High Speed Rail in the Chilterns Part 1: General Long Tunnel Requirements

June 2015

Explanatory note

In response to a proposals by petitioners in the Chilterns, and in response to petitions against the High Speed Rail (London – West Midlands) Bill, a number of options for a tunnel or tunnel extension in the Chilterns have been evaluated by HS2 Ltd.

This document was prepared by HS2 Ltd in May 2015 for internal use, and has been published to allow petitioners to better understand the Promoter's assessment of various tunnel options.

General requirements for long tunnels are set out in Part 1, and the assessment of various options proposed by petitioners are set out in Part 2-4.

High Speed Rail in the Chilterns
Part 1: General Long Tunnel Requirements

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London West Midlands

High Speed Rail in the Chilterns
Part 1: General Long Tunnel Requirements

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List of acronyms

AONB Area of Outstanding Natural Beauty
TBM Tunnel Boring Machine
CDC Chiltern District Council
TSI Technical Specification for Interoperability
FFP Fire Fighting Point

References

Title	Reference
HS2 Project dictionary	HS2-HS2-PM-GDE-000-000002
Style guide	HS2-HS2-CO-GDE-000-000001

1 Executive summary

1.1.1 The section of the Proposed Scheme directly north-west of London passes through the area of the Chiltern Hills that is designated an Area of Outstanding Natural Beauty (AONB). The Proposed Scheme railway alignment within the AONB consists of twin-bore tunnel, cut and cover tunnels, viaducts and open cut areas. The presence of the above ground elements of the infrastructure has led to submission of petitions concerned with the impact of the line on the environment and requiring the elimination of above ground element and consideration for a longer bored tunnel through the Chilterns.

1.1.2 This report deals with the general requirements applicable to various long tunnel options considered in the Chilterns AONB. Specific issues relating to specific long tunnel proposals has been dealt in separate reports.

1.1.3 The Chiltern tunnel as developed in the Proposed Scheme, is approximately 13.5km long, with its south portal immediately east of the M25 and its north portal in an area of ancient woodland in Mantle's Wood, near the village of Hyde Heath. It has been assumed that the 8.8m ID tunnels would be constructed using Tunnel Boring Machines (as described in HS2 Information Paper D7: Tunnel Construction and Methodology). To minimise impact on the Chiltern AONB, the TBMs are launched and driven from the construction compound at the southern portal, with tunnel spoil arising from the southern portal only.

1.1.4 To mitigate impact of the railway, cuttings and green tunnels have been proposed with environmental measures such as areas of landscaping, noise fence and planting to reduce visual and noise effects of the Proposed Scheme.

1.1.5 All long tunnel proposals submitted have been described as alternative options compliant with general high speed rail, fire and safety requirements and the HS2 Project Standards. High level standards relating to Safety in Railway Tunnels are provided in the Technical Specification for Interoperability (TSI), and in particularly in the latest 2014 revision of this standard. Safety measures that may be required may consist of additional intervention and ventilation shafts, or intermediate emergency evacuation facilities (gap structures).

1.1.6 The Proposed Scheme assumes that all excavated material from tunnelling operations is removed from the tunnel via the southern portal, and is then used to form the landscape environmental mitigation in the immediate vicinity of the south portal. Any extended tunnel option would result in the change in this assumption depending on the construction methodology used.

1.1.7 A review of the rail systems requirements associated with long tunnel options concludes that the lengthened tunnel options would require additional tunnel ventilation, smoke control and cooling requirements compared to the Proposed Scheme. They would require additional ventilation and emergency access shafts, additional cross passages and if greater than 20km, a Firefighting Point. The additional requirements would incur additional capital, maintenance and energy costs as well as operating costs over and above the Proposed Scheme cost estimate.

1.1.8 Additional tunnel ventilation, cooling and shafts are likely to have an impact on the HV non-traction power supply. It is predicted that an appreciable redistribution of average traction power loading would also be required for lengthened tunnel options.

1.1.9 Additional worksites may be required depending on the construction methodology adopted for longer tunnel construction.

