd and one near Wendover, close to the recently constructed A413 Wendover bypass. The additional ventilation shafts on the long tunnel will have some of these features but can be well screened, designed to be unique features and are situated close to existing roads, thus minimising such urbanisation.

Shafts

5.4.23 Vertical shafts connect the running tunnels to the surface at nominal 2.5 km to 3 km intervals. These are provided for emergency intervention access such as fire fighting and escape and for emergency mechanical ventilation to control smoke and hot gasses. Their primary purposes are access for emergency services, regulating air quality and temperature, pressure relief and smoke extract. They also have secondary uses for maintenance access and TBM maintenance. Each shaft will be provided with a surface structure housing the attenuators that will restrict the noise to acceptable levels. The shafts vary in depth along the route but little detail is available on the dimensions or internal structures and equipment required except to note that it is known that HS2 suggest they require a minimum depth of 25 m to accommodate the plant and equipment. It is assumed that the same principles would be applied to any tunnel route.

5.4.24 As an example, the Alpine Base Tunnels have far fewer vertical shafts because of their depth below mountains. Nevertheless, the use of current ventilation control systems and emergency evacuation procedures are sufficient to ensure adequate smoke control and safe evacuation. The relatively shallow HS2 tunnels do allow for additional emergency shafts, however, the strict adherence to a 2.5 km to 3 km separation is probably unnecessary and some shafts may be located away from the main roads and new access roads may be required. Consequently, their locations on either route could be re-examined to reduce their number and site them closer to easy surface access points.

5.4.25 The shafts can be constructed using a number of methods; these include for example: bored (secant or contiguous) piling, diaphragm walls, pre-cast concrete segments, in-situ concrete and SCL, singularly or in combination.

Cross-passages

5.4.26 A means of access from one running tunnel to the adjacent tunnel is required for evacuation should an incident occur. This is usually accommodated by means of regular equi-spaced cross-passages so that a central service tunnel is not required.

5.4.27 Tunnel walkways connect to these 3.5 m internal diameter cross passages located at 380 m centres between the twin bores. The cross passage dimensions are set mainly by the requirements for passenger evacuation and emergency services access. In the event of a train emergency passengers can transfer along the walkways and through the cross passages to the adjacent tunnel bore from where they can be evacuated via shafts or train. The cross passages will be provided with doors to maintain the independent air flow along the running tunnels and prevent smoke from moving between them. Other than their basic dimensions, little information is provided as to their construction or internal finishes.

5.4.28 The size and spacing of the cross passages are fairly conventional and are related to the train length and passenger capacity. The Alpine Base Tunnels' cross passages are provided at 325 m to 333 m intervals, whilst they are 375 m apart on the Channel Tunnel. The frequency of these passages warrants review to optimise it with the tunnel design and construction methods. Their construction will not affect the critical path of tunnelling and mechanical fit-out.

5.4.29 The cross-passages would likely be constructed using SCL methods and probably lined with pre-cast segments, in the same manner adopted by the Contractor for Crossrail on Contract C310 in the Chalk.

Fire fighting point – as an underground facility

5.4.30 A tunnel that is over 20km long will require additional facilities to meet the safety requirements for a long a tunnel. As noted in paragraph 4.1.6, these safety provisions can be underground. Whilst there are a number of options, these facilities will need to meet, as a minimum, the revised TSI standards for a passenger railway.

5.4.31 The fire fighting points will be equipped with water supply (min 800l/min), there will be a means of safely stopping the train at the fire fighting point indicated without using specific on board equipment. The fire fighting point will be accessible to emergency services and there will be a means of switching off the traction power. In addition, it will be possible to move the passengers promptly to a safe area, sized for the passenger flow and able to accommodate the passengers until they can be taken from the tunnel and a separate and dedicated access route for emergency services. It will also be possible to control heat and smoke and separate this from the routes to the safe area.

5.4.32 There are a number of ways in which these requirements could be met:

- Bringing the railway to the surface. Previously suggested as an 'intervention gap' in previous feasibility reports and as described above.
- Emergency underground station. Essentially a station with platforms and the facilities to evacuate passengers to a safe area and take them from here to the surface. Perhaps with vehicular access from the surface to the railway via an inclined tunnel.
- Provision of 'safe areas' coincident with ventilation shaft locations with enhanced facilities to control heat and smoke, with a centrally located tunnel attached to the shaft that provides the safe area and a dedicated means of evacuation to the shaft. Perhaps with vehicular access from the surface to the railway via an inclined tunnel.
- Additional cross-passages located adjacent to ventilation shafts to allow evacuation to the non-incident tunnel.

5.4.33 Subject to a safety assessment, it is possible that the ventilation shafts in the government's Proposed Scheme could offer sufficient facilities to meet the requirements for a fire fighting point even on a tunnel over 20 km in length .

5.4.34 The size of the running tunnels are such that enlarged station tunnels are probably not required as there is sufficient space to evacuate passengers onto the tunnel walkway provided. Depending on passenger movement simulations it may be possible to provide facilities to evacuate the incident tunnel via a number of cross-passages. These may be coincident along the length of the location of the stopped train, or perhaps closer to a shaft. They may allow evacuation to a centrally located tunnel (the length of which will be determined by the spacing and location of the cross-passages) or to the non-incident tunnel, if this can be classed as a 'safe area'. Vehicular access would be provided to the centrally located tunnel from the surface via an inclined tunnel as an access ramp. An illustrative general arrangement is shown in Figure 4.1.

5.4.35 It should be noted that ventilation shafts will provide a dedicated means of access for emergency services, fire-fighting facilities to the required standards (including water supply at 800l/s) and separate evacuation arrangements for passengers. These are located at 2.5 km to 3km intervals. Following a safety assessment, it may be considered that the shafts, themselves meet the requirements of the standards and those of the tunnel owner/operator.

5.4.36 Nonetheless, assuming that a firefighting facility in addition to the ventilation shafts is required then there are three constraints to be considered:

- Operational requirements. A firefighting point equidistant from the tunnel portals is optimum. Whilst it will probably be a requirement to take an incident train out of the tunnel, there is the risk that a train will come to a standstill at another location should an incident cause a loss of power or communication. A fire fighting point at a nadir is advisable but this should be the subject of a safety assessment for the whole tunnel.

- Construction efficiencies. It may be preferable to combine this facility with those required for TBM reception and removal along with those required for a permanent ventilation shaft, although separating the two activities might also suit construction logistics.

- Programme necessity. A location close to the mid-point of the tunnel, balances the lengths of the tunnel being constructed from each portal and optimises programme and programme risk. This also supports construction efficiencies but constructing the fire fighting point at a separate location might be beneficial to the programme.

5.4.37 The fire fighting point and crossover could be constructed by conventional SCL methods gaining access via a vertical shaft sunk from the surface or by inclined tunnels. This vertical shaft becomes the Ventilation Shaft, fitted with fans and dampers for forced ventilation and smoke extraction of the fire fighting point whilst the inclined tunnels will provide the passenger escape route to the surface and access for the emergency services.

5.4.38 The running tunnel walkways will give way to additional cross passages; say at intervals of train doors to facilitate easy evacuation and access to the escape and emergency services tunnel situated between the tunnels at platform level and connected inclined access tunnels to the surface at a nominal gradient of about 1:10. The crosscuts will be provided with double ventilation doors that will prevent smoke entering the escape and emergency services tunnel and the adjacent platform tunnel. In addition, the escape and emergency services tunnel will be pressurised by the ventilation system to maintain a clean airflow during an emergency evacuation. Passengers would be directed by electronic signage and public address announcements to either move along the escape and emergency services tunnel to the inclined escape tunnel leading to the surface or into the adjacent tunnel. Lifts would be provided in the ventilation shaft to convey mobility impaired persons to the surface; alternatively electric vehicles could be stationed at the bottom of the inclined escape tunnel.

5.4.39 Smoke and heat extraction would be through a tunnel located above the escape and emergency services tunnel, which is connected by horizontal crosscuts at suitable intervals to the crown of the platform tunnels via vertical ducts. The crosscuts will be provided with dampers to prevent smoke and heat from entering the adjacent platform tunnel. The smoke and heat extraction tunnel is connected to the ventilation shaft where fans maintain a negative air pressure in the tunnel and crosscuts.

5.4.40 Sprinkler or fire suppression systems would be installed at the fire fighting point to control the spread of fire and reduce heat allowing the emergency services to gain access.

5.4.41 The main advantages of the emergency underground fire fighting point are that:

- It can be sited at the most advantageous location along the tunnel route for emergency access;
- The running tunnels vertical alignment will be relatively unaffected by the location of the station and could therefore be the most economical in terms of train operations;
- The surface environmental impact of the facility will be minimal;
- Security will be much simpler;
- The facility will be unaffected by weather;
- A fire will be better contained and controlled whilst the emergency services arrive; and
- Passengers can be rapidly evacuated to safe and secure areas to await the arrival of the emergency services.

5.4.42 The selection of a position for the fire fighting point can be governed by a number of factors, but each position is primarily dictated by location of proposed Vent Shafts. It is possible that the fire fighting point could be located at a different location to the TBM extraction point.

5.4.43 This evaluation is based on interpretation of the requirements for a fire fighting point which will include the need for safe access and egress by emergency vehicles down to the incident. It assumes that the ventilation shaft facilities already planned at each locality will be provided and enhanced as appropriate to deal with additional ventilation and firefighting capacity appropriate to meet fire fighting point specifications.

Location options

5.4.44 It is considered that the overall balance of the TBM drive strategy needs to be maintained to minimise effects on the construction programme. To this end and as discussed in the tunnelling strategy in section 6, it is proposed that the TBMs are driven to the Little Missenden ventilation shaft from both north and south portals and withdrawn using the shaft. This means there will be some major construction activity at this location, in addition to the equivalent for the other ventilation shaft sites, for the removal of the TBMs and finishing the ventilation shaft.

5.4.45 The commentary on each aspect is used to conclude which is the preferred location in that regard for the requisite fire fighting point. An overall conclusion is drawn on the basis of these. The preferred option is illustrated in Figures 4.2.

Table 5.1 Selection Criteria for fire fighting Point location

Aspect considered		Amersham VS	Little Missenden VS	The Firecrest VS	Conclusion
1	**Position in long tunnel (24.5km between portals)**	10km from south portal; 14.5 km from north portal	12.3km from south; 12.2km from north	20.2km from south; 4.3km from north	Little Missenden VS is most centrally located but Amersham VS could be

	Aspect considered	Amersham VS	Little Missenden VS	The Firecrest VS	Conclusion
					considered as a reasonable positon. The Wendover Dean VS location, whilst meeting the criteria, does not offer operational benefit.
2	**Depth below ground level (for access ramps)**	43m	40m	34m	Each of these are relatively similar depths and the access ramp lengths will be of a similar order although the Wendover Dean VS site is slightly shallower
3	**Proximity to major highway**	Adjacent to dual section of A404 and of Wielden Lane with junction onto A404. Awkward and potentially unsafe highway access	Adjacent to A413 between Little Missenden and Old Amersham where dual with wide median strip	Adjacent to A413 between Wendover and Great Missenden	All have good access to major highway except Amersham. The Wendover Dean VS is on a single carriageway section of A413 but has sufficient space around it to provide safe off highway accessibility.
4	**Accessibility to major emergency services**	3.5km from Amersham Fire Station; 20km from Stoke Mandeville Hospital; Within 500m of Amersham Hospital ;	Approx. 6.6km from Amersham Fire Station; 17.5km from Stoke Mandeville Hospital; 3km from Amersham Hospital;	Approx 14.5km from Amersham Fire Station; 9km from Stoke Mandeville Hospital; 10km from Amersham Hospital	The equal distance to both hospitals makes the Wendover Dean more accessible although the closer proximity to the fire station of the other two might be preferable. In an incident the activity so close to a hospital could make accessibility difficult for Amersham, which also has limited emergency treatment facilities.
5	**Space availability at the locality for construction**	A very confined site surrounded by roads, covered in trees with a notable level difference	The sloping arable field site is more open but surrounded by stands of ancient	A relatively flat site with no major physical restrictions.	The Wendover Dean VS site is the least restricted in terms of construction

	Aspect considered	Amersham VS	Little Missenden VS	The Firecrest VS	Conclusion
		between these roads as one crosses over the other.	woodland.		accessibility
6	**Space availability at the locality for operations**	A confined site and any enhancement of the location to be a fire fighting point with ramped access down to the tunnel will be difficult and could result in access points being positioned on different roads, increasing hazards during and incident.	The broad frontage onto the A413 provides flexible options for positioning emergency access points and would allow entrances to be separated sufficiently to avoid conflict during an incident whilst maintaining low risk between them. The adjacent dual carriageway section of A413 offers opportunities for traffic management which will reduce obstruction of passing vehicles.	The open, level nature of the site provides wide scope for access options and for any surface facilities to be developed as necessary to provide good flexibility and avoid obstruction of the single carriageway A413 at this location.	The operational needs of the fire fighting point are significant. The Wendover Dean VS location offers the most flexibility of arrangement, but Little Missenden VS is also a good option. The Amersham VS site is too confined and close to two roads which will introduce further hazards.
7	**Position in landscape (AONB)**	Least intrusive. On the edge of a built-up area, close to a major road and least visible from any point in the AONB.	In a central location in the AONB with visibility from a number of locations in the AONB, including Little Missenden and the listed Shardeloes Park. Proximity to the A413 reduces the intrusion and surrounding woodland would provide screening to immediate vicinity. Additional planting will improve this screening.	Most intrusive. Exposed location in open section of the valley floor is visible from a wide area and from adjacent valley sides. Proximity of listed buildings at The Firecrest and Wendover Dean Farm. This will be difficult to screen and affect the setting of the adjacent listed buildings.	The Amersham VS site would have the least impact on the AONB and the Wendover Dean VS site, the most. The enclosed nature of the Little Missenden VS site, facing the A413 and with the ground sloping up to the rear will reduce its impact. The sloping ground will assist in the creation and enclosing of the access routes down to the tunnel and associated entrances.
8	**Effect on construction programme and logistics**	Separate activity to construct the surface accesses and underground access chambers for safe evacuation and firefighting will increase/extend the activity and works at	The activity at this site will already be increased compared with the VS alone to allow for the removal of the TBMs. Including the fire fighting point as an element	Separate activity to construct the surface accesses and underground access chambers for safe evacuation and fire fighting	A single extended period of site setup at one location at Little Missenden VS for removal of the TBMs will make the other fire fighting point works more

Aspect considered		Amersham VS	Little Missenden VS	The Firecrest VS	Conclusion
		this site. The confined nature of the site and access will have extended impacts. It will require a more substantial site compound than for the VS alone	of the works will make this site set up more cost effective.	will increase/extend the activity and works at this site. The open nature of the site will not constrain this and the impacts will only be related to visual effects in the AONB. It will require a more substantial site compound than for the VS alone.	economical and easier to service than separating it to the alternative sites.

Location conclusion

5.4.46 Based on the above aspects, which are primary considerations for the construction and operation of the railway, we consider that the fire fighting point should be located at the Little Missenden ventilation shaft site and combined with the ventilation shaft construction, where it is also proposed to remove the TBMs for the Chilterns Long Tunnel.

5.4.47 The alternative would be the Wendover Dean ventilation shaft site, which might be preferable for construction programme and impacts on the setting of the listed buildings at Shardloes, although these are already affected by the proposed ventilation shaft on the government's Proposed Scheme. It is noted that The Firecrest at Wendover Dean and a number of adjacent buildings in Wendover Dean Farm are listed and the setting would therefore be considered more adversely affected.

Alternative underground crossover

5.4.48 The crossover can be readily constructed underground at any point along the tunnel alignment for the Chiltern Long Tunnel route using SCL techniques. This approach has been adopted for the Alpine Base Tunnels and has also been employed on Channel Tunnel, Heathrow Express Rail Link, Jubilee Line Extension and Crossrail.

5.4.49 The form of construction is simply four SCL turnout caverns constructed from the running tunnels and linked by SCL crossover tunnels. Depending on programme requirements, the crossover could be constructed in advance of the TBM drive reaching it, in which case access for construction would be via a vertical shaft from the surface, which would later serve as a ventilation and emergency escape shaft. Alternatively, it could be constructed from the running tunnels once completed.

5.4.50 The main advantages of the underground crossover are:

- The running tunnels vertical alignment would be unaffected by the location of the crossover and could therefore be the most economical in terms of train operations;
- The surface environmental impact of the facility would be minimal, particularly noise;
- Security would be much simpler; and

- The facility would be unaffected by weather;

6 Construction, Logistics and Programme

6.1 Introduction

6.1.1 The dominant element of the proposed route is the boring of twin tunnels between the south and north portals of the Chilterns Long Tunnel Route, and it is this aspect which is focussed on with respect to construction logistics and programme in this report section. The elements on the surface northwards to tie in to the government's Proposed Scheme will have similar logistics to those already described in the Environmental Statement and are not therefore discussed further in this report.

6.1.2 The logistics of the tunnel construction will be based on the selection, number required and procurement of the TBMs, together with their back-up facilities including spoil treatment and disposal and the manufacturing and supply of the precast concrete segmental lining.

6.1.3 For example, using 4 TBMs may reduce the overall construction time as compared with using 2 or 3 machines. Rates of spoil disposal and materials supply would increase, and larger temporary servicing facilities would therefore be required It is assumed that 4 TBMs will be used, with a pair driving from each portal.

6.2 Ancillary Activities

6.2.1 The main ancillary construction activities to the running tunnel drives are:

- Portal construction;
- Cross passage construction;
- Shaft-sinking; and
- Pre-cast concrete segment manufacture and delivery.

6.2.2 The underground fire fighting point may also include the following although the actual requirements for the fire fighting point as described in the recently adopted TSI could reduce this to the same facilities in the ventilation shafts as proposed in the government's Proposed Scheme:

- Inclined SCL escape and emergency services access tunnel, each about 500m long;
- Horizontal SCL escape and emergency services access tunnel, about 500m long;.
- Running tunnel walkways, two at 500m long, already provided along the tunnel;
- SCL escape and emergency services access cross passages;
- Smoke extraction ducting about 500m long; and.
- Vertical smoke extraction ducts in ventilation shaft.

6.2.3 The layout of the underground emergency fire fighting point utilises the existing running tunnels and includes a central horizontal access tunnel, serviced by inclined access tunnels that allow vehicles to rail level. The length of the fire fighting point can be optimised according to the anticipated flow of passengers disembarking from the incident train. The optimised fire fighting point may be only 400 m long, sized to accommodate evacuated passengers but with cross-passages, say at every 20 m intervals or so to match train length and door positions to provide an efficient evacuation route.

6.2.4 A fire fighting point located close to the mid-point of the route allows the running tunnel drive lengths to be balanced, such that overall programme for tunnel construction can be minimised. A possible location for this site is at Little Missenden, where there is already a ventilation shaft proposed in the government's Proposed Scheme. The site lies adjacent to the A413, where it is dual carriageway, with good access for emergency services. The proposed ventilation shaft will also be used for TBM retrieval. However, other alternative sites on the Chilterns Long Tunnel Route are also feasible, such as near The Firecrest on the A413.

6.2.5 The additional works required for the underground fire fighting point and potential possible underground crossovers could be phased into the TBM drives by commencing them early in the programme.

6.3 Ground Movement

6.3.1 The tunnels, by and large, are being constructed in chalk, which is a weak rock sufficiently strong to withstand the strains associated with creating a tunnel. Consequently, ground movements of the surface above the tunnels will be negligible.

6.3.2 The greatest risk of ground movements is probably associated with very low strength materials where the Chalk is highly weathered or faulted/fractured. These locations are likely to be very small and will be examined in advance by adequate ground investigation and geotechnical analysis. The greatest risk of significant ground movement will occur if karstic features or buried valleys were encountered. This risk can be quantified and form part of the tunnel design criteria.

6.4 Spoil Behaviour, processing and potential use

6.4.1 Chalk slurry arising from a slurry TBM will usually require processing to convert it into a material suitable for other purposes, such as engineering fill. This involves passing the slurry first through screens (to separate flints) and then into filter presses, with the addition of a small amount of slaked lime to make a suitably dry filter cake. Given the size of the slurry TBMs, their likely rate of advance and the length of the tunnel a very large quantity of slurry will require treatment.

6.4.2 An advantage of the slurry system is that it can be transported for very long distances by pipeline before treatment, which reduces both the cost and impact of transportation. It will, therefore, be preferable to locate the slurry treatment plant close to the site of final disposal, otherwise it will be necessary to remove the filter cake by rail or road to its disposal site, discussed further in paras 6.4.11 and 6.4.16.