1.1.10 Construction of additional lengths of tunnel, longer fit-out periods for slab track, construction of additional vent shafts. Firefighting Points, tunnel and shaft equipment associated with the rail systems could result in the delay to the construction programme currently assumed for the Proposed Scheme, unless a strategy is adopted where fit out activities can take place in parallel to the Chiltern tunnel construction programme. It should be noted that the Proposed Scheme Chiltern tunnel is on the overall project programme critical path. Any increased construction period to that assumed for the construction of the Chiltern tunnel would thus represent a delay to the opening of the railway.

2 Abbreviations and descriptions

2.1.1 The abbreviations, descriptions and project terminology used within this document can be found in the project dictionary.

3 Introduction

3.1.1 The section of the Proposed Scheme immediately north-west of London passes through the area of the Chiltern Hills that is designated an Area of Outstanding Natural Beauty (AONB). The Proposed Scheme railway alignment within the AONB consists of twin-bored tunnel, cut-and-cover tunnels, viaducts and open cut areas. The presence of the above-ground elements of infrastructure has led to the submissions of petitions concerned with the impact of the line on the environment and requiring the elimination of above ground elements and consideration for a longer bored tunnel through the Chilterns.

3.1.2 This document summarises the design criteria used for the Proposed Scheme Chiltern tunnel, and general requirements that are applicable to longer tunnel options under consideration.

3.1.3 A number of specific long tunnel options have been considered. Specific issues relating to these proposals will each be captured in separate reports:

- High Speed Rail in the Chilterns: Part 2 Chiltern Long Tunnel
- High Speed Rail in the Chilterns: Part 3 CRAG proposal
- High Speed Rail in the Chilterns: Part 4 REPA proposal
- High Speed Rail in the Chilterns: Part 5 Northolt tunnel to Wendover

4 The Proposed Scheme Chiltern Tunnel

4.1 General

Background

4.1.1 Following consultation in 2011, there was a review of a number of long tunnel options for the tunnel under the Chilterns AONB. This review was documented in a report entitled 'Review of possible refinements to the proposed HS2 London to West Midlands Route' which considered extended twin-bore tunnel options. As a result, additional tunnelling was incorporated into the scheme as part of the announcement made in January 2012. Further development of the route was undertaken and published in mid May 2013 as part of the consultation process for the draft Environmental Statement. Following the draft Environmental Statement and the Design Change Consultations, further development of the design was reported upon within the Environmental Statement which was published in November 2013.

4.1.2 As well as the bored tunnel, the Proposed Scheme within the Chilterns AONB will include sections of cuttings and green tunnel to help mitigate the impact of the railway. In addition, environmental measures such as areas of landscaping, noise fence and planting have been proposed to further reduce the visual and noise effects of the sections of the route which are not in bored tunnel.

4.1.3 The Proposed Scheme route characteristics within the Chilterns AONB is shown in Table 4.1.

Table 4.1: The Proposed Scheme Route Characteristics

Section	Chainage (m)		Length (m)	Type
	from	to		
M25 to Mantle's Wood	31+350	44+650	13,300	Twin bored tunnel
Mantle's Wood to Chesham Road	44+650	46+100	1,450	Cutting
South Heath Tunnel	46+100	47+300	1,200	Cut and Cover Tunnel incl. portal hoods
Frith Hill to Bowood Lane	47+300	50+500	3,200	Cutting
Wendover Dean Viaduct	50+500	51+000	500	Viaduct
Wendover AT Station	51+000	51+600	600	Cutting
Rocky Lane	51+600	52+600	1000	Embankment
A413 Small Dean Viaduct	52+600	53+100	500	Viaduct
Wendover	53+100	53+800	700	Embankment
Wendover Green Tunnel	53+800	55+050	1,250	Cut and Cover Tunnel incl. portal hoods
Green Tunnel to B4009	55+050	56+200	1,150	Cutting
Route Length	***31,500***	***56,200***	***24,850***	

Chiltern Tunnel

4.1.4 The Proposed Scheme Chiltern tunnel is an approximately 13.3km (excluding portal hoods) long twin-bore tunnel, with its south portal located just before the M25 and its north portal at Mantle's Wood north of the village of Hyde Heath. Each bore will have an internal diameter of approximately 8.8m, and an external diameter of approximately 9.6m. Depending on the surface topography, the tunnel depths will vary between approximately 10m and 90m.