6.4.3 Since 1965 Cemex (and its predecessors) have been operating a chalk slurry pipeline from the Chilterns near Dunstable to its cement works at Rugby. Such a pipeline could be laid to Calvert, approx. 20 km northwards along the trace of HS2, for disposal of chalk slurry.

6.4.4 There could be opportunities to use the material for cement making or to feed the slurry to local disused quarries for selective backfilling. This gives a number of options for the final locations of the spoil and the slurry treatment plants and will reduce the impact of potentially transporting the material by road through adjacent communities such as Stoke Mandeville and Aylesbury. Transport by rail along the Chiltern Line to Calvert or elsewhere, subject to planning consent and permitting requirements, is also a possibility. This is also discussed in paragraphs 6.4.9 to 6.4.16.

6.4.5 Initial communication has been had with the relevant Network Rail Freight Management team regarding potential for use of the Chiltern Railway for transport of materials as well as with CEMEX at Rugby regarding the potential use of the tunnel arisings in their manufacturing process. The latter has indicated a potential interest in the materials subject to more detailed analysis of the nature of the materials and the costs of delivery. Discussion with rail freight operators with the expertise in moving bulk materials by rail also indicate an interest in developing a rail based transport solution including the provision of the appropriate rail infrastructure, wagons and locomotive resources necessary.

6.4.6 HS2 Ltd propose for the government's Proposed Scheme to move materials within the Chilterns AONB and in the surrounding area along the trace of the line, particularly for the deposition of over 1Mm³ of surplus material in Hunts Green and a further 0.5Mm³ at South Heath, much of which has been stated in the Environmental Statement will be unsuitable material which cannot be used for engineering purposes. The deposition itself will require all the necessary waste permits.

6.4.7 The approximate volumes to be removed from the north portal are shown in Table 6.1. The assumed drive rate for the TBM strategy is 80 m/week adopted by HS2 Ltd. If the drive rate were to increase to say 100m/week then the spoil removal and segment delivery arrangements considered in this report are considered to be sufficiently robust to be able to accommodate this tunnel advance rate. A more detailed study would have to be undertaken into the construction logistics of a faster tunnel drive rate of say 120m/week.

Table 6.1 Approximate volume of arisings from Chilterns Long Tunnel

Strategy	Volume to be removed m³	Extraction rate m³/week
North Portal (Nash Lee Road): TBM drive to Little Missenden VS	1,900,000	12,000
South Portal (M25): TBM drive to Little Missenden VS	*1,700,000	11,000

*Approx. 300,000 m^3 less than for the government's Proposed Scheme

6.4.8 It is likely that the chalk resulting from the TBM drives would be chalk slurry which would be transported by pipeline back to the tunnel entrance. Thereafter there are three possible forms of transport for removing these arisings for disposal: construction plant, road, rail and pipeline. In each case the moisture content of the spoil is to a large extent a determining factor. If it is too high then some means of reducing the moisture content would be considered such as the use of centrifuges and possibly settlement ponds or some similar arrangement.

Construction Plant

6.4.9 The key construction issue are the arrangements for removing arisings along the trace of the line to be used as structural fill or for other purposes. Clay, gravel and chalk spoil arising from open excavations or SCL tunnelling should be generally suitable for use as construction fill material either within the remainder of the works requiring embankments or for local ground raising. Depending on its type and moisture content it could, however, be sensitive to excessive disturbance and handling resulting in a rapid degradation to what is often referred to as 'putty chalk'. In this form it becomes difficult to handle, store, deposit and compact and can present an unsightly mess or even a hazard on site and nearby roads that is difficult to remove. This may limit the use of tracked or wheeled vehicles in favour of an extension to the conveyor arrangement to extract it along the tunnel and continue to the place of deposit.

6.4.10 Subject to suitable environmental assessment, particularly in relation to groundwater impacts, there could be opportunities also to use the material for cement making, feed the slurry to Pitstone Quarry approximately 11 km north east, or to Chinnor Quarry 11 km south west, for selective backfilling.

Rail

6.4.11 In terms of likely train movements the TBM drive would require 8 trains per week to remove the spoil. The destination of these trains could, for example be to the land fill site at Calvert, which may not be suitable, or elsewhere or, from 2019, direct to Rugby when the East/West rail line is reopened between Oxford and Bletchley. The necessary siding and railhead required could be located nearby on the Chiltern Line south of Stoke Mandeville or possibly on the Princes Risborough – Aylesbury line approximately 3.6km north of the tunnel construction compound where other modifications are already planned under the government's Proposed Scheme.

Pipeline

6.4.12 An advantage of the chalk slurry from the TBM drives is that it can be transported for very long distances by pipeline before treatment, which reduces both the cost and impact of transportation.

6.4.13 The CEMEX pipeline referred to in paragraph 6.4.3 is 92 km (58 miles) and transports chalk slurry from near Dunstable to its cement works at Rugby. It is a 280 mm diameter welded steel pipe which delivers 4,000 m³ per day or nearly 30,000m³ per week which is 2½ times the TBM drive requirement. 12,000 m³ per week would require a pipe with a diameter of about 200 mm.

6.4.14 Such a pipeline could be laid to Calvert, approx. 20 km northwards along the trace of HS2, for disposal or 20km eastwards to the Kensworth Quarry near Dunstable from where CEMEX extract the chalk for the Rugby cement works.

Road

6.4.15 Probably the least satisfactory forms of transport and on the basis of the information provided in Table 6.1 would require about 300 vehicle movements per day for the TBM drive. It is flexible however, enabling a range of destinations for the material to be selected.

6.4.16 Overall, the tunnel arisings strategy can offer a number of options and the facilities provided will be designed to address these options. It is possible, for example, that material in the early stages will be transported by road, but later by rail or pipeline once the infrastructure and facilities are in place.

6.5 Tunnel lining segment manufacture and delivery

6.5.1 The bored tunnels will be lined with precast concrete segments forming rings. These are manufactured under controlled conditions to ensure quality particularly for dimensional control and the forming of the joints. It will likely incorporate one or more gaskets to prevent water ingress and a system for post-grouting behind the lining. Once installed it is extremely difficult and costly to repair a damaged segment therefore quality control is essential at all stages leading to the completed lining installation. However, this is well-proven technology and does not represent a risk to the delivery of the long tunnel.

6.5.2 The tunnel segment rings are likely to be about 2 m wide and assuming that 7 segments are required for each ring, then, very simply 3,500 segments are required for 1km of one tunnel. For 25km of twin bored tunnel then the number of segments required is approximately 175,000. Crossrail, currently under-construction, involves the excavation and lining of 21km of running tunnels using pre-cast concrete segments and the casting of about 173,000 segments each 1.7m wide. On Crossrail, segment manufacture is being undertaken from 4 factories; two located in the Medway, one located in west London and one located in central Ireland. The choice of location for manufacture is highly dependent on the proximity to the location of use, the availability of land to create a temporary (site) factory and transportation costs. For

HS2 it would be possible to create a temporary (site) factory at or close to the point of use i.e. at the tunnel portal, particularly given the very large size of the segments and this is proposed at the southern portal. Another and preferred option would be to establish a rail-served manufacturing site located elsewhere and a rail loop and handling facility from the Chiltern Line near the portal. Although this could duplicate some infrastructure it could be shared with spoil handling arrangements if this was also transported by rail, for which see paragraph 6.4.11.

6.6 Tunnel Impact

Construction noise, dust, light pollution and vibration

6.6.1 Construction noise dust and light pollution arising from the tunnelling operations will be confined to the worksites located adjacent to the portals and shaft headworks. Modern tunnelling sites impose strict controls on these areas, particularly at sensitive locations such as near hospitals, schools and residential properties. The local environmental impact can be restricted by the erection of hoardings or even acoustic sheds around the worst affected areas. Further restrictions on floodlighting and night-time traffic movement can also be imposed.

6.6.2 The main noise pollution emanates from the ventilation fans, mobile generators and compressors, assuming that they are required and other plant operating in these areas. Virtually no noise will emanate from the underground tunnelling operations themselves.

6.6.3 Ground vibration arising from the tunnelling and shaft-sinking excavation activities may be a problem in certain sensitive areas, particularly at night. However, these will likely be confined to areas where the tunnels and shafts are at shallow depth which is not so much of a problem with the relatively deep Chilterns Long Tunnel. Since most, if not all of these activities will comprise mechanical excavation in weak rock ground-borne vibrations are likely to be small. Ground vibration problems tend to arise from the use of hydraulic breakers and blasting, neither of which are anticipated on this project.

Operational noise and vibration

6.6.4 A source of operational noise will be the portal areas where trains enter and emerge from the tunnels at high speed causing a pressure wave to emanate from the portal mouth. To counter this effect the portals will be provided with specially designed structures that will attenuate this effect to an acceptable level. Once a train has fully entered the tunnel there will be no discernible noise transmitted to the surface.

6.6.5 As second significant source of operational noise will be the ventilation fans located in the shafts. Each shaft will be provided with a surface structure housing the attenuators that will restrict the noise to acceptable levels. However, during an emergency or routine maintenance testing, the fans may be boosted and the normal noise levels exceeded for the duration of the incident.

Worksite locations

6.6.6 Due to the length of the tunnels two main tunnelling worksites are required one located at the southern portal the other at the northern. Main tunnelling worksite locations from which the tunnels are constructed, are largely dictated by where the tunnels break the surface, at the tunnel portals. The southern portal in all of the options appears fixed and lies between the M25 and the River Colne/A412 corridor. In this study it is considered that the northern portal location is likely to be near the B4009 and A413 as presented in the plans. The location of the tunnelling worksite may also vary but is likely to be positioned for access off the A413 and lie adjacent to the trace and the Chiltern Line.

6.6.7 The main tunnelling worksites for this project will need to provide the following:-

- Access to the tunnel, probably via an open cut or retained cutting (a retained cut will occupy a smaller plan area than an open cut);
- Space to construct the portal structure;
- Space along the alignment to allow for construction of the tunnel boring machines;
- Space for materials storage, welfare facilities, offices, workshops, car parking etc;
- Space for slurry processing, water treatment and spoil stockpiling if the slurry is not pumped direct to the disposal site;
- Space for segment manufacture including batching plant and storage, although this could be off-site with a smaller storage area to feed the TBM on-site; and
- Space for temporary worker accommodation.

6.6.8 To incorporate all the above features, a main tunnelling worksite will cover a total area of about 200,000 m2. A segment factory would cover an area of about 30,000 m2. The possible extent of the construction area for the North Portal is shown in the Figure 6.1a, with a comparison of the construction area of the government's Proposed Scheme extending south to the Small Dean Viaduct in Figure 6.1b. The notable difference is the parcel of land alongside the Chiltern Railway (shown in Pink in Figure 6.1a) which could be used to store tunnel lining segments and/or tunnel arisings if rail transport was used. Figure 6.1a also highlights that the area to the south (in Green), adjacent to Wendover and within the AONB, is no longer affected by construction.

6.6.9 The location of the worksite for the northern portal on the Chilterns Long Tunnel Route can be considered to be nominally the same as the government's Proposed Scheme works site to construct the Wendover Green Tunnel. Figure 6.2 shows the completed Alptransit Erstfeld Tunnel Portal in open cut with road over and headhouse, a similar arrangement to that proposed for the Chilterns Long Tunnel North Portal.

6.6.10 The initial activity associated with the construction of the portal and preparation for the launch of the TBM will be similar to that which will occur under the government's Proposed Scheme. The main difference will be the 24 hr, 7 days/week operation of the two TBMs, the associated provision of tunnel lining segments from the local store and the removal of arisings to local stockpile. Once the TBM is underway it is only these two activities which will be continuing on the surface at night in the construction compound. A conveyor or pipeline will deliver material to the stockpile and tunnel linings will be handled using bespoke mechanical equipment, usually driven by electric motors. The stockpiles and stores will generally be serviced, that is material removed and tunnel segments delivered, during the daytime to minimise activities off the site during the night time hours.

6.6.11 Worksites will also be required at other locations to receive the TBMs and construct the vent shafts and fire fighting point. The most substantial of these will be located wherever the drives are concluded which is proposed to be at the Little Missenden Ventilation Shaft. Ideally, it would be preferable not to have to construct a further worksite and access point specifically to retrieve the TBMs, rather they should be combined with a permanent structure.

Figure 6.1a North Portal Construction Area – Chilterns Long Tunnel

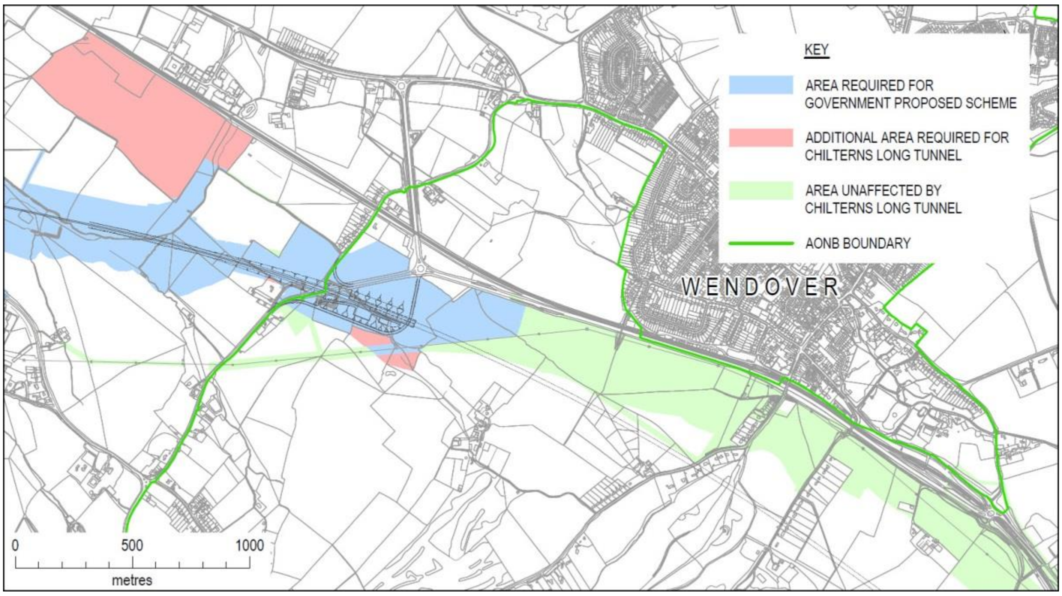


Figure 6.1b Nash Lee Road Construction Area – Government's Proposed Scheme

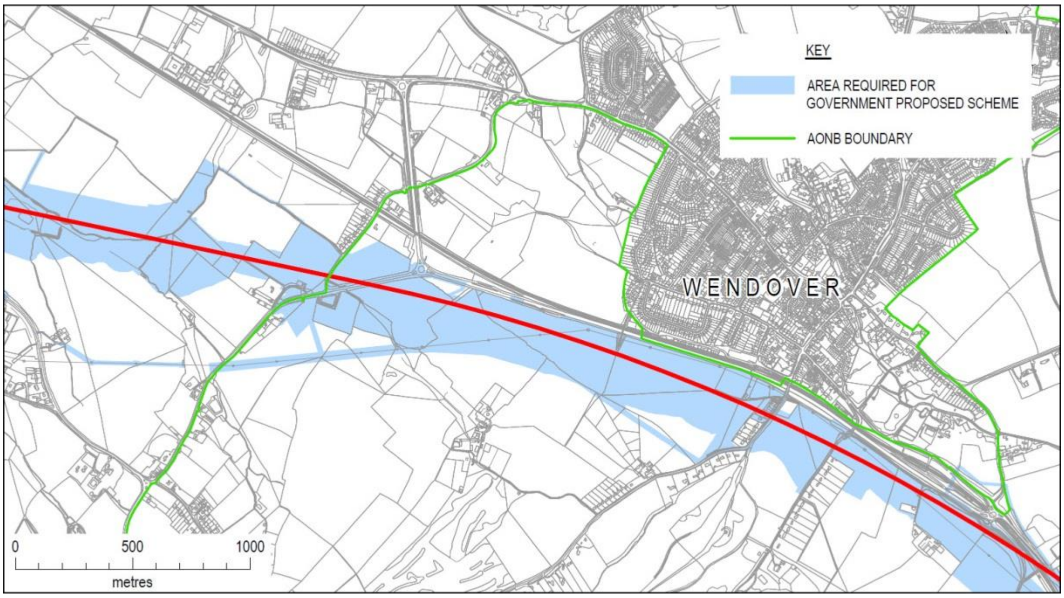


Figure 6.2 Completed Erstfeld Tunnel Staggered Portal with road over and headhouse

6.6.12 An underground fire fighting point referred to in paragraph 5.4.32 gives significantly greater options for its location, though for programming and optimising the works from any one worksite this would make a location close to mid-point along the alignment preferable. The location of the main surface worksite for the fire fighting point may not necessarily coincide with the plan position of the underground facility as its location may be gained via inclined adits (direct surface access above the fire fighting point will probably be required for ventilation shafts).

6.6.13 As concluded in Table 5.1 above it is considered that the location of the fire fighting point would be combined with the TBM removal at the Little Missenden ventilation shaft.

6.6.14 Smaller worksites will be required for the other shafts. These are ideally located adjacent to existing roads where these cross the alignment. It may be necessary to provide new or improved access roads for these shafts if located away from the main road such as at Leather Lane. If additional facilities are required for pressure relief then these should be managed within the tunnel system without breaking the surface, such as was done on the Channel Tunnel and reducing the number of shafts. For this reason the potential for a shaft at Ellesborough Road is considered optional as it is relatively close to the tunnel portal.

6.7 Construction Programme

6.7.1 Consideration has been given to the potential programme for the Chilterns Long Tunnel and compared with the government's Proposed Scheme. The options are discussed in the following section. However, the most beneficial solution is used to calculate the time to complete the civil works shown in the indicative programme set out below in Table 6.2.

6.7.2 This shows there is very little difference in programme time between the options being considered. A programme for the construction of the Chilterns Long Tunnel will provide for as much parallel working as possible and should be comparable to the time taken for the embankment/viaduct and track fit-out. It is estimated that the Chilterns Long Tunnel Route option would take 64 months to construct through the Chilterns in comparison to the government's Proposed Scheme taking 63 months. This comparison excludes the completion rail systems installation and testing (common to both options), which is discussed in Section 6.7.7.

Table 6.2 Comparative Construction Programme

Option	Activity	Duration	Cumulative
All	TBM order, manufacture, delivery and assembly prior to drive. Construct working sites	19 months	19 months
Government's Proposed Scheme	Drive two 13,272 m running tunnels northwards from M25 working site.	38 months	57 months
	Complete cross passage construction	Drive plus 1 month	58 months
	Mantle's Wood to SM Maintenance Loop	<59 months	
	Install track slab	5 months	**63 months**
Chilterns Long Tunnel Route	Drive two 11,600 m running tunnels northwards from M25 working site to LM Ventilation Shaft site.	34 months	53 months
	Complete cross passage construction	Drive plus 1 month	54 months
	Construct fire fighting point accesses and escape chambers	<54 months	
	Install track slab	4 months	58 months
	Drive two 12,500 m running tunnels southwards from Nash Lee Rd working site to LM Ventilation Shaft site.	39 months	58 months
	Complete cross passage construction	Drive plus 1 month	59 months
	North Portal to SM Maintenance Loop	< 59 months	
	Install track slab	5 months	**64 months**

Construction Options/Arrangements

6.7.3 There are a number of options available for sequencing the tunnelling and shaft sinking activities and will be largely dictated by the overall programme requirements and the decision on how many TBMs will be used. This means there are flexible solutions and programme elements which have to be managed.

6.7.4 As discussed, the ancillary works such as the portal construction, shaft sinking, underground FFP fire fighting point and possible underground crossover could be undertaken as advance works, which will be separate from the main TBM tunnelling, though there will be risks associated with interfaces and delays if they were procured as a separate contract or contracts. However, this is a usual construction risk for projects of this nature.

6.7.5 It is possible to undertake the entire tunnelling with only two TBMs working from one end of the scheme and progressing to the other. However, this increases the programme and introduces significant programme risk and is not realistic.

6.7.6 Four TBMs are preferred with two progressing from each portal on opposite sides of the Chilterns to the ventilation shaft at Little Missenden. This will balance the drive lengths and reduce programme risk. The use of four TBMs also allows for contingency should one TBM be delayed. This arrangement will require the establishment of TBM construction support facilities at the northern portal as well as at the south.