4.1.5 There will be four ventilation and intervention shafts associated with the Chiltern tunnel, namely: Chalfont St Peter, Chalfont St Giles, Amersham and Little Missenden Vent shafts. More details about the shafts are described in Section 4.3.

4.1.6 To minimise impact on the Chilterns AONB, the TBMs are launched and driven from the construction compound by the M25 at the southern portal, with tunnel spoil arising from the southern portal only.

4.2 Design Criteria

4.2.1 The HS2 design criteria and requirements for all bored tunnels along the route have been based primarily on current good practice and experience from previous projects, and was produced by a focus group comprising HS2 and tunnel specialists from consulting and contracting engineers. This ensured a consistent and robust approach for underground structures across all areas of the HS2 Phase 1 Proposed Scheme.

4.2.2 The HS2 design criteria gives the requirement for cross-passages as follows:

- Cross-passages are to be spaced at a maximum of 380m centres; and
- Two cross-passages in the vicinity of each shaft location for the sole use of emergency services.

4.2.3 Cross-passages will function as emergency escape routes from an incident tunnel to a neighbouring bore as a place of relative safety. They are also proposed to be used as intervention routes for fire-fighters and rescue services. Sufficient space would be provided for escape and intervention according to Safety in Railway Tunnels (TSI 2014).

4.2.4 Spacing of cross-passages is determined on the basis of train length, method of evacuation, and the requirements of the emergency services. Consideration has been given to the passage of smoke and heat and the risk to people from trains in any parallel tunnel, including any aerodynamic effects.

4.2.5 The HS2 design criteria for bored tunnels requires a minimum gradient of 0.5% along the tunnel in order to provide the required drainage.

4.2.6 Clearance between HS2 tunnel bores is a minimum of approximately one diameter. This is to minimise, as far as reasonably practicable, the effect of ground movement on third party structures both above and below ground, and so that additional tunnel strengthening would not be required to take account of secondary loading effects. The alignment of the HS2 tunnels has been developed to comply with this requirement.

4.2.7 Key design criteria in Table 4.2: contains particular requirements for the Chiltern tunnel:

Table 4.2: Key Design Criteria – The Proposed Scheme

Description	Criterion
Line speed in bored tunnel	320kph
Running speed in open track	400kph
Running speed in cut-and-cover tunnels	360kph
Free cross-sectional area in bored tunnel	56.0m² per bore (equivalent internal diameter 8.8m)
Minimum gradient for tunnel drainage	0.5%
Geological Conditions Drawing No C222-ATK-GT-DPP-020-000034	The bored tunnel is expected to be driven through the Lewes and Seaford Chalks (LESE) running in close proximity to the upper surface of the Chalk Rock. At the portals the sequence will be of Clay-with-flints within majority of the cutting face overlying LESE chalk at the lower part of the slope and base of the cutting and the Chalk Rock.
Particular features required, subject to detailed design	2014 Edition of TSI: Intervention/ventilation shafts required at nominally 3000m centres.

4.3 Intervention and Ventilation Shafts

4.3.1 The HS2 design criteria is set for Intervention and Ventilation Shafts to be provided at regular distances (typically 3km) along the line of long (twin-bore) tunnels (>2km). Each shaft shall contain a number of combined functions, namely:

- Emergency intervention access/egress points and would contain protected stairs and lifts as appropriate;
- Provision for mechanical ventilation to assist in controlling the tunnel environment during various scenarios including control of smoke and hot gases in an emergency; and
- Provision for pressure relief/natural draught relief, assisting with natural ventilation of the tunnels.

4.3.2 There will be four intervention and ventilation shafts associated with the Chiltern tunnel. Location and depths of the shafts are shown in Table 4.3.

Table 4.3: Chiltern Tunnel Vent Shafts

Shaft	Chainage (m)	Depth to Rail Level Below Existing GL (m)
Chalfont St Peter	34+100	65
Chalfont St Giles	37+400	35
Amersham	40+100	34
Little Missenden	43+000	35

4.3.3 A compound will be located at each vent shaft and would comprise of a shaft headhouse building, an approximately 550m^2 of hard-standing to allow for maintenance and emergency access/egress from the tunnel, drainage tanks and utility connections providing firefighting and tunnel building drainage. An access road will be provided from the public highway to the vent shaft area.

4.3.4 Connection to tunnels, the depth of shafts, the requirement for 550m^2 hard standing rescue areas, and their internal arrangement would need to be re-assessed for compliance at detailed design stage. In addition their architectural form, construction form, and constructability would need to be considered in further detail.

4.4 Construction and Spoil Management

4.4.1 It is proposed to use a closed face tunnel boring machine (TBM) for the Chiltern tunnel Proposed Scheme as described in HS2 Information Paper D7: Tunnel Construction and Methodology.

4.4.2 The bored tunnels will be formed with precast segmental concrete linings that are erected behind a TBM. Each tunnel will be driven by its own TBM from the southern portal at an average rate of approximately 80m/week (rate used for planning and programme assumptions). On completion of the drive, the TBMs will be withdrawn from the TBM reception chamber at the north portal.

4.4.3 It is proposed that Chiltern tunnel be constructed from the Chiltern tunnel Main Compound located adjacent to the M25 within CFA 7 Colne Valley. All the tunnel construction process i.e. slurry supply and treatment, segment manufacturer and supply, water supply, etc. will be serviced from this compound.

4.4.4 All excavated material from the tunnelling operations is removed from the tunnel via the southern portal, and is then used to form the environmental landscape mitigation in the immediate vicinity of the south portal. The volume of material arising from the construction of Chiltern tunnel equates to approximately 2 million m^3.

4.5 Railway Systems

4.5.1 A summary of the Rail Systems provisions for Chiltern tunnel is described below.

Tunnel Ventilation and Smoke Control

4.5.2 The system proposed for the Proposed Scheme adopts features that are both in accordance with the TSI and found to be acceptable to the regulators on similar projects in the UK. Key factors in this are the ability to provide intervention points for fire fighters and to limit the number of trains between ventilation shafts to one. The maximum shaft spacing on HS2 is currently 3.3km. If the shaft spacing becomes longer then there are risks that the fire authorities may not find this acceptable (3.3km is the longest shaft spacing on any UK project to date).

Tunnel Heating

4.5.3 The principal cause of heating in the Chiltern tunnel is aerodynamic drag and the traction package inefficiencies in converting energy into motion.

4.5.4 The tunnels have a maximum operating temperature criterion of 35°C. This is to allow the train cooling system to be able to keep the insides of the trains cool enough when running through tunnels, to allow temperatures to be controlled with a practicably sized tunnel ventilation system if the trains stopped in the tunnels, to provide reasonable conditions for maintenance and evacuation within the tunnel and to limit the probability of tunnel based equipment prematurely failing due to hot conditions. The Chiltern tunnel is predicted to begin to exceed this condition after about 10 km and rise to about 38°C by the time the air leaves the portal. This was judged to be a small enough exceedance to be acceptable over a short length of tunnel and a short duration of exposure.

Construction Programme and Logistics

4.5.5 The rail system fitout for the Chiltern tunnel would be carried out in a northerly direction away from West Ruislip railhead compound, located west of Breakspear Road South, in CFA 6 South Ruislip to Ickenham.

4.5.6 Programme considerations have been based on the following rates for the Proposed Scheme Chiltern tunnel:

- Track laying rate of 1.08km per month (average);
- All other railway systems 0.72km per month (average)

4.5.7 The railway systems installation works include track, overhead line equipment, communication equipment and traction power supply. The installation of track in tunnels will be on concrete slab track.

4.5.8 Before the railway systems installation can commence, adequate civil engineering work will need to be completed to allow continuous track laying sequence.

4.6 Programme

4.6.1 An Integrated construction phase programme has been prepared for the Chiltern tunnel which is contained within Appendix B.

4.6.2 Programming of the Chiltern tunnel has been based on an assumed average TBM advance rate of 80m/week. This figure is based upon a review of previous projects of comparable tunnel size and in comparable ground conditions. This average advance rate makes allowance for issues such as TBM maintenance, 'learning curves' and unplanned down-time.