6.7.7 Railway systems fit out rates will not be the determinants of overall programme progress, as long as appropriate hand-over of accessible linear sections can be provided, ensuring unobstructed continuity of related construction operations. Modern ballastless track laying on this scale will be achieved by purpose built contractor-owned track-laying trains, which achieve progress rates of around 300 m per day. There are unlikely to be any demands for complex resilient track such as floating track systems, which do have a much more significant cost and programme impact. Fit-out of control, communication and electrification systems will generally follow close behind the track laying train. It is recognised that on completion of track installation there would be a time lag for the completion of systems installation, which may typically be in the order of 3 months, excluding testing. This would be common to both schemes. Testing and commissioning can be achieved in stages and again, this will not have any significant impact upon the overall programme comparison.

Rates of progress

6.7.8 It is important to bear in mind the long lead-in time for each TBM. The works programme should allow for:

- Design.
- Procurement.
- Manufacture.
- Factory commissioning.
- Transportation to site.
- Assembly.
- Site commissioning; and
- Launching.

6.7.9 The entire process can take about 12 to 18 months and may be affected by the demand for TBMs worldwide at the time since there are only a limited number of manufacturers, particularly in Europe that would be capable of producing machines to the specifications required. The lead-in times can, however, be managed.

6.7.10 The average rate proposed for the government's Proposed Scheme is 80m/week and this has been used. However, it is likely that considerably better rates of output than this could be achieved and segment supply and spoil treatment facilities will need to be sized for rates in excess of this.

6.7.11 The work will require careful sizing and implementation of the segment manufacturing facility, together with storage at the factory and on site with adequate transportation arrangements for their delivery to site. There is an advantage for major tunnelling projects such as this to locate the manufacturing facility as close as possible to or within the worksite thereby reducing transportation costs and storage areas, but this has to be considered alongside space availability, environmental impact and other material transport options. As discussed previously options for off-site manufacture and transport to site are feasible and need to be considered at the appropriate stage.

6.7.12 Similarly the tunnel arisings treatment facility would normally be located close to or within the worksite, although it may be possible using modern slurry pumping technology to transfer this to a more remote location to reduce the local environmental impact.

6.7.13 Rates of progress for SCL tunnelling and shaft-sinking will be far less than the TBM drives amounting to only several metres per day. However simultaneous multiple drives can significantly increase the overall rates of progress and the materials delivery and muck away logistics can become significant. However, this is balanced by the shorter mobilization times.

6.7.14 For large SCL projects sprayed concrete and cast-in-situ concrete batching is normally undertaken on site. This provides better control and consistency of the concrete mix but the process will impact on the worksite environment. Smaller SCL projects often rely on pre-mixed concrete but this would be unlikely for the HS2 tunnels and shafts except to supplement the site batching if necessary.

6.7.15 It should be noted that major tunnelling projects such as this where large volumes of concrete are consumed there can be an impact on local supply of cement and aggregates that can affect concrete quality and production and consequently affect the programme. This risk should be taken into account.

Activity durations

6.7.16 The entire tunnelling works, not including TBM procurement, should be completed in about 3.5 years.

6.7.17 Activity durations will vary according to how the Chilterns Long Tunnel Route is delivered. Four TBMs driving to Little Missenden would probably offer the shortest overall construction programme for this section of the railway and the costs associated with the extra TBM's would be outweighed by the reduced costs associated with shorter construction duration.

6.8 Constructability

6.8.1 In order to compare the government Proposed Scheme with the alternative Chilterns Long Tunnel Route, the issue of constructability of the government Proposed Scheme is considered below. This section considers the physical issues which the design and construction of each of the routes will need to address. The consequent effect of these issues on cost and programme is considered further in the report on risks to the project covered separately.

6.8.2 As well as the portal structures in Mantles Wood (government's Proposed Scheme) there are a number of significant structures proposed, namely:-

- Wendover Green Tunnel;

- Small Dean Viaduct;
- Wendover Dean Viaduct; and
- South Heath Green Tunnel

6.8.3 As discussed in Section 5 of this report, it is considered certain that sink hole features will be encountered on any of the proposed routes as they cross the Chilterns. The effect these have will vary dependent on the chosen solution. The effect on the tunnel is important but as noted it is something that can be dealt with through the use of an appropriately designed TBM. However, if these are encountered in the vicinity of the proposed viaducts on the government's Proposed Scheme, then this could have consequences for the foundations to the viaducts. This instability could also impact the cuttings, embankments and surface sections of track on the government's Proposed Scheme. The infilling of the sink holes and/or redesign of the foundations will have a programme and cost impact.

6.8.4 If the sink holes, deep fissure and groundwater flows are encountered near the locations of the green tunnels, they will also have a cost and programme impact. In addition the stability of the slope across which the Wendover Green Tunnel passes, as discussed in Section 5, could make this construction solution very challenging, increasing the risk to programme and cost.

6.8.5 As the costs included in the current figures for the Government Proposed Scheme are very generic it is difficult to estimate what has actually been included for the construction of the viaducts alone. An estimate of £790 million is included in HS2 Ltd.'s Cost and Risk Model (Jan 2012) at Table 4 for bridges and viaducts. The cost of infilling sink holes could be relatively small compared to this figure, although still run into millions of pounds. However, the effect on the programme could be several months of delay and the costs associated with this delay will potentially be more significant.

6.8.6 The issue of risk was considered in the appendices of HS2 Ltd.'s Cost and Risk Model. The issue of geology and potential impact does not appear to have been considered to any significant extent. This will affect both tunnel and surface route; however, the means by which it can be dealt with can be mitigated more effectively with the TBM proposed for the long tunnel. For the viaducts and surface route permanent way encountering a sink hole will result in a halt to construction work while the issue is overcome. In the long term, instability below the surface track due to undiscovered solution features below the formation, potentially destabilised due to the change in surface loading, drainage regime or more direct exposure to weathering could cause ongoing maintenance problems with the permanent way.

6.8.7 The Cost and Risk Model at Appendix C includes a risk to the programme of 'uncertain ground conditions' but this does not appear to adequately address this issue, and neither does the table in Appendix D of the same document. It is therefore concluded that this significant risk has not been adequately dealt with in these estimates.

6.9 Comparative Cost Model

6.9.1 The effectiveness and value of the proposed tunnel alternative can only truly be assessed by consideration of its whole life costs. A detailed quantitative examination of the cost basis is beyond the remit of this report. However, it is possible to assess comparatively and qualitatively the relative impact of the proposals on cost in terms of capital expenditure (CAPEX) and operational expenditure (OPEX) such as set out on Tables 6.3 and 6.4 below.

Table 6.3 Qualitative CAPEX comparison

CAPEX cost	Comparison of Chilterns Long Tunnel Route against Government Proposed Scheme
Land acquisition and permanent rights (incl. compensation)	Lower
Environmental mitigation measures	Lower
Permanent civil works	Higher
Rail systems	Similar

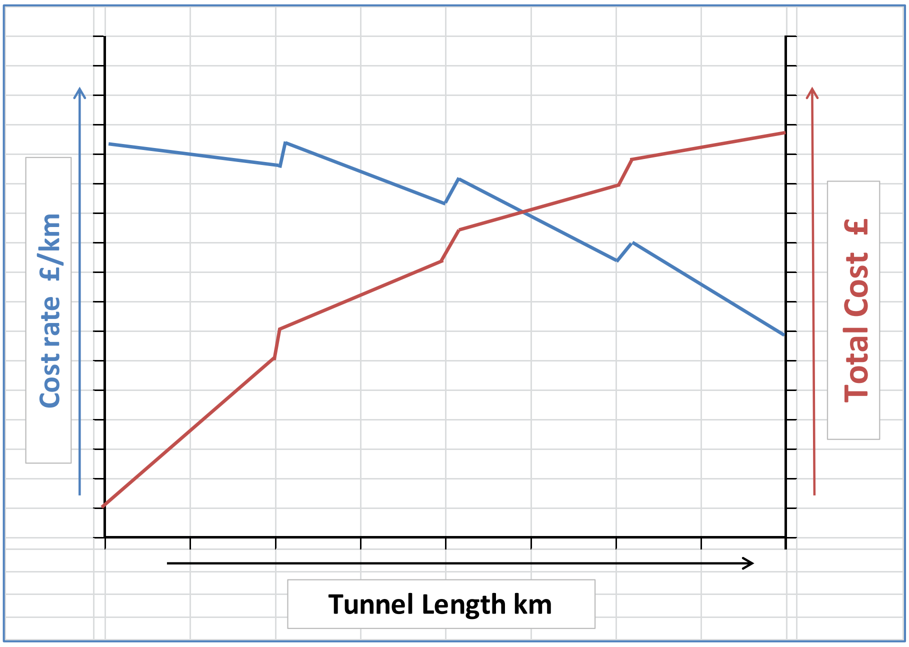
Table 6.4 Qualitative OPEX comparison

OPEX cost	Comparison of Chilterns Long Tunnel Route against Government Proposed Scheme
Traction power	Lower
Maintenance	Similar
Renewals	Lower
Operation	Lower

6.9.2 Against these comparisons must be placed the costs of 'loss of environment' in the government Proposed Scheme. It is for society to judge, perhaps through the Cabinet Office's Natural Capital Committee, whether indeed the costs of permanent and irretrievable 'loss of environment' outweighs the cost of the government Proposed Scheme, which is affecting over 400ha of highly protected landscape. In the past, infrastructure promoters and planners have been all too ready to develop schemes to the detriment of the environment and the permanent and irretrievable 'loss of environment' even though engineering solutions could have been used that would have prevented the loss at a small additional capital cost when considered against the whole life costs. Schemes such as the M40 cutting at Stokenchurch, M27 Brighton Bypass and the M3 at Winchester have all demonstrated the incredible permanent damage infrastructure schemes have on the environment and the chalk landscape in particular, when greater mitigation measures could have been employed to limit the damage had the cost of 'loss of environment' been considered. Conversely, the A3 at Hindhead has demonstrated the tremendous value of delivering major infrastructure with negative 'loss of environment' costs. For the government Proposed Scheme, the cost of 'loss of environment' is very high. This is discussed in the Non-Market Effects Report prepared by Peter Brett Associates and Chilterns Conservation Board, submitted in response to the Environmental Statement and revised recently to reflect the government's Scheme now proposed.

6.9.3 There are some very important considerations that have to be taken into account in estimating the costs associated with long distance tunnels and the provision of the railway in tunnel. There are considerable economies to be achieved in long distance tunnelling and the cost per metre reduces the longer the tunnel, even taking account of elements of infrastructure which have to be added as the length increases, such as number of ventilation shafts. The illustrative graph below in Figure 6.3 shows how the overall rate per km reduces and the rate of change in total cost over any given distance also reduces due to the economy of scale.

Figure 6.4 Change in Cost Rate and Total Cost over increasing Tunnel Length



6.9.4 It is necessary also to consider whole life route cost per metre for a long tunnel compared to the whole life route cost per metre for surface railway. The Chilterns Long Tunnel will be constructed from essentially only two sites, whereas the government's Proposed Scheme involves the costs associated with multiple and long linear sites throughout much of the length of the route through the Chilterns with a single tunnel boring site. The government's Proposed Scheme also requires diversion of major overhead powerlines which can be avoided in the Chilterns Long Tunnel Route.

6.9.5 Arguably the scheme can be amended to reduce the scope in some areas, for example, it is unnecessary to have shafts at 2 km to 3 km centres for the full length of the route. Rather these can be placed at key points along the alignment best for ventilation and emergencies and for access. The number of cross-passages can also be reviewed with a view to reducing scope. For example, a spacing of 500 m has been used on the 9 km long Katzenberg Tunnel in Germany.

6.9.6 As discussed in paragraphs 4.1.15 to 4.1.17 above, rail systems whole life costs are probably cheaper for the tunnel than for the surface, because the systems are protected from the weather which extends their life.

6.9.7 Well-constructed ballastless track (which, by the time these tunnels are fitted out, will be better defined due to the pending Euronorm EN-16432-1 Railway Systems – Ballastless Track Systems) will require significantly less maintenance than ballasted track.It is well suited to semi-automatic inspection and fault detection, such that, as noted in paragraphs 4.1.19 to 4.1.21 the whole life cost of the tunnel track system can be expected to be lower than that for ballasted track.

6.9.8 The cost basis which has been used is the Estimate of Expense dated 15th November 2013. This document provides costs for elements of work associated with HS2 and is a document presented before Parliament. It identifies CAPEX costs only and suggests a total of £19.39bn for Phase One, including contingencies at a P50 level of confidence.

6.9.9 A comparison of costs has been undertaken using this document along with a pro-rata calculation of the options adjusted to examine the relative cost difference between the government Proposed Scheme and Chilterns Long Tunnel Route.

6.9.10 Clearly, it is not practical to challenge the cost basis for the government's Proposed Scheme as this is being used to set fiscal budgets for the project with Government, though it would be possible to do so. In particular the extension of the tunnelling work will result in significant economies of scale. However, the Estimate of Expense cost can be considered to include everything associated with the delivery of that element of works.

6.9.11 Table 6.5 below summarises the costs of each between the portals and equivalent chainage at Wendover. They include anticipated land, road and services diversion costs. The Chiltern Long Tunnel Route is about 100m shorter. Figure 6.5 below indicates the relative costs of the four main components of capital cost and the resulting total using data published by HS2 Ltd, associated with the two schemes being compared.

Table 6.5 Summary of comparative costs

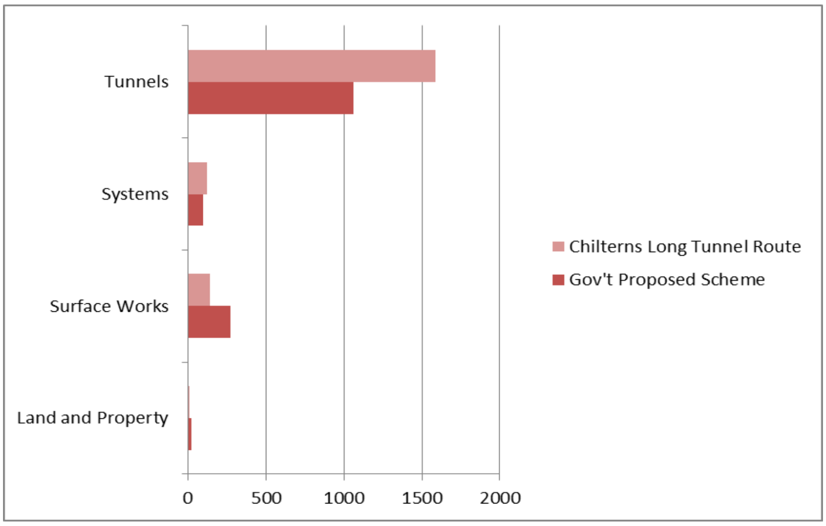
Government Proposed Scheme	Chilterns Long Tunnel Route	Difference
£1.45 bn	£1.85bn	£0.40 bn

Note:

1 The government's Proposed Scheme has recently been quoted by HS2 Ltd as costing £1.29 bn (-11% lower than the above estimate) within the overall budget of £19.4 bn

2 Applying this reduction to the Chilterns Long Tunnel Route could mean a comparative cost of £1.65 bn, the cost represented by the 13% reduction in tunneling cost rate discussed in para 7.9.14 below

Figure 6.5 Costs comparison



6.9.12 The cost base used by HS2 Ltd has also been used in these calculations. It is therefore not surprising that the Chiltern Long Tunnel Route has been estimated to cost more. 85% of the estimated cost of the Chiltern Long Tunnel Route is accounted for by the cost of the tunnelling and the total cost is therefore very sensitive to the unit rates which have been used. For example, the costs are very sensitive to the drive rate for the boring machines and the fixed costs associated with the material handling at each end. The former adds time but the latter depends on the capacity needed to cope with the rate of construction (arisings removed and lining installed). A 13% reduction in this cost due to economy of scale results in a reduction of £200 m in the total cost.

6.9.13 In order to make a true cost comparison then the design refinements and logistics proposals must be considered, the whole life cost of the alternatives must be independently assessed taking into account the protected status of the Chilterns AONB and the non-market effects of the government's Proposed Scheme, in addition to land, property and compensation costs.

6.9.14 The issues raised and discussed in this report can be summarised in a comparison of risks between the government's Proposed Scheme and Chilterns Long Tunnel Route. These are set out in Table 6.6 which applies to the whole of the Chilterns AONB.

6.9.15 This broad overview illustrates the benefit of adoption of the Chilterns Long Tunnel Route on the Chilterns AONB and also the long term operation of the line through this challenging section of the line. These are specific elements for which no detail costs are available and can only be considered subjectively. Therefore it is worth considering the real effect on the long term benefits of High Speed 2 as a result of the additional expenditure perceived by the adoption of the Chiltern Long Tunnel Route.

6.9.16 Overall, the difference in cost presented by the Chilterns Long Tunnel Route represents 1.5 - 2% of the overall construction cost of the HS2 Phase One in a budget currently with a P50 contingency level, that is it is assumed that there is a 50% probability of the estimate being exceeded. However it will be a significant mitigation of the environmental effects of the route through the Chilterns AONB, and avoid extensive compensation costs which are not included in this budget.

Table 6.6 Risk and Impacts comparison

		Assessed Route	
Topic	**Indicator**	**Government Proposed Scheme**	**Chilterns Long Tunnel Route**
Rail alignment	Gradients	H	L
	Curvature	H	L
	Exposure	H	L
	Security	H	L
	Safety	M	L
Rail Systems	Maintenance Liability	H	L
	Journey Time	L	M
	Operational Flexibility	L	M

		Assessed Route	
Topic	**Indicator**	**Government Proposed Scheme**	**Chilterns Long Tunnel Route**
Geology	Stability	H	L
	Ground Movement	M	L
	Groundwater	M	L
Tunnelling	Construction Sites	H	M
	Spoil Handling	H	M
	Imported Materials	M	H
Construction	Unforeseen ground	H	L
	Traffic	H	M
	Weather delays	H	L
	Complex foundations	H	L
	Programme	H	L
	Cost	L	H
Environmental	See Environmental Appraisal at App A	H	L

Risks and Impacts	**In comparison to each whole route**
High	High risk or impact on programme, cost or receptor
Medium	Medium risk or impact on programme, cost or receptor
Low	Low risk or impact on programme, cost or receptor

6.9.17 The risk assessment associated with this budget and set out in Appendix C concludes that the qualitative risk differentiators between the Chilterns Long Tunnel Route and the government's Proposed Scheme show that the long tunnel option has several important risk mitigation advantages, which in summary are:-

- The extra CAPEX cost will not reduce the strength of the Business Case for HS2;
- The higher CAPEX is offset by the lower OPEX;
- The Environmental and Reputation risks to HS2 Ltd are virtually eliminated over the route section considered;
- The technical feasibility and TSI safety compliance of extending the tunnel to the Wendover boundary of the AONB is justified;
- The 4 TBM Tunnelling Strategy for the extended tunnel will not impact on the overall construction programme; and

- The security features required for an extended tunnel are simpler than a surface route

6.9.18 This assessment shows that, in addition to the many other supporting justifications put forward for the Chilterns Long Tunnel Route the risk justification for extending the Chiltern Tunnel to the boundary of the Chilterns AONB at Wendover offers a significant risk mitigation opportunity to the delivery of High Speed 2 Phase One.

7 Environmental, Social and Local Economics

7.1 Introduction

Background

7.1.1 The Chilterns AONB is covered by two forms of designation:

- That recognised by The International Union for Conservation of Nature (IUCN) provides international recognition for the AONB designation, which it places in its Category V - Protected Landscapes and Seascapes; and

- That required by Section 87(1) of the National Parks and Access to the Countryside Act 1949 and Section 82(1) of the Countryside and Rights of Way Act 2000 (the CRoW Act 2000) which define an AONB in England as an area that is not in a National Park but which appears to Natural England to be of such outstanding natural beauty that it is desirable that the protective provisions of Part IV of the CRoW Act 2000 should apply to it for the purpose of conserving and enhancing the area‘s natural beauty.

7.1.2 This protection is currently based on Natural England's six technical criteria for designation of AONBs relating to:

- Landscape quality;
- Scenic quality;
- Relative wildness;
- Relative tranquillity;
- Natural heritage features; and
- Cultural heritage.

7.1.3 The Chilterns AONB was designated in 1965 and satisfies all of these criteria. In 2004 the Chilterns Conservation Board was subsequently set up whose duties under S.87 of the CRoW Act 2000 are to:

i) Conserve and enhance the natural beauty of the AONB; and
ii) Increase the understanding and enjoyment by the public of the special qualities of the AONB.