5 Long Tunnel Options

5.1 General

5.1.1 This section summarises the general issues applicable to the various long tunnel options being considered.

5.2 Assumptions

5.2.1 The following assumptions are included in the appraisal for long tunnels under consideration:

- The line speed would remain at 320kph through the longer tunnels.
- Sufficient space would be available at the defined north portal location or could be made available for the extraction of the TBMs (where required), the construction of the 550m^2 hard standing rescue area and the associated portal buildings.
- The ground conditions and ground water levels permit consideration of an alternative simplified TBM method for use in the lower cover additional tunnelling options.
- The average drive rate for bored tunnel construction is taken as 80m/week.
- Ground cover to the bored structure will be a minimum of one diameter. There would otherwise be risks that would need to be considered in respect to design, construction impacts, programme and costing, which would include:
    - Significantly raised risk of variable and unstable ground, giving rise to slower advance rates and higher costs. May also represent a worse case for tunnel lining design, requiring more heavily reinforced segments.
    - Likelihood of higher ground settlements due to the shallower depth, and hence tighter settlement trough, and greater volume losses in tunnelling.
    - Significantly higher risk of collapse(s) due to tunnelling extending to ground level.
    - Raised risk of encountering physical obstructions e.g. sewers, buried plant, etc. although in the semi-rural position being considered, this would probably be less of an issue.

5.2.2 The Key Design Criteria, included as Table 5.1 contains particular requirement of the long tunnel options:

Table 5.1: Key Design Criteria – Long tunnels

Description	Criterion
Line speed in bored tunnel	320kph
Running speed in open track	400kph
Running speed in cut-and-cover tunnels	360kph
Free cross-sectional area in bored tunnel	56.0m² per bore (equivalent internal diameter 8.8m)
Minimum gradient for tunnel drainage	0.5%
Geological Conditions Drawing No C222-ATK-GT-DPP-020-000034	The bored tunnel is expected to be driven through the Lewes and Seaford Chalks (LESE) running in close proximity to the upper surface of the Chalk Rock. At the portals the sequence will be of Clay-with-flints within majority of the cutting face overlying LESE chalk at the lower part of the slope and base of the cutting and the Chalk Rock.
Particular features required, subject to detailed design	2014 Edition of TSI: Additional intervention/ventilation shafts required at nominally 3000m centres. Firefighting Point approximately 900m long [train length +100m and 2No approximately 200m long portal hoods], to limit the maximum length of any tunnel to 20km.

5.3 Intervention and Ventilation Shafts

5.3.1 Ventilation and intervention shafts will be required at nominally 3km spacing along the route. Any extended tunnel option will need to be assessed for additional vent shaft requirements to that proposed for the Chiltern tunnel.

5.3.2 The system proposed for the hybrid bill adopts features that are both in accordance with the TSI and found to be acceptable to the regulators on similar projects in the UK. Key factors in this are the ability to provide intervention points for fire fighters and to limit the number of trains between ventilation shafts to one.

5.3.3 The location of the new shafts will need to be carefully selected. Similar to the Proposed Scheme vent shafts, the new vent shafts will need to be connected to the running tunnels from the ground surface and will require both temporary and permanent vehicular access, 550m^2 hard standing rescue area, and connections to services/utilities including power, telecommunications, water supply and sewerage.

5.3.4 The ventilation shafts need to be designed with sufficient depth within ground cover in order to be able to accommodate the required ventilation equipment. Subject to detailed assessment and space planning, ventilation-intervention shafts less than about 25m depth would require a change in overall configuration from that chosen for the Proposed Scheme.

5.4 Tunnel Separation

5.4.1 An updated technical specification for interoperability (TSI) relating to the 'safety in railway tunnels' of the rail system of the entire European Union, was adopted in November 2014 and came into effect in January 2015 (the '2015 TSI'). Relevant clauses from the 2015 TSI relating to long tunnels such as the proposed CRAG or Chiltern Long Tunnel proposals, include the following clauses:

> *2.2.1. 'Hot' incidents: Fire, explosion followed by fire, emission of toxic smoke or gases.*
> (b) The fire starts on a train.
>
> Whenever possible the train leaves the tunnel. Passengers are evacuated, directed by the train crew, or by self-rescue, to a safe area in the open air.
>
> If appropriate, the train may stop at a fire fighting point inside the tunnel. Passengers are evacuated, directed by the train crew, or by self-rescue, to a safe area.
>
> 4.2.1.5. Evacuation facilities
>
> 4.2.1.5.1 Safe area
>
> This specification applies to all tunnels of more than 1 km in length.
>
> (a) A safe area shall allow the evacuation of trains that use the tunnel. It shall have a capacity corresponding to the maximum capacity of the trains planned to be operated on the line where the tunnel is located.
> (b) The safe area shall maintain survivable conditions for passengers and staff during the time needed for the complete evacuation from the safe area to a final place of safety.
> (c) In case of underground/undersea safe areas, the provisions shall allow people to move from the safe area to the surface without having to re-enter the affected tunnel tube.
> *(d)* The lay-out of an underground safe area and its equipment shall take into account the control of smoke, in particular to protect people who use the self-evacuation facilities.
>
> 4.2.1.7. Fire fighting points
>
> This specification applies to all tunnels of more than 1 km in length.
>
> (a) For the purpose of this clause, two or more consecutive tunnels will be considered as a single tunnel unless both of the following conditions are met:
>
> 1) The separation between tunnels in open air is longer than the maximum length of the train intended to be operated on the line + 100 m and
>
> 2) The open air area and track situation around the separation between tunnels allow passengers to move away from the train along a safe space. The safe space shall contain all passengers of the maximum capacity of the train intended to be operated on the line.
>
> (b) Fire fighting points shall be created
>
> 1) Outside both portals of every tunnel of > 1 km and

2) Inside the tunnel, according to the category of rolling stock that is planned to be operated, as summarized in the table below:

[Applicable HS2 requirements from the table: for tunnels >20km and rolling stock Category B; the maximum distance from the portals to a fire fighting point and between fire fighting points shall be 20km]

5.4.2 Under the Proposed Scheme, the longest tunnel is proposed at just over 13km and evacuation of passengers from within the tunnel in the event of an incident is proposed to be via the adjacent tunnel bore, with appropriate tunnel infrastructure and ventilation requirements to meet the TSI regulations and safety requirements as set by the emergency services.

5.4.3 Continuous tunnel lengths would be over 20km for the long tunnel options petitioned and thus additional fire and safety consideration would be required. TSI clause 4.2.1.7 above notes the requirement for Firefighting Points in such circumstances. Provision of an open to air gap within the tunnel length would create two shorter tunnels (of length <20km each); this would also allow the gap to be used as an appropriate Firefighting Point and would better support the TSI clause 2.2.1 (b) which states for train fires 'Whenever possible the train leaves the tunnel'. Without a gap, an underground Firefighting Point would be required with associated infrastructure requirements for safe egress and emergency access.

5.4.4 Where a gap is provided the minimum length of the gaps between successive sections of tunnel is set at train length (approx. 400m for HS2) plus 100m in the 2015 TSI Clause 4.2.7.1 (1). To this length, two portal hood lengths, currently estimated at 200m each, must be added, giving a minimum 900m length of gap between the tunnel drives.

5.4.5 To function as a Firefighting Point, the intervention gap would also need to comply with the following HS2 requirements:

- Inclusion of lifts and stairs to allow passenger egress from track level to the ground surface;
- Vehicular access to track level;
- Access for emergency vehicles to track level with passing bay provision to allow for passage and parking of emergency vehicles alongside the train;
- Access from public roads; and
- Provision of storage facilities for firefighting apparatus and water supply.

5.4.6 The proposed layout for the intervention gap and Firefighting Point could comprise either part cutting, part reinforced concrete anchored walls, or an open cut over its full length with propped or anchored head walls, or open cuts completely without any reinforcement. The choice would depend on the location of the gap structure and would determine the land take required.

5.4.7 A single portal structure and rescue area would be needed with a permanent access and with pedestrians and vehicles separated. Trackside access including passing and turning areas would need to be provided.

5.4.8 HS2 preference would be for an open to air gap and Firefighting Point as a separation point on tunnels longer than 20km, compared to an underground Firefighting Point. See Section 5.7 of this report for more detail on tunnel ventilation and safety issues.

5.5 Construction

5.5.1 For long tunnel options it would also be proposed to use a (closed face) tunnel boring machine (TBM), as per the Proposed Scheme Chiltern tunnel as described in HS2 Information Paper D7: Tunnel Construction Methodology.