7.1.4 It is acknowledged that because planning consent is being obtained through an Act of Parliament the CRoW Act 2000 can be overcome. However government should take account of Section 85 of the CRoW Act 2000 places the following general duty on public bodies (including the Government): "85: (1) In exercising or performing any functions in relation to, or so as to affect, land in an area of outstanding natural beauty, a relevant authority (including a Minister of the Crown) shall have regard to the purpose of conserving and enhancing the natural beauty of the area of outstanding natural beauty."

7.1.5 It is also accepted that the status of AONBs and National Parks is equal in planning terms. Paragraph 115 of the National Planning Policy Framework (NPPF) states: "Great weight should be given to conserving landscape and scenic beauty in National Parks, the Broads and

Areas of Outstanding Natural Beauty, which have the highest status of protection in relation to landscape and scenic beauty."

The government's Proposed Scheme compared to the Chilterns Long Tunnel

7.1.6 The government's Proposed Scheme will affect the upper Misbourne valley. The designation of the protected landscape of the Chilterns AONB rests on the unique characteristics of its landscape. The upper Misbourne valley system represents not only a fine example of this landscape but also has the distinction of being different to the other four valley systems which cut through the north west facing scarp slope of the Chiltern Hills – being the highest and least urbanised.

7.1.7 The designation and the unique special qualities of the Chilterns AONB within the upper Misbourne valley are summarised in the following subsections, together with a summary of how these national assets will be irrevocably harmed by the HS2 scheme and how they would substantially benefit from the long tunnel proposals.

7.1.8 Most infrastructure programmes or projects impact on the urban or rural landscape in which they are placed and on the people within them. The impacts which are the subject of this report are those which impact on environmental quality and value of a nationally designated landscape.

7.1.9 The long-term consequent changes to the environment after construction, and the temporal changes as a result of the construction process, will generate considerable direct and indirect adverse impacts on the Chilterns AONB.

7.1.10 In the face of criticisms that the environmental impacts on the Chilterns AONB would be considerable and unacceptable, HS2 Ltd gave an undertaking to consider an investigation into the feasibility of extending the tunnel in the government's Proposed Scheme to the northern boundary of the Chilterns AONB. The purpose of this extension would be to reduce considerably the negative environmental and economic impacts. It was expected there would be an additional cost for a longer tunnel compared with the published surface alignment and this proved to be the case. The conclusion which it reached was that such a tunnel extension was a practical engineering solution.The ES (CFA 9 Central Chilterns) notes that:

"Whilst the extended (tunnel) options are feasible in engineering terms and would have an environmental benefit; there would be a financial cost in extending the bored tunnel".

7.1.11 The decision to have a bored tunnel from the M25 to Little Missenden is in the opinion of HS2 Ltd in recognition of the terrain on this part of the Chilterns. The recognition of its nationally protected status as an AONB was referred to by the Secretary of State when the government decided to place the southern section in a tunnel. This principle is supported. It does, however, raise the question why only one half of the Chilterns AONB is to be protected with a tunnel when the impacts on the remainder of the route in the Chilterns AONB are similar and in some respects worse. The principle should be applied equally to the whole AONB.

7.1.12 This section of the Report is not therefore concerned with the wider harm arising from HS2 which is addressed elsewhere in other petitions, but with the harm arising from the above ground proposals along 10 km of the upper Misbourne valley and the significant environmental, social and local economic benefits of the long tunnel option.

7.1.13 Impacts on the upper Misbourne valley arise from the specific attributes of the government's Proposed Scheme. These include:

- **Major changes to the landform** through cuttings, embankments, acoustic and visual screen mounding, remodelling into adjacent natural levels, deposit of large amounts of surplus soil material, realignment of routeways, green bridges, and tunnel portals
- **Vertical elements** such as gantries, masts, fencing, solid barriers (safety and acoustic)
- **Horizontal elements** such as the track itself, access roads, road and track and path realignments, power supply infrastructure
- **Major new structures** such as the tunnel portals, green tunnels, viaducts, bridges, underpasses
- **Major demolition and disruption** during construction which are avoided in the long tunnel option

7.1.14 These impacts may have a number of effects:

- Elimination of valued assets of the upper Misbourne valley;
- Severance of valued assets, land holdings, social networks and landscape features and connections;
- Permanent and significant adverse effects on the character and appearance of the special qualities of the upper Misbourne valley; and
- Long term temporary effects of construction phase such as compounds, storage and temporary accesses over 8 years

7.2 Environmental Appraisal

The special qualities of Chilterns AONB and the upper Misbourne valley

7.2.1 The Chilterns AONB forms part of a broad belt of chalk running across England. It extends from Goring, where the gap carved through the chalk by the River Thames separates the Chilterns AONB from the North Wessex Downs AONB, to Hitchen and forms the northern boundary of the Tertiary London Basin. The tilting of the chalk has produced a steep escarpment along the north western edge, overlooking the Jurassic clay vales of Oxford and Aylesbury. The dip slope to the south east is dissected by valleys most of which are dry and a few of which almost break through the escarpment to form easy routes across the hills. The Misbourne Valley is a good example of this.

7.2.2 The defining characteristics of the Misbourne valley system are a result of the landform and human intervention. This intervention has left a strong natural and cultural heritage in the valley. In common with many other landscapes it has produced a distinctive pattern of farms, fields, settlements and tracks but within the upper Misbourne valley of the AONB this has led to a favourable balance of landscape features which together have created a landscape of nationally recognised natural beauty.

7.2.3 The value of this landscape is not only confined to its outward appearance. The rich variety of natural and cultural heritage, much of which predates the medieval legacy of agricultural endeavour and ownership, have a significant value in their own right and when taken together form a powerful attraction for locals and visitors. This is demonstrated by the substantial tourist industry and high level of public enjoyment of the Chilterns AONB in general, and in the Misbourne valley in particular.

7.2.4 The significance of the hill tops and valley sides on each side of the Misbourne valley system lies in the fact that the landscape evolved very slowly over a long time in areas where colonisation was piecemeal. These hilltops reflect the local diversity of relief and soils, generating a small-scale character to the patchwork of hedged fields and woodlands, tiny winding lanes, and dispersed settlement pattern. This was typical in upland areas that were heavily wooded and clearance was often very late.

7.2.5 The network of smaller lanes, tracks and holloways running up and along the valley sides is also clear by 1620 and today forms part of the labyrinth of single track lanes such as Leather Lane and Bowood Lane which are typical of the Misbourne valley. These lanes and tracks are deep, high-sided, over hung with tree tunnels and edged with ancient coppiced wood banks. Many have been there, like the hedgerows, for a thousand years and have been measured according to their botanical richness. Some, like Kings Lane between Kings Ash and The Lee follow the ancient Parish Boundary.

7.2.6 The upper Missenden valley north of Little Missenden escaped the worst of the suburbanisation with Wendover and Great Missenden having comparatively modest growth, allowing them to maintain their village status. Residential growth had already been concentrated in Prestwood and South Heath on the old commons previously dissolved by parliament. The presence of Missenden Abbey, founded in 1133, and its surrounding parkland restricted new development to the south and east of the village.

7.2.7 The current landscape on the modern OS maps still shows a dispersed settlement pattern on the valley sides and hill tops with grander houses, tiny hamlets and individual farmsteads remaining very much where they were located on the 1620 map.

Environmental Effects

7.2.8 This section highlights the main adverse environmental effects of the government's Proposed Scheme on the upper Misbourne valley and how the Chilterns Long Tunnel Route would not only avoid these effects but ensure that the long term purposes of this part of the Chilterns AONB are fulfilled. The adverse impacts include, but are not limited to, those referred to in this Section. The benefits of the long tunnel include, but similarly are not limited to, the avoidance of these adverse impacts.

7.2.9 Some minor changes will arise from the Chilterns Long Tunnel Route such as the need for 3 additional ventilation shafts. The effects of a fire fighting point/intervention facility with access have also been considered. The underground fire fighting point has major benefits in environmental terms.

A) Effects on Landscape quality

7.2.10 The special landscape qualities of the upper Misbourne Valley include its shallow wide bottomed chalk valley indented with smaller dry valleys and undulating valley sides in the steeper middle and upper reaches; the narrow gently flowing meandering Misbourne river; the larger scale arable fields on the valley sides with small fields under pasture, rough grassland and paddocks in the valley floor; the woodland on the higher slopes and in some narrow dry valleys; its historic landscape field patterns including parkland and other large estates; the sunken and high banked lanes; the dense matrix of hedgerows and tree lines; and its rural settlement pattern.

7.2.11 The Missenden valley is the longest of the five valleys that pierce the hills. It is the highest valley with a col height of 157m, compared with 145m on the Gade Valley at and 140m on the Wye Valley. It breaches the scarp between the two highest points in the Chilterns at Wendover Woods at a height of 267m on one side and at Coombe Hill at a height of 260m on the other. It is also the least urbanised and the only one that remains predominantly rural along its length. This is reflected in the 16km of valley that is within the Chilterns AONB almost double the length of that in any of the others.

7.2.12 For most of the protected landscapes of the Chilterns AONB agriculture and woodland forms one of the key land uses that have shaped it in the past and continue to influence its nature and character as described in Chilterns AONB Management Plan 2013 to 2018. The mosaic of farms, woodland and rural settlements is an essential element of the character of the upper Misbourne Valley. The HS2 Environmental Statement identifies most of the agricultural land as Grade 2 or Grade 3a which, together with Grade 1, NPPF classifies as the 'best and most versatile agricultural land' to be protected under national planning policy.

7.2.13 The effect on scenic quality and natural beauty of the upper Misbourne valley is considered below. This section summarises the main effects on the part tunnel option on the landscape elements that define the distinctive character and appearance of the landscape.

7.2.14 **Smooth undulating valley sides**: These will be permanently broken up and altered by the introduction of large scale bunding and mounding; steep and high unnatural embankments to carry lanes, footpaths, farm accesses over the track for example between Springfield Farm and Havenfield Wood; and deep cuttings for example at Jones' Hill, Bowood Lane and Mantles Wood.

7.2.15 **Flat plateau tops and dry valleys**: These are severely affected by the creation of very large permanent soil storage mound (covering an area of up to 38ha) south of Hunts Green Farm and a further 0.5Mm^3 (1M tonnes) at South Heath; and linear features cutting through and terminating side dry valleys of uncharacteristic uniform design; .

7.2.16 **Misbourne river and valley floor**: The route crosses the valley floor south of Wendover between Smalldene and Wendover Dean and introduces 2 long viaducts and high embankments. It passes in and out of the saturated zone with associated risk of interference with the aquifer, that is water flow and quality, and River Misbourne which is an internationally recognised chalk stream.

7.2.17 **Woodlands and trees**: The government's Proposed Scheme would result in the elimination of 18 ha of woodland (including 10.2 ha of ancient semi-natural woodland). There would be a loss of woodland skylines for example at Mantle's Wood and Sibley's Copse. The landscape and wildlife quality of remaining woodland will be fragmented and severed. Damage will occur to woodland from the increased effect of wind blow, dust, air pollution, vibration, and hydrological changes. Innumerable hedgerow and individual mature trees would require felling leaving a wide treeless corridor.

7.2.18 **Field patterns**: Temporary soil storage and permanent long bunded earthworks cut across historic field patterns for example between Smalldene and Mantles Wood and another near the B485. A permanent very large soil storage mound on fields south of Hunts Green Farm affects a large land holding. The part tunnel route cuts across the grain of the landscape with no respect for historic field patterns severing fields and hedgelines leaving isolated corners disconnected with the adjacent landscape.

7.2.19 **Sunken rural lanes**: Lanes are truncated and raised on steep embankments or realigned as at Leather Lane. In many cases sunken lanes are severed from the historic landscape setting. Modern utilitarian bridges with parapets replace the narrow lanes with soft verges and hedged banks.

7.2.20 **Rural settlement pattern**: In addition to the total loss of 19 individual properties, the part tunnel option decimates the rural setting of the settlement through which it passes. The worst examples of this are around Hyde Farm, South Heath, Potter Row, Hunts Green Farm and Wendover Dean.

7.2.21 All of the above adverse impacts and many more can be completely avoided by adopting the Chilterns Long Tunnel Route.

B) Effects on Scenic quality

7.2.22 The special scenic qualities of the upper Misbourne valley include the combination of prominent wooded skylines and horizons which contain the valley landscape; open dry and river valleys; field and settlement pattern; extensive views over the valley floor and over the surrounding hills from upper slopes; visual enclosure within the valley floor; sequential views of the natural beauty of the upper Misbourne valley; and a high level of access to enable enjoyment of the scenic qualities. Local small scale intrusive elements and even the single pylon line along part of the upper Misbourne valley do not urbanise the landscape or substantially detract from the natural beauty of the area.

7.2.23 The outstanding natural beauty of the Chilterns is why it is designated and why it is protected under government planning policy. It is a fragile quality, easily lost, even when the individual elements of the landscape are retained. It is impossible to conserve the current scenic quality of the upper Misbourne valley if the government's Proposed Scheme is adopted. The following are some of the significant adverse effects which could be avoided altogether with the Chilterns Long Tunnel option.

7.2.24 **Visual impacts of permanent soil storage mounds and bunds**: these are on a very large scale affecting open hillsides such as, but not limited to, at Mantle's Farm (750m long), Hyde Farm (three very large mounds either side of the track); and Hunt's Green Farm (an enormous mound 1km by 400m). Even with landscaping these are of such a scale and of such an artificial form that they will be visually intrusive and incongruous.

7.2.25 **Visual impacts of cuttings and embankments**: These are currently small elements in the upper Misbourne valley landscape created by the alignments of the A413 and Chilterns rail line. Chalk cuttings and embankments are very visually prominent and take a long time, if ever, to merge into the landscape (see the M40 cutting at Stokenchurch). The government's Proposed Scheme results in a 10km series of these most of which are steep, and of a considerable scale. Such scarring of the landscape will be large scale and largely permanent.

7.2.26 **Visual impacts of engineering and built structures**: The government is being urged to adopt the highest standard of design in all locations along the HS2 route, no more so than within sensitive scenic landscapes such as the Chilterns AONB. This is the better-case scenario, with a potential worst-case should good design not be funded. However, even under the better-case scenario, these structures cumulatively will significantly detract from the scenic quality of the upper Misbourne valley. These structures, by necessity, are very large and completely out of scale with the natural beauty of the upper Misbourne valley. Permanent examples include two viaducts 500m long and up to 26m high (including gantries) at Durham Farm and across the A413 at Smalldene; the tunnel portal at Mantle's Farm, two portals at South Heath, and a further two portals either end of the Wendover cut and cover tunnel; several modern overbridges with their embankments, parapets, new alignments; track and gantries; an as yet unknown number of telecommunication masts. Temporary but long term examples include several compounds, road and path diversions, storage stockpiles, heavy traffic, and construction equipment all of which will scar the landscape for several years. The best-case scenario, the long tunnel option, will avoid this.

7.2.27 **Visual impacts of mitigation measures**: These are regarded as a benefit by HS2 but often destroy the very features that make an important contribution to the distinctive natural beauty of the upper Misbourne valley. Examples include noise barriers; the planting up of open dry valleys such as at Mantle's Farm; and large scale planting to try and hide bunds, highway infrastructure, mounds, and embankments such as at Hyde Farm. These reflect the shape of the infrastructure associated with the government's Proposed Scheme, not the natural beauty of the landscape composition. The Chilterns Long Tunnel conserves the natural composition and has the benefit of avoiding extensive, inappropriate, mitigation.

C) Effects on Tranquillity

7.2.28 Tranquility is becoming increasingly difficult to find in the south of England. The AONBs were designated to conserve and enhance remaining tracts of land noted for this quality, often in close proximity to major urban areas and major infrastructure such as our motorways. The Chilterns AONB is one such area now under threat. The upper Misbourne valley is noted for its high level of tranquillity, seclusion and unspoilt rural character on the middle and upper slopes away from the A413 corridor. The government's Proposed Scheme will run through this sensitive area, not the more disturbed road corridor on the valley floor. It will introduce structures (tunnel portals, viaducts, raised track section etc) which, however well designed, will still be visually and aurally intrusive and incompatible with the quiet secluded valley sides of the upper Misbourne valley.

7.2.29 The Chilterns Long Tunnel Route would leave the majority of this stretch of the upper Misbourne valley totally untouched by visually intrusive engineered structures or invasive noise, retaining sections of quiet secluded sunken lanes, footpaths, small rural hamlets, woodland and fields undisturbed. The visual impacts of the ventilation shafts are small and easily mitigated.

7.2.30 The effects of loss of tranquillity are not just felt locally where the difference can be directly perceived. It blights a whole area, deterring visitors, affecting the local community where the quiet seclusion of the area is its major asset. The Chilterns Long Tunnel and the underground fire fighting point would avoid this altogether.

D) Effects on Natural Heritage

7.2.31 The special natural heritage qualities of the upper Misbourne valley include ancient and semi-natural woodlands; mixed, broadleaved and coniferous woodlands of significant biodiversity and ecological value; calcareous grassland on the upper slopes; ponds associated with farmsteads and small villages; a matrix of historic and species rich hedgerows and tree lines; SSSIs; local wildlife sites; the River Misbourne recognised as an internationally valued chalk stream.

7.2.32 In addition, the valley contains a number of Biodiversity Opportunity Areas (BOAs) - recognised as key areas within the county for achieving a landscape-scale approach to conserving biodiversity. These BOAs provide the best opportunity to fulfil the Lawton principles of 'more, bigger, better and joined', which form a key part of the Government's 2011 Natural Environment White Paper.

7.2.33 In contrast, the government's Proposed Scheme will directly destroy 18ha of woodland including 10.2ha of ancient semi-natural woodland; over 200 mature and veteran trees outside woodland; 41km of hedgerow including 5.6km of important and historic hedgerow; lead to the loss of the entire barn owl population within a 3km wide corridor and severely restrict wildlife movement essential for survival. Fragmentation and isolation of habitats will lead to further biodiversity loss.

7.2.34 The Chilterns Long Tunnel and the underground fire fighting point would avoid these losses altogether.

E) Effects on Cultural Heritage

7.2.35 The land through which the government's Proposed Scheme is planned to pass is remarkably rich in important cultural and historic features of ancient origins and is part of the history of Southern England. The special cultural heritage qualities of the upper Misbourne valley include strings of historic hamlets, larger villages and farmsteads along the valley floor; distinctive listed churches; listed buildings; historic parkland; scheduled monuments, roman villas and historic earthworks and other archaeological remains; ancient valley floor routeways linking the Chiltern towns of Amersham to Wendover; a network of historic minor sunken lanes, trackways and paths including national and regional trails; ancient woodland and field patterns dating back to medieval times that form the backdrop of a truly historic landscape.

7.2.36 The government's Proposed Scheme passes directly through or within the setting of many features of cultural heritage. Other sites lie relatively nearby and are in danger of damage, and indeed complete loss, during the broader scale HS2 works. If these are demolished or damaged their loss is a national loss of heritage and not just a local misfortune.

F) Effects on Public enjoyment

7.2.37 There are 55 million leisure visits to the Chilterns every year, making this one of the most popular protected landscapes in the world (Chilterns AONB Visitor Survey 2007).The Chilterns countryside is highly valued for the wide variety of recreational opportunities it offers, which includes walking, cycling and horse-riding, gliding, canoeing and bird watching.

7.2.38 It is evident from local authority surveys that the Chilterns countryside is visited and enjoyed by most of its residents. The Chilterns has an extensive rights of way network and is nationally recognised for its walking, with several promoted trails passing through the Chilterns, including the Ridgeway National Trail and the Thames Path National Trail. The Misbourne Valley is also an important visitor destination, with high volumes of day visits from London and the urban areas adjacent to the Chilterns AONB. The excellent existing rail and London underground links make this the most visited protected landscape in England.

7.2.39 There are many promoted routes passing through the Misbourne Valley and these are some of the most heavily used routes due to their accessibility to London and other major towns in the South East. More than 200 walks and rides leaflets are featured on the Chilterns AONB website.

7.2.40 The Misbourne Valley is used by a large number of groups for walking, cycling, geocaching, orienteering and other countryside-based activities. There are many affiliated clubs based in and around the Chilterns AONB, and it also attracts large numbers of groups from outside the area for day visits. There are 10 health walk programmes in the Misbourne Valley organised by Simply Walk, which generated 7,000 health walk attendances in 2012/13.