5.5.2 The bored tunnels would be formed with precast segmental concrete linings that are erected behind the TBM. Each tunnel would be driven by its own TBM, Depending on construction methodology used, some options may require additional TBMs. On completion of the drive, these would be withdrawn from a TBM reception chamber. This may be a portal, Firefighting Point or ventilation-intervention shaft, each having different logistical requirements. Additional land may be required at TBM reception pits, with an approach access suitable for heavy craneage (typically 1200t) and other plant required for the TBM removal. When broken down, the typical size of individual elements to be transported is shown in Figure 5.1.

Figure 5.1: Transportation of TBM elements

5.5.3 Construction compounds, located at the tunnel portals, would service both the parallel drives with segment supply, spoil removal and spoil treatment. Is it estimated that the plan size of each of these sites will be approx. 100,000 – 150,000 m^2 plus a possible additional 30,000 m^2 should a segment casting factory be needed.

Additional land would also be required for materials storage and handling for treatment of the tunnel spoil before re-use or disposal. If segments are not cast on site, to maintain 2 TBMs at an average advance rate of 80m/week would require approximately 40 lorries/day to deliver segments over the required construction programme. The provision of a segment factory on site would reduce, but not eliminate the 40 lorries/day, as materials for casting the segments would still need to be delivered.

5.5.4 The power supply demands of the northern portal site, servicing TBMs driven south, must be provided for. An assessment with the utility providers would need to be carried out to determine the source or resilience of this power supply. This may require a large quantity of plant/equipment at the northern portal locations.

5.5.5 Local construction compounds would be required for the construction of the vent shafts and gap structure (if required).

5.6 Spoil Management and Disposal

5.6.1 The Proposed Scheme assumes that all excavated material from tunnelling operations is removed from the tunnel via the southern portal, and is then used to form the environmental landscape mitigation in the immediate vicinity of the south portal. Any extended tunnel option would result in this assumption becoming invalid as different construction solutions are being considered.

5.6.2 If the tunnel bores are driven from both ends of the extended tunnel, this would result in tunnel excavated material arising from the TBM launch locations at the northern portal as well as the southern portal. If the tunnels are driven from just the southern to the northern end, this would result in additional tunnel excavated material arising from the southern portal over and above what is produced in the Proposed Scheme.

5.6.3 Based upon the assumed TBM drive rate of 80m per week, there would be approximately 12,000m^3 per week of tunnel arisings that will need to be removed from TBM launch locations. The tunnel excavated material would need to be temporarily stored at these locations for material treatment. Once treated, this material would either have to be incorporated permanently within revised landscaping proposals on site, or would need to be removed from site. This could be via the public highway networks by rail disposal or by slurry pumping.

5.6.4 Traffic impact for removal of excavated material from site would need to be assessed for each individual tunnel extension option. In all cases, the traffic impacts would be most significant close to the northern portal, ie around Stoke Mandeville, Aylesbury and Wendover, although it is envisaged that some material would be run up the HS2 trace for use in mitigation earthworks.

5.6.5 Disposal by rail would require the incorporation of a railhead at the Stoke Mandeville compound with associated additional working areas. There would be a need for around 20 train paths/week on average to dispose of material, plus additional paths for import of material by rail if required and this number of train paths, over and above those required for the Proposed Scheme, would be difficult to achieve.

5.6.6 As an alternative to the above strategies, the material arising from the tunnel could be pumped in lieu of transport or haulage either through the HS2 trace to Calvert or offsite to selected reception sites. The options would be to either process the material at the tunnel portal and pump it as a slurry, or pump the chalk slurry directly to the reception site for cleaning. The selection will depend on the type of boring machine to be employed, availability of construction corridor and treatment areas required, cost and programme. Particular concerns for this disposal method include:

- Time to achieve design and planning permission for pipe routes;
- Availability of space within the existing trace;
- Quality control required on material consistency to facilitate pumping.

5.7 Rail Systems

5.7.1 A review of the rail systems requirements associated with long tunnel options suggests there would be additional safety, cost and programme impacts as compared to the current Proposed Scheme. The lengthened tunnel options would require additional ventilation and emergency access shafts, additional tunnel cross passages, and more extensive tunnel ventilation and smoke control requirements.

Tunnel Ventilation and Smoke Control

5.7.2 It is proposed to maintain the maximum shaft spacing to 3km to provide intervention points for fire fighters and keep the limitation of the number of trains between ventilation shafts to one.