7.2.41 A recent report: The Volume and Value of Tourism in the HS2 Corridor of the Chilterns AONB (TSE Research Services, February 2015, commissioned by the Chilterns Conservation Board), provided the results of an audit of the main tourism assets within and close to the HS2 corridor. This corridor is about 190 sq. km and the Chilterns AONB is 833 sq. km. The results of the audit established that just over 2.3 million tourists visited the HS2 corridor area in 2013 with a further 2.2 million visits by local people.

7.2.42 It is clear that the government's Proposed Scheme will have a significant damaging effect on the public enjoyment of this well visited valley both during the construction period and throughout operation. In contrast, the Chilterns Long Tunnel would largely avoid any disruption to public enjoyment.

G) Effects on Local Economy

7.2.43 It is estimated that the government's Proposed Scheme will require over 400ha of land during construction, over 200ha permanently of which 194 are currently productive farmland. It is not only loss of land that will impact farming profitability and, indeed, viability. Fragmentation of land holdings making machinery and stock movement difficult; loss of economies of scale for both individual farm businesses and farm contractors; long term 'temporary' loss of land used for soil and material storage before adequate restoration to agricultural use is possible will all contribute to significant negative impacts on the farming community. It is likely that a number of farm businesses will not survive as a result.

7.2.44 The Tourism report mentioned above, while not estimating the impact of HS2, shows that tourism income at risk amounts to about £80 million per annum. This amount excludes the income generated by local visitors to tourist attractions who are already residents of the Chilterns AONB. The report estimates that a further 2.2 million visits a year are made by local residents who spend a further £14 million a year, or £25 million a year with multiplier effects, on local goods and services during their recreational visits. In addition, tourism expenditure supports approximately 2,800 jobs in the HS2 corridor within the Chilterns AONB.

7.2.45 Besides the agricultural and tourism industries, many other local businesses and trades will suffer damage as a result of the construction of the government's Proposed Scheme. In addition, local residents' travel to work will be disrupted and property values will be blighted. These impacts are the subject of a number of other studies and reports and are, therefore, not covered in detail here.

7.2.46 The Chilterns Long Tunnel would largely avoid any disruption to the local economy.

7.3 Conclusion

7.3.1 In addition to the descriptive assessment set out above, a SIFT Assessment has been carried out on the environmental effects as set out in Appendix A, which summarises this appraisal. This clearly demonstrates that the Chilterns Long Tunnel Route is a significant improvement in environmental terms to the government's Proposed Scheme through the Chilterns. Whilst the short-term increase in construction traffic for moving tunnel arisings from additional ventilation shafts by road is assessed as a minor worsening this could be completely avoided by adopting an alternative method of disposal. Overall the Chilterns Long Tunnel Route is a major improvement against the majority of key sustainability themes;

- Natural and cultural resource protection and environmental enhancement;
- Creating sustainable communities; and
- Sustainable consumption and production

7.3.2 It can be concluded therefore, with a high degree of certainty, that the Chilterns Long Tunnel Route offers the best solution to the protection of the Chilterns AONB.

References

1. TSI 2008/163/EC - Safety in Railway Tunnels in the trans-European conventional and high-speed rail system

2. Engineering Review of the Continuous Tunnel (Peter Brett Associates, November 2012; CCB contribution) (Commissioned by Conserve the Chilterns Countryside)

3. Proposal for the Chilterns Tunnel Extension (the CRAG option) Chiltern Ridges (HS2) Action Group, December 2013

4. Edmonds, C.N. (2008). Karst and mining geohazards with particular reference to the Chalk outcrop, England. Quarterly Journal of Engineering Geology and Hydrogeology, Volume 41, pp 261-278.

5. Morigi, A. N., Woods, M. A., Reeves, H. J., Smith, N. J. P. & Marks, R. J. (2005) Geology of the Beaconsfield district – a brief explanation of the geological map Sheet 255 Beaconsfield. British Geological Survey, Keyworth, Nottingham.

6. Ineson, J. (1962) A hydrogeological study of the permeability of the Chalk. Journal of the Institute of Water Engineers, Volume 16, pp 449-463.

7. Catt, J. (2010) Hertfordshire Geology and Landscape J Catt (ed) Published by Hertfordshire Natural History Society

8. Mortimore, R.N. 2012. Making Sense of Chalk. The 11th Glossop Lecture. Quarterly Journal of Engineering Geology and Hydrogeology, 45, 251-334.

9. Warren, C. D. & Mortimore, R. N. 2003. Chalk engineering geology – Channel Tunnel Rail Link and North Downs Tunnel. Quarterly Journal of Engineering Geology and Hydrogeology, 36, 17-34

10. Newman, T. G., Allen, R. G., Mortimore, R. N., & Moore, R. J. 2003. The application of Geological Modelling with the Observational Method to identify and manage ground hazards for tunnelling on the Ramsgate Harbour Approach Road. Quarterly Journal of Engineering Geology and Hydrogeology, 36, 35-50

11. High Speed Rail (London – West Midlands): Estimate of Expense, In Parliament Session 2013-14, dated 15 November 2013 and HS2 supporting Abstract.

12. High Speed Rail in the Chilterns Little Missenden to Wendover: An assessment of the non-market effects of the Proposed Scheme compared to the Alternative Proposal – Volume 1 (Peter Brett Associates, November 2013; CCB contribution) (Commissioned by Conserve the Chilterns Countryside)

13. High Speed Rail in the Chilterns Little Missenden to Wendover: An assessment of the non-market effects of the Proposed Scheme compared to the Alternative Proposal – Abstract (Prepared by CCB based on references 14 and 15 (September 2013))

14. High Speed Rail in the Chilterns: Feasibility Study of Alternative Tunnelling Options (Peter Brett Associates, April 2014) (Commissioned by Chiltern District Council)

15. Modern Railway Track 2nd Edition (Dr Coenraad Esveld, 2001)

16. Written Statement to Parliament from DfT and RT Hon Justine Greening MP, High Speed Rail (January 2012)

Appendix A Environmental Appraisal

A.1 Background

A.1.1 The Appraisal of Sustainability (AoS) process was devised by Temple Group, in conjunction with HS2 Ltd and in consultation with Government departments and agencies, as a way of appraising how HS2 would support or conflict with objectives for sustainable development.

A.1.2 The AoS approach was first established in 2009 to assist the appraisal and development of the Phase One proposals. Its use continued during the evolution of the Phase Two scheme. Throughout this time the AoS formed a key part of the “sifting process”, helping to:

- Advise engineers and HS2 Ltd during scheme design of particular sustainability constraints and opportunities;
- Inform the engineers in refining scheme proposals to avoid or lessen potential adverse effects;
- Advise HS2 Ltd at key decision stages of the relative sustainability advantages and disadvantages of different options, and the consequence of potential impacts; and
- Formally report the sustainability impacts of the options at each stage.

A.1.3 The AoS is founded on four overarching sustainability priorities. These derive from the government priorities that were set out within the 2005 UK Sustainable Development Strategy: Securing the Future.

A.2 Purpose

A.2.1 The AoS framework and method referenced for the assessment was provided in Appendix B of the Sustainability Statement of HS2 Phase Two, HS2 Ltd.(July 2013). This is an updated methodology from the original AoS undertaken for Phase One in 2011 and therefore is appropriate for this assessment

A.3 Method

A.3.1 This is a qualitative strategic appraisal using key sustainability themes namely:

- greenhouse gas emissions and climate change;
- natural and cultural resource protection and environmental enhancement;
- creating sustainable communities; and
- sustainable consumption and production.

A.3.2 An example AoS assessment undertaken by HS2 Ltd in relation to Hartwell House was reviewed prior to completing the assessment of the Chilterns Long Tunnel in comparison with the HS2 Proposed route through the Chilterns.

A.3.3 The information presented in relation to the likely effects of the government’s Proposed Scheme is based on published data and principally the HS2 Phase One Environmental Statement. The assessment of the likely effects of the proposed Chilterns Long Tunnel Route is based on professional judgement, publically available data, site visits and local knowledge. It also draws on the information and appraisal set out in Section 7 of this report.

A.3.4 The assessment is a qualitative comparison between options using the sustainability themes and topics as defined by the AoS framework. The options are assessed comparatively for effects arising in construction and the years following in operation.

A.3.5 The comparison of the effects are then defined qualitatively using the following criteria;

Colour code and symbol	Definition
- -	Major worsening on the Comparator Scheme
-	Minor worsening on Comparator Scheme
O	Neutral / no change to Comparator Scheme
+	Minor improvement on Comparator Scheme
+ + +	Major improvement on Comparator Scheme
N/A	Not applicable

A.4 Key Issues

A.4.1 The proposed Chilterns Long Tunnel follows the government's Proposed Scheme as far as Great Missenden, crossing under the River Misbourne at Chalfont St Giles and again at Shardloes Park. The route then diverges vertically but on the same line horizontally as the government's Proposed Scheme under the B485 Chesham Road and Leather Lane. It then diverges horizontally westwards to cross the A413 at the Firecrest at Wendover Dean and heads towards Bacombe Hill passing Wendover to the North Portal at Ch 55+600. It then continues on the surface to rejoin the government's Proposed Scheme at Ch 57+000.

Permanent vs Temporary effects

A.4.2 The most significant difference between the government's Proposed Scheme and the Chilterns Long Tunnel Route is the type of the effects identified. In general the Chilterns Long Tunnel Route removes the permanent adverse effects of the government's Proposed Scheme in operation which include loss of ancient woodland, severance, noise, water and landscape impacts.

Construction Phasing, duration and activities

A.4.3 A comparison of the likely construction effects for both of the alternatives has been a key consideration for this study. In order to assess these, certain assumptions regarding the construction activities that will occur and their phasing and duration have had to be made.

A.4.4 It is estimated that the Chilterns Long Tunnel Route option would take 65 months to construct through the Chilterns in comparison to the government's Proposed Scheme taking 63 months. A significant difference between the two options however would be the majority of the Chiltern's Long Tunnel new tunnel sections construction would be undertaken underground with surface activity at discrete locations and predominantly at the north portal site. See comments on section 6.7 and if necessary remove and PBA must argue the case at the select committee which will be difficult.

Working hours

A.4.5 The assessment of the government's Proposed Scheme assumes a 10-hour working day. The majority of the construction activity will be at the surface and will involve extensive excavation and working of up to 400ha of land.

A.4.6 In comparison, the Chilterns Long Tunnel Route will involve both daytime and night time working, however the night time working will be limited to activities within the tunnel and therefore not audible at the surface and to mechanical handling of arisings and tunnel lining segments at the north portal (and within its associated construction compound), which will avoid off-site activities and will be unlikely to result in increased noise levels at residential properties.

A.4.7 It has been assumed that the construction of the tunnel portal would follow the same 10-hour work day pattern. It has been estimated that it will take 18 months to construct the 300m portal and incorporated Nash Lee Road over bridge.

A.4.8 In comparison, in the environmental statement (CFA 10, Sect 2.3) it has been estimated that it will take 39 months to construct the proposed 1.3 km Wendover Green Tunnel and north cutting following diversion of major overhead power lines. Within this time it is also programmed to construct the Nash Lee Road over bridge or diversion over an 18 month period, increasing the concentration of activity in the equivalent area of the Chilterns Long Tunnel north portal.

A.4.9 Thus, the HS2 proposal would expose nearby sensitive receptors to noise impacts for a longer period.

Disposal of Spoil

A.4.10 In considering the tunnel solution, the disposal of spoil from the TBM at the northern portal and potential options to avoid the use of road transport, which would have to travel through Stoke Mandeville and Aylesbury, have been considered for feasibility, however for the purposes of the assessment a “worst case scenario” of transport by road has been shown in the SIFT table (Table E.1 below).

A.4.11 Since 1965 Cemex (and its predecessors) have been operating a chalk slurry pipeline from the Chilterns near Dunstable to its cement works at Rugby. Such a pipeline could be laid to Calvert, approx. 20 km northwards along the trace of HS2, for disposal.

A.4.12 Transport by rail along the Chiltern Line to Calvert or elsewhere, subject to planning consent and permitting requirements, is also a possibility.

A.4.13 There is a realistic possibility that the tunnel spoil could in fact be transported by rail or via a pipeline (as discussed in section 6.4 of this report) but both these options would need to be assessed further.

Construction traffic

A.4.14 The most significant adverse effects of the Chilterns Long Tunnel Route construction would be those related to the additional HGV traffic through Stoke Mandeville and Aylesbury. If the tunnel arisings are removed by road it is predicted that this will result in approximately 300 one way lorry movements per day past Stoke Mandeville and through Aylesbury on the A413 and associated major roads. This is in addition to the vehicle movements required to construct the ventilation shafts and fire fighting point which will be about 260 lorries per day, but over a shorter period of time. This is compared to the road traffic predicted for the government's Proposed Scheme, where the ES assumes the majority of the earthmoving traffic, about 200,000 large off road vehicles, will be along the trace of the line within the Chiltern's AONB.

A.4.15 These additional trips have the potential to increase noise levels, vibration levels, and traffic congestion and to deteriorate local air quality. However, it is anticipated that the increases in air emissions will not result in a significant effect on the Aylesbury AQMA and do not represent any significant worsening of the impacts predicted for the government's Proposed Scheme.

A.5 Conclusion

A.5.1 The table clearly demonstrates that the Chilterns Long Tunnel Route is a significant improvement in environmental terms to the government's Proposed Scheme through the Chilterns. Whilst the short-term increase in construction traffic for moving tunnel arisings by road is assessed as a minor worsening this could be completely avoided by adopting an alternative method of disposal. Overall the Chilterns Long Tunnel Route is a major improvement against the majority of key sustainability themes;

- Natural and cultural resource protection and environmental enhancement;
- Creating sustainable communities; and
- Sustainable consumption and production

Table A.1 SIFT Assessment Table

		Location:	Between Chainage: Ch.31+300 and Ch.57+000,		
		Option name and description			
		OPTIONS CONSIDERED	**A**	**B**	
		OPTION DESCRIPTION	The **HS2 Government's Proposed Scheme**: 1 bored tunnel (13.2km) and 11km of surface works in AONB including 2 green tunnels (approx. 1km each).	The **Chiltern's Long Tunnel Route**; 1 continuous bored twin tunnel of 24.2 km and 500m of surface works at north portal	
Key Sustainability Theme	**Related ES Topics**	**Stage:**	**Qualitative Impact Description And/or Quantitative assessment**	**Qualitative Impact Description And/or Quantitative assessment**	**Rating**
Greenhouse Gas emissions and climate change	Traffic and transport	Construction	Lorry movements throughout the Misbourne Valley (CFA 9 & 10) totalling an average of 300 hgvs per day and peaking at 440 hgvs per day for about 3 years, a total of about 230,000 HGV trips. These vehicles have to access the valley past Stoke Mandeville and through Aylesbury on the A413 and associated major roads. Overall movement of 12m tonnes of soil within the surface works resulting in about 200,000 movements of large off road earthmoving equipment with consequent greenhouse gas emissions.	The tunnel boring machines are electrically driven. The tunnel arisings may be taken off site by road. This is calculated as being 300 HGV round trips per day, plus localised works at ventilation shafts resulting in 280 two way HGV trips (based on ES figures). Likely to be more construction traffic through Stoke Mandeville throughout the construction period. This will likely result in an additional 1 lorry a minute past Stoke Mandeville and through Aylesbury on A413 and associated major roads. Transport of arisings by pipeline or rail will significantly reduce this. No construction CO_2 emission calculation has been undertaken.	-

		Location:	Between Chainage: Ch.31+300 and Ch.57+000,		
		Option name and description			
		OPTIONS CONSIDERED	**A**	**B**	
		OPTION DESCRIPTION	The **HS2 Government's Proposed Scheme**: 1 bored tunnel (13.2km) and 11km of surface works in AONB including 2 green tunnels (approx. 1km each).	The **Chiltern's Long Tunnel Route**; 1 continuous bored twin tunnel of 24.2 km and 500m of surface works at north portal	
		Operation	The proposed route is anticipated to result in significant reductions in car trips (nation-wide) and consequently result in significant CO_2 emission savings.	The proposed route would provide the same benefit in terms of overall CO_2 emission savings I.e. it would not affect the number of car trips reduced.	**O**
	Water resources and flood risk	Construction	Potential impacts on groundwater from piling for structures into weathered chalk and likely solution features The construction of new surface water attenuation ponds and infiltration basins increase risk of opening pollution pathways to ground and ground water.	Controlled grouting as necessary ahead of tunnel boring to minimise effects on groundwater. No need for surface water attenuation or infiltration.	+
		Operation	Surface route requires the creation and maintenance of a series of attenuation ponds and infiltration basins for surface water drainage.	No need for surface water attenuation or infiltration.	+
Natural and cultural resource protection and environmental enhancement	Cultural Heritage	Construction	Listed buildings affected by adjacent operations Loss of 1 Scheduled Ancient Monument	Significantly reduced impacts on listed buildings (setting only) and no loss of scheduled ancient monuments	+++
		Operation	10.2 ha. area of Ancient Woodland affected 13 historic sites impacted (Listed buildings and Scheduled Ancient Monuments)	No (0 ha) Ancient Woodland directly affected. No listed buildings directly affected No additional1 listed building indirectly affected potential slight	+++

Location:			Between Chainage: Ch.31+300 and Ch.57+000,		
Option name and description					
OPTIONS CONSIDERED			**A**	**B**	
OPTION DESCRIPTION			The **HS2 Government's Proposed Scheme**: 1 bored tunnel (13.2km) and 11km of surface works in AONB including 2 green tunnels (approx. 1km each).	The **Chiltern's Long Tunnel Route**; 1 continuous bored twin tunnel of 24.2 km and 500m of surface works at north portal	
				effect on the setting of Wellick Farm Grade II listed building) No scheduled ancient monument affected No additional areas of archaeological interest affected	
	Ecology	Construction	Major impacts on ecological habitats along whole Misbourne Valley and near Stoke Mandeville	Localised Much reduced impacts from ventilation shaft construction, and construction compound at portal sites.	+++
		Operation	Major permanent impacts on ecological habitats along whole Misbourne Valley and near Stoke Mandeville Biodiversity Opportunity Areas affected permanently SSSIs affected permanently Significant permanent effect on Barn Owls	No Biodiversity Opportunity Areas affected permanently No SSSIs affected permanently No permanent effect on Barn Owls The Chilterns Long Tunnel Route will have some local impacts on ecological receptors in the vicinity of Nash Lee at the location of the Northern Portal and surface section. At this location however, the surface Chilterns Long Tunnel Route is very close to the government's Proposed Scheme and therefore ecological impacts	+++

Location:			Between Chainage: Ch.31+300 and Ch.57+000,		
Option name and description					
OPTIONS CONSIDERED			**A**	**B**	
OPTION DESCRIPTION			The **HS2 Government's Proposed Scheme**: 1 bored tunnel (13.2km) and 11km of surface works in AONB including 2 green tunnels (approx. 1km each).	The **Chiltern's Long Tunnel Route**; 1 continuous bored twin tunnel of 24.2 km and 500m of surface works at north portal	
				will be very similar to those already assessed in the HS2 ES.	
	Landscape and Visual Assessment	Construction	Major impacts on views along whole Misbourne Valley	No major impacts on views along whole Misbourne Valley Localised impacts from ventilation shaft construction, and construction compound at portal sites	+++
		Operation	Major permanent impacts on views along whole Misbourne Valley This route includes 8,870m of track at surface level within the Chilterns AONB. The visibility of the route within the AONB is expected to be significant **for 60 years** despite the proposed mitigation planting. Sustainable placement of 1m cu.m. material will affect the landscape with local deposition up to 3m high. Mitigation screening along the route also permanently changing the landscape.	This route includes 405m (the ventilation shafts and north portal) on the surface within the Chilterns AONB. The visibility of the route within the AONB is minimal and with the proposed mitigation is considered to be not significant. No need for placement that material within the AONB	+++
	Land quality	Construction	12m tonnes of excavation arisings.	3.2m tonnes of excavation arisings.	+
		Operation	Area of surface disturbance within Chilterns AONB 419 ha. Sustainable placement of surplus excavated	Area of surface disturbance within Chilterns AONB 47ha. Tunnel arisings can be used in	+++

Location:			Between Chainage: Ch.31+300 and Ch.57+000,		
Option name and description					
OPTIONS CONSIDERED			**A**	**B**	
OPTION DESCRIPTION			The **HS2 Government's Proposed Scheme**: 1 bored tunnel (13.2km) and 11km of surface works in AONB including 2 green tunnels (approx. 1km each).	The **Chiltern's Long Tunnel Route**; 1 continuous bored twin tunnel of 24.2 km and 500m of surface works at north portal	
			material within the AONB, permanently altering the landscape and agricultural quality of the land.	backfill of voids or for cement making. No sustainable placement in the AONB	
Creating sustainable communities	Community.	Construction	Major impacts on communities along whole Misbourne Valley	Localised impacts from ventilation shaft construction, predominantly close to the A413. Most activity situated between Wendover and Stoke Mandeville directly onto A413 or utilising Chiltern Railway	+
		Operation	Permanent severance of local routes	No permanent severance of routes.	+++
	Air quality	Construction	Dust generation for extensive earth moving along whole route in AONB	Generation of dust at local shaft sites. Main work at tunnel boring site at north portal will enable localised mitigation of dust generation	+
		Operation	Major overall reduction in air emissions resulting from reduction of car trips at a strategic level along M1 and M40.	No difference in terms of car trip reduction.	O
	Socio-economics	Construction	Impacts on visitors to the AONB and businesses due to severance and additional delays	Less impact on visitors to the AONB	+
		Operation	Permanent Impacts on tourism within the AONB resulting in knock-on impacts on local business. Permanent impacts on viability of farms due to severance of land holdings.	Significantly less impacts on the AONB therefore likely reduced knock-on impacts on tourism and local business.	+++

		Location:	Between Chainage: Ch.31+300 and Ch.57+000,		
		Option name and description			
		OPTIONS CONSIDERED	**A**	**B**	
		OPTION DESCRIPTION	The **HS2 Government's Proposed Scheme**: 1 bored tunnel (13.2km) and 11km of surface works in AONB including 2 green tunnels (approx. 1km each).	The **Chiltern's Long Tunnel Route**; 1 continuous bored twin tunnel of 24.2 km and 500m of surface works at north portal	
				No impacts on farm viability. No severance of land holdings	
	Sound, noise and vibration	Construction	Noise at many locations from works along whole route	Localised noise from vent shaft sites with main activity adjacent to other surface works near Stoke Mandeville. Additional traffic on roads past SM and through Aylesbury might have slight adverse effect.	+
		Operation	Many properties permanently affected by noise	Very few properties affected by noise	+++
Sustainable consumption and production	Agriculture, Forestry and Soils.	Construction	12m tonnes of excavation arisings	3.2m tonnes of excavation arisings.	+++
		Operation	250 ha of land permanently lost due to the works The proposal will have a significant land-take in relation to maintenance access routes, environmental mitigation features which will result in the loss of farmland soils, woodland, trees and hedgerows. Of particular concern is the loss of farm buildings, severance and impact on viability of existing farm holdings, field access, and soil quality.	Approximately 50a of land permanently lost, at ventilation shaft sites and northern portal.	+++
Preferred Option: B				**Overall rating**	+++

Location:	Between Chainage: Ch.31+300 and Ch.57+000,	
Option name and description		
OPTIONS CONSIDERED	**A**	**B**
OPTION DESCRIPTION	The **HS2 Government's Proposed Scheme**: 1 bored tunnel (13.2km) and 11km of surface works in AONB including 2 green tunnels (approx. 1km each).	The **Chiltern's Long Tunnel Route**; 1 continuous bored twin tunnel of 24.2 km and 500m of surface works at north portal
Reason for overall rating: **The overall environmental benefit of the Chiltern Long Tunnel Route is clear from this assessment. The overall minor and major improvements against every measure, except for minor worsening of impact from construction traffic, means that this short term impact, which has the potential for further mitigation, does not have a lasting effect on the AONB.**		

Appendix B Geology and Lithology

B.1 General

B.1.1 The Chiltern Hills ('the Chilterns') is a south-west to north-east trending chalk escarpment up to 267 m high that forms the northern edge of the London Basin, a broad synclinal structure bounded to the south by the North Downs escarpment. As a consequence, the Chalk and overlying Lambeth Group dip gently south eastwards; normally <5 degrees.

B.1.2 The geology of the Chilterns influences the fundamental nature of the Chilterns AONB; the chalk escarpment and its dip slope and the nature and degree to which it has been weathered and eroded means there is a range of features that also influence the development of the railway and how it will be delivered. Geology specifically influences the hydrology and hydrogeology of the Chilterns and the Misbourne Valley. The Chilterns also forms a Major Aquifer, which is used for public water supply. At the northern edge of the Chilterns AONB the route is underlain by Upper Greensand/Gault Formation strata where they outcrop just beyond and underlie the weathered edge of the chalk.

B.1.3 PBA's work on geology and hydrogeology has been peer reviewed by the industry recognised chalk engineering expert Rory Mortimore, Emeritus Professor of Engineering Geology at the University of Brighton, Visiting Professor of Geology at the University of Leeds and immediate past-President of the Geologists Association; and by Dr Haydon Bailey, President of the Geologists' Association, who specialises in Chalk micropaleontology and stratigraphy. The geological sequence along the tunnel route corridor is summarised in Table B.1 below and in more detail in section B6 at the end of this appendix.

Table B.1 Summary of geological sequence along route corridor.

	Stratum	Lithology	Thickness
Superficial (Drift) geology	Alluvium	Silt, sand and gravel	<3 m
	Head	Gravel, silt and clay	<6 m
	Clay with Flints	Clay with flint gravel	<6 m
	River Terrace Deposits	Sands and gravel	<10 m
Solid geology	Lambeth Group	Clays with gravel and sand	<1 m
	Seaford Chalk	White chalk with flints	<40 m
	Lewes Nodular Chalk	Nodular chalk with flints, marls and limestone	<35 m
	New Pit Chalk	White chalk with marls	<45 m
	Holywell Nodular Chalk	Nodular chalk with marls and limestone	<15 m
	Zig Zag Chalk	Grey chalk	<70 m
	West Melbury Marly Chalk	Mudstone and limestone	
	Upper Greensand Formation	Sand and sandstone	<70 m
	Gault Formation	Mudstone	

B.1.4 The geology is characterised by the Cretaceous Chalk that dips gently south eastwards and underlies the majority of the route through the Chilterns from the River Colne to south of Stoke Mandeville. This is overlain unconformably by the clays and sands of the Palaeogene Lambeth Group, though these are only present over the southern part of the Chilterns. Over much of the northern Chilterns the Lambeth Group has been deeply weathered to leave a residual soil called 'Clay with flints' that caps much of the hills.

B.1.5 River Terrace Deposits (sands and gravels) are present over the southern part of the route and valleys are also characterised by superficial deposits formed by mass movement (variously termed 'Head') and by Alluvium deposited by recent watercourses. In places the River Terrace Deposits directly overly the Chalk where the intervening Palaeogene deposits have been eroded away.

B.1.6 The river terrace deposits are present as a staircase of terraces that step down progressively showing that the former proto-Thames river cut down gradually into the geological sequence through geological time. Prior to the onset of the Anglian glaciation the proto-Thames river flowed north-eastwards. Extension of the ice sheet southwards into the Vale of St Albans blocked the river's flow and produced a pro-glacial lake that caused the river to back up and find a new route to the south and east, eventually forming the route of the modern River Thames that extends south past Maidenhead.

B.1.7 At the northern edge of the Chilterns AONB Lower Cretaceous deposits of the Upper Greensand and Gault Formations come to the surface at the edge of the weathered chalk outcrop beyond the base of the escarpment. They unconformably underlie the chalk and also dip gently south eastwards.

Route Geology of the government's Proposed Scheme

B.1.8 The following describes the broad geology presented in the cross sections shown on Drawings 30067/001/021 and 023 at Appendix D**.**

B.1.9 At the southeast end of the government's Proposed Scheme the portal is located just south of the junction between Chalfont Lane and the M25 Motorway. At the portal the tunnel lies within the Seaford Chalk. Northwards the tunnel alignment curves eastwards around Chalfont St Peter passing close to Robert's Wood near to Hornhill. The tunnel route then swings westwards and passes below the eastern edge of Chalfont St Giles and crosses the River Misbourne close to the position of Chalfont Mill. Between the southern portal and Chalfont St Peter the tunnel passes through southwards dipping Seaford Chalk. However, as it approaches the River Misbourne valley the tunnel passes into the underlying Lewes Nodular Chalk. The tunnel level continues within the Lewes Chalk as it passes below the River Misbourne.

B.1.10 As the government's Proposed Scheme continues northwards beyond Chalfont St Giles it penetrates down through the dipping chalk sequence eventually encountering the Chalk Rock at the base of the Lewes Nodular Chalk. The Chiltern Long Tunnel Route is located at a deeper level than the Government Proposed Scheme hence it meets the Chalk Rock layer at differing depths and locations beneath the River Misbourne valley and northwards beyond. In plan, the tunnel routes continue northwards to pass closely below Hobbs Hole along Bottom House Farm Lane that runs along the floor of a dry valley. At this point the geological sequence comprises a deeply eroded dry valley feature which cuts down through the Lambeth Group capped Seaford Chalk hilltops either side of the valley to reveal Lewes Chalk in the valley floor. The feature forms a northeast trending tributary valley to the Misbourne valley.

B.1.11 Continuing northwards below the west side of the Misbourne valley, the government's Proposed Scheme passes to the southwest side of Amersham and Amersham Old Town. The route takes the tunnels below an area of high ground in the vicinity of Gore Hill and the north east side of Coleshill, crossing below Amersham Road, where Lambeth Group deposits cap the Seaford Chalk locally. A little further north is a large chalk dry valley feature with Whielden

Lane extending along its floor, southwest of Amersham Old Town. Along this section the tunnel passes through the New Pit and Holywell chalks, approaching the level of the Melbourn Rock.

B.1.12 The government's Proposed Scheme then turns back under the River Misbourne valley floor beyond Amersham Old Town forming an oblique angle with the valley floor axis of the Misbourne. The tunnel line passes beside/beneath Shardeloes Lake within the valley floor. The Chiltern Long Tunnel Route runs at a constant grade and begins to rise after passing beyond the River Misbourne. South of the river the topographical highs comprise Seaford Chalk capped by Clay-with-Flints above the Lewes Chalk. Within the Misbourne valley floor river alluvium overlies New Pit Chalk exposed at the sides of the river. The tunnel passes through the New Pit and Holywell chalks just before the river valley floor position and then passes below the Melbourn Rock at the base of the Holywell Chalk into the Grey Chalk Subgroup strata below the valley floor.

B.1.13 The next section of the government's Proposed Scheme runs north, passing to the west side of Hyde Heath and South Heath towards Chainage 48500 m. The route passes through higher ground to the east side of the Misbourne valley where mostly Lewes Chalk is present overlain by variable thicknesses of Clay-with-Flints. Within some of the minor tributary valleys trending southwest towards the Misbourne valley the underlying New Pit Chalk is exposed. In this section the Government Proposed Scheme rises in level to the surface continuing along in a series of deep cuttings (some covered), embankments and viaducts.

B.1.14 For the government's Proposed Scheme beyond Chainage 48500 m similar ground conditions continue north towards Wendover Dean and Wendover. The route follows the curve of the valley floor, crossing back over the Misbourne valley again in its northern reaches past Wendover. At this point the railway passes the west side of Wendover at the surface within a cut-and-cover tunnel (between approximately Chainages 53000 m and 55000 m) where it is likely that the chalk exposed here in the valley floor is the Holywell Nodular Chalk Formation overlain by Head deposits in the valley floor axis. Beyond Wendover the head of the valley breaches the north-west facing chalk scarp face of the Chilterns. This results in a subdued topography where the Melbourn Rock and the Grey Chalk Subgroup strata outcrop and land levels fall away north-west towards the Lower Cretaceous strata (Upper Greensand/Gault Formations) outcropping from the south side of the Stoke Mandeville area (in the vicinity of Nash Lee Road).

B.1.15 By contrast the Chiltern Long Tunnel Route follows a more westerly alignment from Chainage 48500 m onwards, crossing below the Misbourne valley and then goes below Bacombe Hill, staying at depth within the Grey Chalk Subgroup strata. The railway emerges finally to the surface at the northern portal location (about Chainage 55600m) just beyond where a line of pylons cross farmland and to the south side of Nash Lee Road. This position lies very close to the published geological boundary of the Grey Chalk Subgroup strata with the underlying Upper Greensand/Gault Formations. The Chilterns Long Tunnel Route crosses the Upper Greensand/Gault Formations going towards Stoke Mandeville at the surface before joining together with the Government Proposed Scheme alignment at about Chainage 57000 m.

Hydrogeology

B.1.16 Information on chalk groundwater levels has been derived from the published hydrogeological map and these levels are shown on the geological sections. It should be noted that the levels represent those measured before 1984 and that they will also vary with time, season and prolonged spells of rainfall as well as abstraction for water supply. The appearance of the groundwater in springs at the surface, particularly at the northern end of the study area is dictated by the ground water levels as well as the proximity of the groundwater divide, the variability at the interface between strata, weathering and surface topography.

B.1.17 The volume of ground occupied by a twin bored tunnel is very small when compared with the overall volume of the Chalk aquifer and therefore its construction will not have any long term impact upon storage and water flow. It may affect local water supply boreholes where the tunnels are located in close proximity.

B.1.18 Ineson (1962) recognised the enhanced permeability of the Chalk below valley floors, increasing water flow largely as a result of periglacial weathering and dissolution widening of sub-vertical joints and bedding planes.

B.1.19 Significant portions of the tunnel route alignment pass below valley floors, particularly the Misbourne. This is because the Government Proposed Scheme crosses the valley floor axis at an oblique angle.

B.1.20 The government's Proposed Scheme and the Chilterns Long Tunnel pass below and close to Shardeloes Lake which is an important feature in the Misbourne valley. There is considerable uncertainty as regards the origin and form of construction of this feature and concern as regards the potential impact of the tunnel upon its integrity and water levels. Mitigation measures such as ground treatment by permeation grouting may be required but will apply equally to either tunnel option selected. The benefit of the Green Route in this regard is that it crosses the Misbourne well upstream of this feature and will therefore have much less impact.

B.1.21 Overall, whilst the Chalk is a major aquifer its main water flow and storage is essentially confined to the network of fractures (joints and bedding planes) within it. Consequently the permeability of intact Chalk is very low and greatest within fault and fracture zones. The distribution of permeability is therefore highly variable and will change according to stratigraphical level, geological structure and weathering.

B.1.22 The impact on tunnel construction is that it may impede or limit the location of interventions made from a tunnel boring machine (TBM). It may also require that sections of tunnel, cross-passages and shafts may require dewatering. It is noted that HS2 have already identified the potential for an intense fracture zone near to the south portal. This will need to be mitigated and will apply whichever route is selected. The Seaford Chalk in particular has high porosity and extends the duration of extreme groundwater flood events. This will need to be accommodated in the southern section of the tunnel

B.2 Geological Hazards

Solution Features

B.2.1 Chalk is a soluble carbonate rock in which solution features are present. The interface between the Chalk surface and overlying cover deposits often forms a karstic horizon where solution features can be found and the Palaeogene/Chalk interface contains solution features that penetrate more than 50m from the upper surface of the Chalk. Solution features can also be present at depth as a result of the flow of groundwater including solution widened joints and bedding planes, phreatic tubes, cavities and tubular karst.

B.2.2 There are a large number of recorded solution features in the Chalk (Edmonds 2008) and more than 10,000 records are held within the UK's Natural Cavities Database managed by PBA, although not all of these are in the Chilterns. Those that are relevant to this study are indicated on the Drawings 021 & 023. Note that only those features that have been reported are shown. The records are indicative of the susceptibility of the Chalk of the Chilterns to solution and the prevalence of solution features.

B.2.3 Solution features may be columnar, planar or irregular shaped and may be present as an empty cavity or may be infilled with overlying cover deposits. Karst is a recognised hazard for tunnelling as it may result in the loss of slurry and face instability where infilled with soil. Where karst is of sufficient size it may lead to difficulties steering a TBM. However, very many tunnels have been constructed in karst that is far more severe than the solution features associated with the Chalk in the UK, in other parts of the world (e.g. Balkans, China, Singapore, Malaysia). Consequently, the risks associated with it are very well understood.

B.2.4 Instability within an infilled solution feature could result in localised higher ground movement, cavitation and potential collapse leading to the development of a sinkhole at the surface, particularly so where the tunnel is shallow. Where these features are known to exist (e.g. M25) or where the tunnel is shallow and in close proximity to sensitive structures and utilities it may be necessary to pre-treat these in advance of tunnel construction.

B.2.5 In this part of the route the chalk is overlain initially by the Gerrards Cross Gravel then mostly by the Beaconsfield Gravel. In this area the PBA Natural Cavities Database (as shown on Drawings 021 and 022) records that many solution features are present. A significant number of the recorded solution features have been identified as a result of carrying out ground investigations following the appearance of sinkholes causing subsidence and structural damage to property. The investigation results reveal that solution pipes commonly penetrate down into the chalk to depths of 30m or more and in some cases in excess of 50m. Based on the recorded field evidence the schematic cross sections (Drawings 021 and 022) indicate that dissolution weathering of chalk may feasibly extend to around 50m depth or more. About half of the tunnel length south and east of Chalfont St Peter passes through this zone. If metastable solution pipe infills were to be triggered to collapse as a result of the tunnelling activity then this could cause considerable subsidence damage if sinkholes appeared at the surface, particularly below buildings and utility services. Consideration will need to be given to advance stabilisation of the ground ahead of the TBM or from ground level.

B.2.6 Beyond the northeast side of Chalfont St Peter and Hornhill area the tunnel level passes below the water table and the main zone containing solution features (i.e. within 50m below the superficial geology and chalk surface interface). It should not be interpreted that solution features below the water table will be absent, simply that their number, size and impact should be reduced. However further along below the Misbourne valley floor the tunnel route may encounter more zones of disturbed ground – described later below.

B.2.7 It will be essential to investigate the distribution and nature of solution features along the proposed tunnel corridor and to develop process-response models to allow their distribution, form and number to be predicted with confidence. It will also be necessary to ensure that the tunnelling methods adopted can manage the potential presence of soft/weak material in an otherwise competent face of chalk.

B.2.8 These issues are common to either of the routes as they are common over this section.

Periglaciation

B.2.9 The manner in which Chalk weathers reflects its particular characteristics in respect of porosity and solubility that make it especially prone to certain forms of weathering. The porosity of Chalk and its ability to hold high moisture contents make it susceptible to the action of frost and ice producing fracturing, crushing, breakdown, cryoturbation (erosion due to repeated cycles of freezing and thawing), the development of involutions and even diapiric structures (upward movement of less dense material through overlying denser layers).

B.2.10 In the tunnel route corridor the Chalk has not been glaciated but has been affected by the processes that occurred immediately around the glaciers (i.e. periglaciation). Locally the severity and depth of weathering effects can vary from a few metres to tens of metres and in some cases 100m or more (Catt 2010). Faults within the Chalk may have been the foci for weathering and disturbance. Drawings 021 and 023 showing schematic cross sections for the government's Proposed Scheme and Chilterns Long Tunnel Route have been annotated to show where such faulted, disturbed zones could exist.

Faulting

B.2.11 The Chalk comprises a series of blocks of relatively intact chalk rock mass divided by relatively narrow recti-linear zones of faulting. The effect of faulting is to change the material in the tunnel face and introduce a zone of higher permeability. They may also be associated with a higher incidence of solution features. Fault zones are associated with valleys and consequently also with sources of local water supply.

Flints

B.2.12 Certain levels of Chalk contain nodules, bands and infilled planes of flint. Flint is hard, incredibly tough and resilient. It is very abrasive and consequently tunnelling equipment has to be designed and planned to withstand the action of flint. This includes hardening certain parts prone to wear and planning for wear and replacement.

Chalk Mines

B.2.13 Historically the Chalk has been mined for a wide variety of reasons e.g. to make lime for mortar and spreading over fields to improve clay soil textures, also for brick and tile making.

B.2.14 The UK Mining Cavities Database held by PBA shows that old chalk mines are widespread throughout the Chilterns. Recorded chalk mines are shown on Drawings 021 and 023 (Appendix D). Abandoned mines leave remnant voids beneath otherwise undisturbed ground and, in time, are susceptible to collapse, making their presence known as a result since formal mine records usually do not exist.

B.2.15 A tunnel passing in close vicinity to an existing chalk mine poses a possible risk of triggering ground instability within the mine and immediately surrounding area. It may also result in the loss of slurry and create difficulties for steering the TBM.

B.2.16 There is a risk that unrecorded mines may be discovered as a result of constructing a tunnel. Analysis of recorded mines suggests that chalk mines are particularly associated with Lambeth Group and Clay-with-Flints cover deposits.

Slope Instability

B.2.17 The land surface is characteristically shaped into a series of valleys cut down into the Chalk and intervening hills. Some of the valleys are relatively steep sided and may have originated while the chalk was frozen during the Pleistocene. While chalk can stand for long periods at steep angles, over time the valley sides relax and weather (e.g. frost action and stress relief) causing varying degrees of side slope instability.

B.2.18 This study has concluded that the greatest risk of ongoing slope instability could be associated with the hill slopes around Bacombe Hill near Wendover. The government's Proposed Scheme requires a side long cutting into this hill as it is necessary to form a 1.3km long cut-and-cover tunnel, potentially creating instability, whereas the Chilterns Long Tunnel Route passes beneath Bacombe Hill and daylights at a portal position which is further to the north in gently sloping land and away from this potential area of instability.

Chalk lithostratigraphy and intact geotechnical properties

B.2.19 The Chalk displays a wide variety of lithologies varying according to proportion of carbonate content and grain size. These lithologies and geotechnical properties vary with stratigraphical level and dictate how the Chalk will perform in engineering terms. These details are summarised in Table C.2 below and in more detail in Section C8 at the end of this appendix.

Table B.2 Summary of Chalk Lithostratigraphy

	Density	Flint content	Average calcimetry
Seaford Chalk	Low to medium	5 to 25%	95%
Lewes Chalk	Medium	<10%	95%
New Pit Chalk	Medium	<5%	90%
Holywell Nodular Chalk	Medium to High	<2%	87%
Zig Zag Chalk	High to very high	0%	77%
West Melbury Marly Chalk	High to very high	0%	70%

Superficial deposits

*Based on Morigi et al (2005)

PERIOD	EPOCH	NAME	*LITHOLOGY & TYPICAL THICKNESS (M)
Quaternary	Holocene	Alluvium	Silt, sand & gravel 2-3
	Pleistocene	Head	Gravelly silt & clay Variable
		Clay-with-Flints	Clay with flint gravel Up to 6
		River Terrace Deposits	Sands & gravels Up to 10

Details of River Terrace Deposits

Period	Stage	Development stage of the proto-Thames river	Terrace Name	Thickness (m)
Pleistocene	Pre-Anglian to Anglian	Pre-diversionary	Winter Hill Gravel	Typical thickness ranges from 3.5 to 10, average about 6
			Gerrards Cross Gravel	
			Beaconsfield Gravel	
			Westland Green Gravel	

Solid Geology

*Based on Morigi et al (2005)

AGE	GROUP NAME	FORMATION NAME	*LITHOLOGY & TYPICAL THICKNESS (M)
Palaeogene	Thames	London Clay Harwich	Hard clay to mudstone over sand Locally <10
	Lambeth	Reading Upnor	Clay & sand Locally up to 20+ Clay, sand & gravel Locally 2-5
Upper Cretaceous	Chalk – *White Chalk Subgroup*	Seaford Chalk	Chalk with flints Up to 40
		Lewes Nodular Chalk	Nodular chalk with flints, marl seams and hardgrounds (notably Chalk Rock Member) Up to 35
		New Pit Chalk	Chalk with fewer flints and marl seams Up to 45
		Holywell Nodular Chalk	Nodular chalk with a hardground (Melbourn Rock Member) over marl at base (Plenus Marls) Up to 15
	Chalk – *Grey Chalk Subgroup*	Zig Zag Chalk	Grey chalk over alternating bands of chalk and marl Up to 70
		West Melbury Marly Chalk	
Lower Cretaceous		Upper Greensand	Sand and sandstone Up to 10
		Gault	Mudstone Up to 70

Lithology

Seaford Chalk ('Upper Chalk')	
Typical characteristics	Soft blocky smooth white chalk with abundant seams of large nodular and semi-tabular flint, with thin beds of harder nodular chalk near the base.
Thickness	up to 40m
Density	Low to Medium dense
Unconfined compressive strength	1 to 15MPa

Calcimetry	Average 95%
Flint content	5 to 25%
Brash	The volume of flint and the frequency of large flint nodules is generally much greater than on the Newhaven Chalk. Some of the large flint bands are characteristic enough to be locally recognised in brash. Individual fragments of typical Seaford Chalk are smaller and more equant than those of the Lewes Chalk; flints are generally larger and more abundant
Topography	Forms extensive dip slopes between primary and secondary escarpment. Base at a very slight negative feature in front of, or at, or behind the crest of that escarpment.
Lewes Chalk ('Upper Chalk')	
Typical characteristics	Hard to very hard, white to creamy or yellowish white nodular chalks and chalkstones, with interbedded soft to hard gritty white chalks and common seams of clay-rich chalk (marl seams). Regular bands of nodular flint, some large, occur more commonly than in the underlying beds The Chalk Rock (a variable sequence of mineralised hardgrounds, chalkstone and nodular chalk) occurs at or near base of formation
Thickness	up to 35m
Density	Medium dense
Unconfined compressive strength	1 to 15MPa
Calcimetry	Average 95%
Flint content	<10%
Brash	Rubbly, hard nodular chalk fragments and large nodular flints. Rough-textured and rather flaggy in appearance. It tends to be more voluminous and rather dirtier than that derived from the New Pit Chalk.
Topography	Forms a convex slope at the top of the primary escarpment, commonly including the crest. Base at a positive break of slope.
New Pit Chalk ('Middle Chalk – upper')	
Typical characteristics	Smooth-textured, rather blocky, massively bedded, firm white chalks, with regular thin beds of clay-rich chalk ('marl seams') and sparse smallish flints.
Thickness	up to 45m
Density	Medium dense

Unconfined compressive strength	1 to 15MPa
Calcimetry	Average 90%
Flint content	<5%
Brash	Fragments tend to be of very uniform, smooth, brittle white chalk of medium hardness, with little fossil debris. These break readily under the plough and so the brash commonly shows numerous clean broken surfaces.
Topography	Forms the steepest ground in the face of the primary escarpment, typically with a uniform gradient. Base at a negative break of slope.
Holywell Nodular Chalk ('Middle Chalk – lower')	
Typical characteristics	Medium hard to very hard, nodular, white to creamy white chalk with beds and laminae of clay-rich chalk (marl), including flaser-laminated marls. A thin alternating sequence of clay-rich chalks and clayey limestones (Plenus Marls) overlain by very hard, creamy white limestone (Melbourn Rock) occurs at base of formation. The upper two-thirds is mostly conspicuously fossiliferous: most beds contain gritty shell debris, commonly pink, and some have mytiloid inoceramid bivalves preserved in three dimensions.
Thickness	up to 15m
Density	Medium dense to High dense
Unconfined compressive strength	1 to 15MPa
Calcimetry	Average 87% Range 60 to 95%
Flint content	<2%
Brash	Rougher, more grainy and rubbly brash, compared with New Pit Chalk. Brash is commonly too hard to be easily broken during normal cultivation, and so tend to develop a rather grubby appearance. In the absence of shell debris, the rather grainy texture of typical Holywell Chalk distinguishes it from the smooth chalks of the succeeding New Pit Chalk
Topography	Forms relatively gently sloping ground in the mid part of the primary escarpment, which can slope either towards or away from the escarpment. Base occurs at a weak negative break of slope, just below a strong positive break of slope.
Zig Zag Chalk ('Grey Chalk')	

Typical characteristics	Soft to medium-hard, pale grey, blocky chalk with some thin resistant limestone beds near the base. Basal bed is either a fine-grained phosphatic calcarenite (Totternhoe Stone), or silty to calcarenitic chalk (the Cast Bed)
Thickness	up to 70m
Density	High dense to Very high dense
Unconfined compressive strength	1 to 25 MPa
Calcimetry	Average 77% Range 20 to 95%
Flint content	0%
Brash	Rather sparse angular or blocky fragments of grey chalk.
Topography	Forms relatively steep ground low in the primary escarpment. Base at a negative break of slope.
West Melbury Marly Chalk (‘Chalk Marl’)	
Typical characteristics	Numerous rhythmic alternations, each consisting of soft off-white to grey clay-rich chalks (marls) passing up into grey clayey chalks and hard grey or brownish grey limestones. Glauconitic, clay rich, locally sandy calcareous siltstone/clay (Glauconitic Marl Member)
Thickness	up to 70m
Density	High dense to Very high dense
Unconfined compressive strength	0.5 to 20 MPa
Calcimetry	Average 70% Range 30 to 95%
Flint content	0%
Brash	Rough, rubbly limestone fragments locally voluminous; commonly fossiliferous. Glauconitic base found as brash in places, but is more proven by hand auger samples.
Topography	Forms relatively gently sloping ground in the lowest part of the primary escarpment. Locally can form a subsidiary escarpment with a dip slope facing towards the primary escarpment. Base occurs at a weak negative break of slope.
Upper Greensand*	

Typical characteristics	Sequence of sand and sandstone with beds of chert. In the west the Upper Greensand unconformably oversteps the Gault.
Thickness	Up to 10
Density	No data
Unconfined compressive strength	No data
Carbonate content	No data
Flint content	0%
Brash	N/A
Topography	Forms subdued concave slope below base of chalk
Gault*	
Typical characteristics	Sequence of clays, mudstones and thin siltstones with variable bands of phosphatic nodules.
Thickness	Up to 70
Density	1.89 to 2.10 Mg/m³, mean 1.94 Mg/m³
Undrained shear strength	Ranges from about 50kPa at 3m depth to 100kPa at 6m depth but can be variable
Carbonate content	Range from 1.5% to 66%, mean 39.2%
Flint content	0%
Brash	N/A
Topography	Forms subdued low relief below chalk, prone to landsliding particularly where slope angles exceed 7 degrees and prone to shrinkage/heave.
*Source	Forster et al (1995) Engineering geology of British rocks and soils: Gault Clay, British Geological Survey Technical Report WN/94/31, Keyworth.

Appendix C Qualitative Risk Assessment

C.1 Introduction

C.1.1 The purpose of this discussion on risk assessment is to use a risk assessment approach to identify the risk and opportunity differentiators mainly in respect of:

- Mitigation of the protected landscape;
- Construction logistics and the relative uncertainty of the contingency allowance;
- Programme prolongation;
- Operational safety; and
- Construction cost and the impact on the BCR for Phase 1;

C.1.2 The cost model is are based on the HS2 Cost and Risk Model (Jan 2012) and the consequent Estimate of Expense presented to Parliament dated 15th November 2013

C.1.3 Where some information is not identified this has been added from previous analysis or reporting undertaken by HS2 Ltd and its consultants when reviewing the previous proposals for a Chilterns Tunnel from the M25 to Wendover.

C.1.4 In summary the schemes being considered in this study have the following comparative costs including the contingency incorporated into the HS2 cost model.

Table C.1 Comparative costs

Government's Proposed Scheme	Chilterns Long Tunnel Route	Difference
£1.45 bn	£1.85 bn	£0.40 bn

C.1.5 In considering the reality of this differential in costs it is beneficial to undertake an assessment of the risks to the project budget from the government's Proposed Scheme and how this differential might affect the overall outturn costs and the business case for HS2.

C.2 Risk Assessment Approach

C.2.1 The DfT's Risk & Issue Management Strategy provides a common framework for a qualitative risk discussion of route alignment/construction options. This has been adopted in considering the risk of a wide range of stakeholders.

C.2.2 PBA, working with OTB Engineering have used a risk assessment approach which generally follows the British Tunnelling Society Guidelines[1] . However, when the programme moves

[1] BTS - ABI Joint Code of Practice for Risk Management of Tunnel Projects in the UK, published in September 2003.

forward the DfT's Risk and Issue Management Strategy is expected to evolve to suit each project phase[2]

C.3 HS2 Phase 1 Chiltern Tunnel Design Option Characteristics

C.3.1 The table C.3 below summarises the effects of the design proposals for the government's Proposed Scheme and the Chilterns Long Tunnel Route on the Chilterns AONB.

Table C.3 Summary comparison of design proposals

Chiltern AONB Route Characteristics	Government's Proposed Scheme	Chilterns Long Tunnel Route
South Portal	M25	M25
Twin Bore Tunnel	13.2km from the M25 to Little Missenden	24.2km M25 to Wendover - AONB Boundary
Ventilation Shafts	4	7
TSI Intermediate Fire Fighting Point	None	fire fighting point and Safety Evacuation Access at Little Missenden or Wendover Dean
Little Missenden to Wendover AONB Boundary	11.1 km of Surface Railway including; Cuttings, Embankments, 2 Viaducts and 2 Green Tunnels, plus road/lane crossings.	No impact – underground railway
North Portal	Nr Little Missenden in the middle of the AONB	East West of Wendover near the AONB boundary

C.4 Risk and Opportunity Differentiators

A Reputation risk

The protected landscape - National precedent

C.4.1 The Chilterns AONB:

- is recognised by The International Union for Conservation of Nature (IUCN) which provides international recognition for the AONB designation, which it places in its Category V - Protected Landscapes and Seascapes; and
- satisfies the requirements of Section 82(1) of the Countryside and Rights of Way Act, 2000 (CROW 2000) which defines an AONB in England as an area that is not in a National Park but which appears to Natural England to be of such outstanding natural beauty that it is desirable that the protective provisions of Part IV of CROW 2000 should apply to it for the purpose of conserving and enhancing the area's natural beauty. The legislation which led to the Chilterns AONB being designated is Section 87(1) of the National Parks and Access to the Countryside Act, 1949.

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[2] Tunnelling and Underground Space Technology, 19(2004) 217 – 237, Guidelines for Tunnelling Risk Management, SD Eskesen, P Tengborg, J Kampmann and TH Veicherts

C.4.2 The basis of this protection are the criterion which the Chilterns AONB satisfies which is:

- Six technical criteria which are within the Guidance for Assessing Landscapes for Designation, published by Natural England:
    - Landscape quality;
    - Scenic quality;
    - Relative wildness;
    - Relative tranquillity;
    - Natural heritage features; and
    - Cultural heritage
- Desirability;
- Designation; and
- Purpose

C.4.3 This report adopts a disinterested approach and is largely evidence based although it is accepted that in the case of many of the topics discussed an element of judgement inevitably has been used. This does not detract from its main thrust which is to develop the wider policy debate and recognition of the arguments introduced by the Natural Capital Committee in The State of Natural Capital: Towards a framework for measurement and valuation (April 2013) and subsequent reports.

Government's Proposed Scheme

C.4.4 The Stakeholders in this study are very sensitive to the severe environmental impact of a surface route through the AONB which has also resulted in extensive and well informed lobby group activities. They are also very concerned that the protective provisions of Part IV of Countryside and Rights of Way Act (CRoW Act) 2000 have not been fully exercised in the government's Proposed Scheme.

C.4.5 It is noted that post Public Consultation, as described in their report to Government in January 2012, HS2 Ltd has demonstrated some appreciation of the level of its Reputational Risk Exposure to Environmental Impact (Probability Very Likely * Impact Very High/Severe) and developed its original design to the Proposed Scheme that attempts but fails to go some way towards mitigating the environmental impact between its Tunnel North Portal at Little Missenden (Mantles Wood) and the boundary of the AONB (West of Wendover).

C.4.6 The negative environmental impact of the government's Proposed Scheme is, although somewhat mitigated, still very significant. For example, there is a considerable impact during construction together with the loss of ancient woodland and heritage sites. The Environmental Statement for the government's Proposed Scheme acknowledges that the adverse effects on the landscape will continue for 60 years (the maximum period of assessment). This maximum period relates to the unpredictability of the future and the risk that HS2 will be effectively obsolete in such a timescale. This is not the case for environmental impacts which continue largely unabated unless remedial works are undertaken. There is no allowance in the business case for the cost of such works. .

C.4.7 The Cut and Cover "Green Tunnel" sections do offer a reduction to noise and visual impact past key areas of population. Also, although they remove the barrier to free movement across the route, they still have an impact. The five concrete porous hoods at the portals will be an unfortunate urban intrusion into the landscape and the cuttings along with landscaping mounds will reduce the noise impact at the surface but still create a barrier to free movement and a considerable visual impact.

C.4.8 Overall the environmental impact of the government's Proposed Scheme as a surface railway from Little Missenden north to the AONB boundary is still significant and, as the strength of feeling of Chiltern's stakeholders is very strong it is considered that HS2's Reputational Risk exposure, therefore, remains Very High/Severe * Probability Very Likely.

B Programme prolongation

Chilterns Long Tunnel

C.4.9 The adoption of the Chilterns Long Tunnel Route will result in changes to the route as published in the Hybrid Bill. This will require the preparation of Additional Provisions which will require a formal Environmental Statement and consultation process which could extend the programme during the petitioning stage.

C.4.10 However, there is already precedent for dealing with such major changes, such as the new interchange secured by Staffordshire County Council in October 2014 but for which the Environmental Statement is, at the time of writing, not yet published.

C.4.11 This and many other Additional Provisions should run their course at whatever time in the petitioning process they appear. The fact that the petitioning for this important alternative tunnelling option will be heard relatively late should not be a reason for rejecting an otherwise beneficial solution to this important section of the line.

C.4.12 There is also the matter of the possibility of a longer construction programme to be considered.

C Construction logistics and the relative uncertainty of the contingency allowance

Tunnel boring strategy

C.4.13 It is argued that the Chilterns Long Tunnel Route design and construction strategy with a central point for withdrawal of the tunnel boring machines at the Little Missenden ventilation shaft offers the potential to reduce both the overall programme impact of the Chilterns Long Tunnel and mitigate the risk of tunnelling delays.

C.4.14 In major construction projects, such as HS2, it is normal for major tunnel infrastructure to be programme critical activity. In the government's Proposed Scheme the Northolt and Chiltern Tunnels are 14.0 km and 13.2km long respectively. HS2 Ltd.'s construction strategy for the Northolt Tunnel is to use 4 TBMs, two driven from each end, and that for the Chilterns Tunnel is to use 2 TBMs driven from the South launch portal.

C.4.15 For the 24.2km Chilterns Long Tunnel the proposed tunnelling strategy is 4 TBMs driving 2 from the North Portal and 2 from the South Portal, both exiting at the central location of the Little Missenden Ventilation Shaft.

C.4.16 For the government's Proposed Scheme construction strategy - two TBMs will be used and, assuming they start from the M25 Launch Portals and bore north at an average rate of 80 m/week over 13.2 km it will take some 38 months to reach the North Portal TBM exit point.

C.4.17 For the Chilterns Long Tunnel construction strategy four TBMs are proposed. Two would be launched from the M25 Portals and two from the North Portal launch site near Wendover. Both would bore tunnels towards the meeting point at the Little Missenden ventilation shaft, the nominal mid-point. The maximum length of tunnel drives is about 12.6 km which, boring at a rate of 80 m per week would take 158 weeks i.e. similar to the government's Proposed Scheme. The risk of underperformance of the TBM drive from the south is mitigated by the southern drive being shorter, with the possibility of the drives proceeding past the half way point should there be programme maintenance reasons for doing so.

Construction risk

C.4.18 This element of risk in implementing the scheme is relatively short term when compared to the operational life of the railway. The construction works are potentially over approximately 3 – 4 years, with systems installation following, compared to the operational life of at least 60, but clearly some of the environmental impacts remain whether the railway is operational or not. Therefore such issues associated with risk during construction will be addressed in a short time span and once overcome, should they arise, will not be repeated.

C.4.19 In tunnelling, one of the principal risks is ground conditions and ground water. This is shown in the HS2 Cost and Risk Model, January 2012 Report where Appendix B shows the Top Ten Site Specific Risks exposure values to be dominated by "Tunnels – ground conditions / obstructions affect methodology / alignment" at £245,783k – this risk exposure (value) is believed to be against the full Y Scheme i.e. HS2 phase 1 and phase 2.

C.4.20 Table 4 of the HS2 January 2012 Report shows the Phase 1 Twin and Single Bore Tunnel Cost at £1,410 million.

C.4.21 This cost estimate aggregates all of the phase 1 tunnel costs for the government's Proposed Scheme at that date and does not break out the detail of the Chiltern Tunnel. At the January 2012 date the Cost Estimate and the Risk Model was at an early stage and therefore included 34% Optimism Bias. While this level of cost estimation is interesting it is not very useful for conducting a comparative cost and risk analysis for the Chilterns Long Tunnel.

C.4.22 The HS2 October 2013 Report, discussed above, contains more CQRA results for the Phase 1 Scheme but still does not show the detailed cost and risk information used for the Chiltern Tunnel.

C.4.23 The key construction element of both schemes relates to the disposal of arisings. The government's Proposed Scheme will result in the movement of about 7 million cubic metres of soil within the AONB including creation of a landfill of 1 million cubic metres in the "Sustainable Placement Area" at Hunts Green in the heart of the AONB, and the 0.5Mm^3 at South Heath. The Chilterns Long Tunnel Route from Wendover to Little Missenden will produce approximately 2 million cubic metres of chalk, predominantly in the form of a slurry. This will need careful handling but can potentially be used for cement making and therefore becomes a commercial resource. Handling of this and its transport requires consideration and represents the main risk to the long tunnel solution.

C.4.24 The construction logistics involved in both options are significant. The government's Proposed Scheme where on the surface from Little Missenden to the Wendover boundary of the AONB would probably be more significant than the Chilterns Long Tunnel Route logistics. Both would create significant disruption for the construction phase of the project but those associated with the latter are contained within discrete sites and will have little disruption to existing community infrastructure.

D Operational Safety

C.4.25 Through the inclusion of a 'fire fighting point' at the mid-section, the Chilterns Long Tunnel Route complies with the new TSI Safety Requirements.

C.4.26 The government's Proposed Scheme will also comply with the Operational Rail Safety Requirements although it could be argued that the 11.5 km of surface rail from the Mantles Wood North Portal to the Wendover boundary of the AONB might be less safe than an underground railway as is highlighted in Section 4 of this report.

C.4.27 In general, at the strategic level of this assessment it is felt that as both options will comply with rail safety standards there is no differential operational safety risk. As the design details develop it could be that more consideration has to be given to the operational risks of the surface section regarding intrusion of objects or people and general maintenance.

E Construction cost and its impact on the BCR for Phase 1

C.4.28 In assessing alternatives in the Environmental Statement, the potential for a full tunnel through the Chilterns is considered environmentally better but too expensive and therefore dismissed as an acceptable solution, whilst the government's Proposed Scheme results in significant effects on the AONB after mitigation, Using the costs figures published by the government it is calculated that the study into the Chilterns Long Tunnel has an additional cost of £200 - £400m.

C.4.29 The budget cost of a TBM with back up is approximately £20 million so it is necessary to consider the impact of the Chiltern Long Tunnel using a 4 TBM Strategy with the government's Proposed Scheme option. Unfortunately none of the HS2 Ltd publications show the details of the cost and risk values attributable to the detailed element of the government's Proposed Scheme so such a comparison is not currently possible here. However HS2 Ltd have included some detailed results that show the robustness of the Phase 1 Business Case under three Quantified Risk Analysis (QRA) cost assumptions and it is argued below that the Chilterns Long Tunnel Route would not impact significantly on the Value for Money as demonstrated for the government's Proposed Scheme.

C.4.30 In the Economic Case For HS2 (HS2, October 2013), a QRA is reported and the Phase 1 QRA costs assumptions are shown in Table 5 of that document as:-

- Base cost £15.5 billion
- Target price £17.1 billion
- *P50 cost £19.2 billion
- **P95 cost £21.2 billion

*The P50 cost is the cost for which there is a 50% chance of it not being exceeded.

**The P95 cost is the cost for which there is a 95% chance of it not being exceeded.

C.4.31 It should be noted that the base construction cost estimates include land purchase but no allowance for risk in the form of contingency. The contingency allowance is therefore contained within the Target, P50 and P95 costs.

C.4.32 The construction cost is a key ingredient in the Benefit to Cost Ratio (BCR) used in the Business Case justification for the project as discussed in the Economic Case paper. The paper discussed the scheme's value for money changes with each of the above cost assumptions.

C.4.33 The paper uses graduated levels of BCR and value for money as follows; poor (0.5 to 1.0), low (1.0 to 1.5), medium (1.5 to 2.0), high (2.0 to 4.0) and very high (4 to beyond 4.25).

C.4.34 In the paper Figure 21 (represented in Figure C.1 below) shows the Likelihood vs Value for Money (BCR) under the three cost assumptions with the summary results (paragraph 7.2.4):

- *"If the scheme is delivered for the target price – the budget set for the company – the value for money rises compared to the central case. The probability of the scheme being medium value for money or higher is almost 95% compared with 79% for the central cost.*

- *Even with costs at the highest level of contingency (P95), the value for money of the scheme still has a good probability, greater than 50% of being medium (1.5 to 2.0); although the risk of being in the 1.0 to 1.5 category does rise from around 20% under the central case to around 45%".*

Figure C.1 Extract from Economic Case for HS2, October 2013

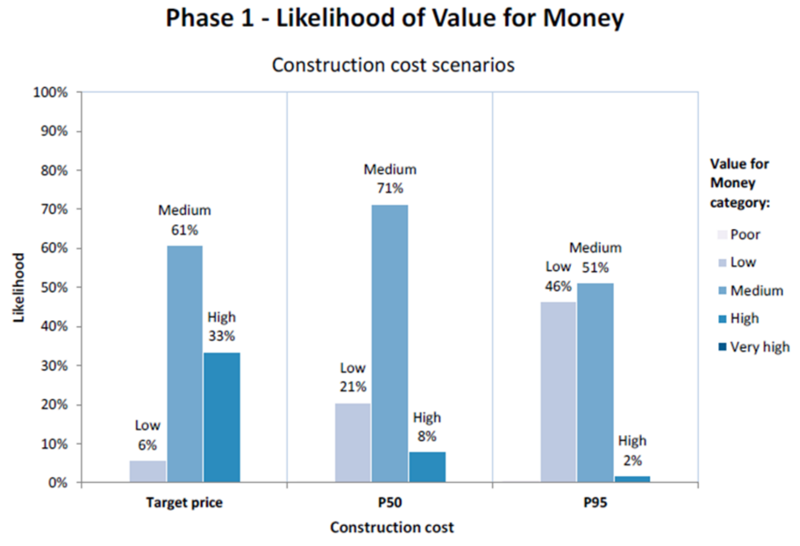

Figure 21: Risk analysis results for Phase One under three different assumptions

C.4.35 This implies that the BCR is very robust and therefore a small increase in construction cost of £200 – 400m, associated with the Chilterns Long Tunnel Route, would have a minimal impact on the value for money of the scheme and hence the Business Case justification .

C.4.36 This excludes the operational costs for which risks have been identified in the study in terms of the government's Proposed Scheme and the benefits which are likely to accrue from the Chilterns Long Tunnel Route. The accrual will occur over the life of the scheme which will reduce the risk of higher than anticipated costs during operation and hence improve the BCR.

F Land costs

C.4.37 Clearly the land costs associated with the government's Proposed Scheme surface rail section from Little Missenden to the Wendover boundary of the AONB would be significant relative to the Chilterns Long Tunnel Route. This land cost would probably offset a proportion of the longer tunnel construction costs.

C.4.38 It is felt that the risk of programme delays and reputational impact on HS2 Ltd due to the land take required by the government's Proposed Scheme would be a high probability and have a significant impact.

C.4.39 The Chilterns Long Tunnel Route will only affect a small number of landowners and the broad acceptance by stakeholders who have land interests, for activities on the surface are mostly only those already affected. Therefore the risks to cost, reputation and programme will be significantly reduced. The slightly different alignment at the north end under newly affected landowners will be at depth and therefore this will not increase the risks.

G Surface Archaeology

C.4.40 The Misbourne Valley contains several archaeological features and more may be revealed when the government's Proposed Scheme is constructed, extending over 400ha. The discovery of such archaeological finds will inevitably lead to delays in construction. The Chilterns Long Tunnel Route would avoid most of these risks because the surface work affects about 40 ha and thus offers a positive risk mitigation opportunity.

H Security

C.4.41 The government's Proposed Scheme will have a higher security risk during construction and operation. This would be substantially reduced for the Chilterns Long Tunnel Route.

C.5 Conclusion

C.5.1 In conclusion the qualitative risk differentiators between the Chilterns Long Tunnel Route and the government's Proposed Scheme show that the long tunnel option has several important risk mitigation advantages, which in summary are:-

- The irreversible damage to the Chilterns AONB will be avoided;
- The environmental and reputational risks to government and HS2 Ltd are virtually eliminated over the section of the surface transit north from Little Missenden;
- The extra CAPEX cost does reduce the strength of the Business Case for HS2 but not significantly;
- The Environmental and Reputation risks to government are virtually eliminated over the route section compared;
- The technical feasibility and TSI safety compliance of extending the tunnel to the Wendover boundary of the AONB is justified;
- The 4 TBM Tunnelling Strategy for the extended tunnel will not impact on the overall construction programme; and
- The security features required for an extended tunnel are simpler than a surface route.

C.5.2 This assessment shows that, in addition to the many other supporting justifications put forward for the Chilterns Long Tunnel Route the risk justification for extending the Chiltern Tunnel to the boundary of the Chilterns AONB at Wendover offers a significant risk mitigation opportunity to the delivery of High Speed 2 Phase One.

Appendix D Route Alignment Drawings

D.1 Study Routes

D.1.1 Drawing 30067/001/017: Comparison of Route Features at existing Ground Surface

D.1.2 Drawing 30067/001/018: Plan and sections of government's Proposed Scheme / Chiltern Long Tunnel Route

Geological Plans and Sections

D.1.3 Drawings 30067/001/021 – Schematic Geological Cross Section and Plan for Government Proposed Scheme

D.1.4 Drawings 30067/001/023 – Schematic Geological Cross Section and Plan for Chilterns Long Tunnel Route

Appendix E Alternative Routes Considered

E.1 Introduction

E.1.1 The descriptions set out below outline the primary features of the alternative routes considered in comparison to the government's Proposed Scheme. The alignments of the routes considered are shown in the sketch plan below. This shows all the options considered in the PBA report dated April 2014. The report provided a technical evaluation of alternative continuous tunnel alignments. The alternatives which were considered are all along the Misbourne Valley and within 3km either side of the horizontal alignment of the government's Proposed Scheme. The report advocated one of these alignments, known as the Green Route, as the preferred engineering and environmental option. This alignment was chosen because it satisfied the requirement better than the other alternatives considered.

Figure E.1 Route Alternatives considered

E.1.2 The main principle adopted in developing these alternatives was to commence at the southern (London) portal in the same location as the government's Proposed Scheme and end at an appropriate location to allow alignment with the Government Proposed Scheme to the north of Wendover where it passes Stoke Mandeville, but not further north than Aylesbury. The need for a surface Intervention Gap to limit a single length of tunnel bore to 20km to comply with safety criteria constrained some of the alignment. Consideration was also given to the length passing under residential properties.

E.1.3 The gradients quoted are along any section of the route different from the Government Proposed Scheme and the maximum rise is from the lowest point where it passes under the River Misbourne at Chalfont St Giles to the summit, which in each case is the Intervention Gap.

E.1.4 The government's Proposed Scheme has a maximum up gradient of 3% south to north and 2.1% north to south, and a total rise of 149m from the River Misbourne to the summit. By their nature the Reference Tunnel and Intermediate Routes have slacker gradients and lower summits.

Green Route

E.1.5 Northwards from the portal at the M25, this follows the government's Proposed Scheme across the River Misbourne at Chalfont St Giles as far as the A404. The route then diverges to follow a line east of Little Kingshill and west of Little Missenden to cross under the River Misbourne, Chiltern Line and A413.

E.1.6 It then runs parallel to the A413 passing to the east of Great Missenden and the intervention gap is close to the A413 south of Bowood Lane. This means the source of noise is close to the existing transport sources, ameliorating the effect of this open section. Access to the gap for emergency purposes is achieved from the A413.

E.1.7 The route then continues to a portal at approximately 0.6km west and nearly 1km north of the government's Proposed Scheme, enabling the portal to be located closer to the AONB boundary. The route will run on the surface from here to rejoin the government's Proposed Scheme on the western edge of Aylesbury approximately 1.5 km north of Stoke Mandeville.

E.1.8 The route has a maximum up gradient of 1.1% south to north and 1.0% north to south, and a maximum total rise of 106 m which is 43 m lower than the government's Proposed Scheme.

Chilterns Long Tunnel Route

E.1.9 Northwards from the portal at the M25, this follows the government's Proposed Scheme under the River Misbourne through Chalfont St Giles and under Shardloes Lake. While following the horizontal alignment of the government's Proposed Scheme to the north of South Heath it runs at a flatter gradient of less than 1% and hence at a greater depth of up to 88m to reach a summit level of 118m AOD near the A413 at The Firecrest at Wendover Dean before descending to the North Portal near Nash Lee Road and rejoining the government's Proposed Scheme horizontal alignment about 1km south of, and the vertical alignment about 1km north of, Stoke Mandeville.

Route Overview

E.1.10 The gradients and summits of the Alternatives considered are all less severe than the government's Proposed Scheme. While running in tunnels is considered to increase head and skin friction and hence increase energy requirements the alignment, both horizontal and vertical, achieved by the Chiltern Long Tunnel Route reduces these effects and the proposed tunnel bore minimizes the effects further. The impacts of flat gradients, stable environment and coasting will more than likely outweigh the additional tunnel length. It should be noted that the government's Proposed Scheme alignment includes a section of tunnel at 3% gradient which the Chiltern Long Tunnel eliminates. It is considered that this will lead to more efficient operation and less energy consumption for all rail traffic transiting the Chilterns for the life of the scheme.

E.1.11 The route lengths between south and north portals of the alternative compared to the government Proposed Scheme (to an equivalent north portal location) are as below:

Table E.1 Schedule of Route lengths

Route	Length
Government's Proposed Scheme	29.2 km
Green	29.3 km
Chilterns Long Tunnel	29.1 km

E.2 Description of Study Routes

Chiltern Long Tunnel Routes

E.2.1 The Chilterns Long Tunnel Route shares the HS2 Reference horizontal and vertical alignments from the southern portal at Ch. 31.250 to approximately Ch. 40 km at the Amersham Ventilation Shaft and continues to share the horizontal alignment until approximately Ch.48 km, north of Great Missenden and just south of the proposed Chesham Road ventilation Shaft. However, the vertical alignment starts to diverge from the HS2 Reference Alignment at the Amersham Ventilation Shaft. It re-merges with the HS2 Reference Alignment at approximate ch. 47 km, at the south end of the 1.5 km straight near Stoke Mandeville.

E.2.2 The proposed vertical alignment will provide nadirs and drainage collection sumps at Chalfont St Peter and Amersham Ventilation Shafts and will support options for underground station/emergency intervention chamber at either Little Missenden Ventilation Shaft location (ch.43 km) or Wendover Dean Ventilation Shaft location (ch. 51.750 km) and will tie back into the HS2 vertical alignment at approximate chainage 59 km, at the northern end of the 1.5 km straight near Stoke Mandeville, creating a gradient of less than 0.2% along this straight, to support any proposal for a maintenance loop or sidings.

E.2.3 The variation in the vertical alignment for the Chilterns Long Tunnel Route will create a rising grade from a sagging vertical curve at the Amersham Ventilation Shaft, reducing to a gradient of 1:500, south of Little Missenden Ventilation Shaft for at least 500 m and continue rising at this flat gradient for a further 500 m north of the Ventilation Shaft. This will provide the opportunity to incorporate an underground intervention chamber or station around the Ventilation Shaft location, to suit the best available road access tunnel and interfaces with the A 413 dual carriageway.

E.2.4 The gradient will continue to rise through Chesham and Leather Lane Ventilation Shafts, reaching a summit and creating a further section of no greater than 0.2% (1 in 500) gradient around the Wendover Dean Ventilation Shaft. This will provide the alternative opportunity to incorporate an underground intervention chamber, associated with this ventilation shaft.

E.2.5 Approximately 500 m north of the ventilation shaft, a hogging vertical curve will be introduced to enable the gradient to fall with the topography, passing through the high ground as far as approximate chainage 55.600, where the bored tunnel portal is located.

E.2.6 The vertical alignment will be at approximately 106.5 m level and continue in a cutting or within a cut and cover tunnel to pass out of the Chilterns AONB and under Nash Lee Road, whilst falling northward at a flatter gradient than the ground surface to create a 0.2% (1 in 500) gradient along the straight to support any proposal for a maintenance loop or sidings, tying into the existing 0.2% gradient at the northern end of the straight alignment of the government's Proposed Scheme.

E.2.7 The Chilterns Long Tunnel Route diverges from the government's Proposed Scheme at approximate ch. 48 km by continuing along the straight bearing, where the government's Proposed Scheme enters a RH 8220 m radius curve and transitions into a flatter 10000 m radius RH curve at approximate ch. 49.600 for some 1.5 km then transitions into a straight of approximately 1.4 km through the Firecrest Ventilation Shaft. At the end of this straight, at approximate chainage 53.5 km., the alignment transitions into a further RH curve of approximately 8400 m radius and continues through the bored and cut and cover portal to reconnect with the alignment of the government's Proposed Scheme at ch. 57 km.

E.2.8 The Chilterns Long Tunnel Route divergence/convergence of the track centre-lines to transition at the northern end of the Chilterns AONB, from the open surface 5 m track centres to around 19 m tunnel track centres is achieved by creating a slight stagger in the transitions within the portal approach. This facilitates the alignment without introducing any unnecessary reverse curves or transitions. This arrangement also offers the opportunity to screen the portal on the landscape and reduce the noise impacts on Wendover and Stoke Mandeville.

E.2.9 The Chilterns Long Tunnel Route alignment optimizes both smoother railway alignments and the additional cover provided by the scarp face to minimize the portal zone and avoid the need for the viaduct and exposed green tunnel cutting on the edge of Wendover.

Government's Proposed Scheme

E.2.10 By comparison, whilst the government's Proposed Scheme follows a long straight alignment between approximately Ch.38.600 and Ch.47.800, it has an undulating vertical alignment, falling and then rising at 0.5% to a nadir and then a further sagging curve between approximately Ch.42.300 and Ch.43.100 before a steeply rising grade of 3%, which is approaching the permitted maximum grade through the north portal at Mantles Wood and a cutting at Hyde End. The alignment flattens within the cutting and into the southern portal of a green tunnel at Ch. 46.000. The gradient of 0.76% continues in cutting beyond the northern portal of the green tunnel at Ch.47.300 and over a summit hugging curve between approximately Ch.48.000 and Ch.48.450, then falls at 0.4% out of the cutting and onto an elevated alignment steepening to as much as 2.1% within a long LH curve that takes the alignment just to the western edge of Wendover. Immediately to the west of Wendover, the government's Proposed Scheme is hidden within a green tunnel, approximately 1300m long. Within this green tunnel, there is a sagging curve that reduces the gradient to 1.3% and, at approximately the foot of the northern scarp of the Chilterns, there is a further sagging curve which reduces the gradient to 0.25% into the open country.

Summary

E.2.11 The tables that follow provide a brief set of data for comparison of the Chilterns Long Tunnel Route considered against the government's Proposed Scheme. They provide a quick assessment of the merits and demerits of each. A full SIFT assessment has been undertaken on the environmental impacts as set out in Appendix A.

Table E.2 Summary comparison – Location

Characteristic: Location	**Government's Proposed Scheme**	**Chilterns Long Tunnel Route**
Bored Tunnel length	13.2 km	24.2 km
Bored Tunnel Length compared to Government Proposed Scheme		+10.8 km
% Difference in bored tunnel length with government Proposed Scheme		+80%
Transit length through weathered Upper Chalk deposits under River Misbourne (downstream)	2.0 km	2.0 km
Minimum depth to rail level under River Misbourne (downstream)	29 m	29 m
Minimum depth under River Misbourne (Upstream at Shardeloes lake)	33 m	33 m
Location of Intervention Gap	None	None
Distance from Wendover Station	160 m	480 m
Distance from Stoke Mandeville Church	600 m	600 m

Table E.3 Summary comparison - Energy

Characteristic: Energy Requirement	**Government's Proposed Scheme**	**Chilterns Long Tunnel Route**
South to north		
Maximum up gradient	3.0%	1.0%
Maximum up gradient length	2.3 km	2.1 km
North to south		
Maximum up gradient	2.1%	0.67%
Maximum up gradient length	0.9km	3.3km
Summit location	Leather lane	The Firecrest Wendoverdean A413
Maximum height rise River Misbourne to Summit	149 m	80.5
Proportion of Government Proposed Scheme height rise	100%	54%

Table E.4 Summary comparison - Depths

Characteristic: Depths	**Government's Proposed Scheme**	**Chilterns Long Tunnel Route**
Depth at Chalfont St Giles VentilationShaft	40m (131ft)	40m (131ft)
Depth at Amersham Ventilation Shaft	43m (141ft)	43m (141ft)
Depth under Misbourne adjacent to Shardloes	32m (105 ft)	33m (108 ft)
Depth under South Heath	5 m (16 ft) (cutting)	90m (300 ft)
Depth under Coombe Hill		76m (250 ft)