5.7.3 It is a mandatory requirement of the TSI to provide a Firefighting Point in tunnels longer than 20km. An option has been presented whereby an underground rescue facility has been proposed for the Firefighting Point. Similar facilities have been incorporated in certain long rail tunnels in Europe (with different site-specific risks and constraints to those that apply to HS2). Provision of an underground Firefighting Point and rescue facility poses a number of challenges as listed below.

5.7.4 At such rescue facilities it is necessary for passengers to be able to evacuate from the train to a place of safety in a short period of time. To achieve this, it is common practice to provide a cross passage door for each train carriage. The door would typically lead to a separate evacuation gallery connected to ground level. The cross passage might otherwise lead to the non-incident bore, but this raises risks and delay with the subsequent evacuation of passengers from the tunnel. In either case there would be significantly more cross passage doors within the tunnels to be constructed and requiring maintenance.

5.7.5 A critical factor is the duration passengers can be held in an adjacent non-incident tunnel and the views of the UK fire authorities who will be consulted during the Quantitative Design Review.

5.7.6 It is also common practice to provide transverse ventilation at such facilities. A longitudinal ventilation system, as typically employed in shorter tunnels, may still expose some passengers downstream of the fire to smoke. For the longer tunnels there is a higher likelihood of the train stopping within the tunnel and hence improved tenability is sought. A transverse ventilation system extracts smoke along the length of the train and tangibly reduces the probability of passengers being exposed to smoke during any evacuation and intervention. The nature of these systems has been developed and optimised in other European long tunnels and it has become typical to provide a large duct connected to each bore in at least five locations to provide a reasonable distribution of airflows and control of smoke.

5.7.7 The required airflow capacity at the ventilation shaft is considered likely to be within the current proposed capacity of the HS2 shafts, but at such rescue stations it has also become common practice to supply air to the non-incident bore and exhaust air from the incident bore at the same shaft at the same time. The current above ground shaft arrangements cannot achieve this. Either a larger above ground shaft arrangement would be required, or potentially some of the shafts either side might be used for supply air.

5.7.8 Such below ground rescue stations become the target stopping location for a train on fire. However, by enclosing these facilities below ground there is a greater probability of damage to the structural components and ventilation system equipment. This means that post incident recovery can become extended and the operational consequences and loss of revenue may be much higher than compared to an open to air facility. Such losses of revenue, and also of public confidence, have been tangible for the Channel Tunnel, albeit the fire hazard is higher on the Channel Tunnel considering the types of vehicles using that infrastructure. There may be opportunities to include fire suppression systems at these locations to minimise infrastructure damage and such facilities have been retrospectively added to the Channel Tunnel. This potentially negative impact of the below ground rescue stations should be acknowledged and accounted for in the decision making process.

5.7.9 If the rescue stations are located entirely below ground then the interface point of the rescue station needs to be similar in size to the main tunnel bore. This limits the potential for micro pressure wave generation as well as construction costs.

5.7.10 There is also an effect on the amount of tunnel cooling required for below ground facilities. Individual tunnels up to 20km are predicted to require approximately 13MW of cooling. Therefore, two such tunnels in succession separated by an open to air facility might require around 26MW of cooling. One much longer tunnel without an opening, and associated natural cooling, might require about 36MW of cooling, meaning more equipment and running cost.

5.7.11 A key consideration relates to crossovers at or near the rescue facilities. It may be desirable and necessary to include a crossover at the rescue location for both emergency and tunnel maintenance scenarios. If the rescue station is below ground cavern the crossover potentially needs to be located in a cavern or discrete tunnel bores. In either case it makes it challenging to provide a place of relative safety in a non-incident part of the tunnel since there is no non incident cavern at this location. If the entire cavern were to be made tenable this may be highly challenging given the potential for any smoke to be affected by the high speed airflows that take some time to decay in the non-incident bores. Potentially the evacuation routes may need to be constructed separately on the outside edges of the crossover. There may also be micro pressure wave issues cause by the change in tunnel cross sectional area at the cavern. There is a risk that any such arrangement would not be able to be developed with a satisfactory outcome. It may therefore be necessary to develop any below ground crossover before or after the rescue facility, as has been the case on other long rail tunnels. Such crossovers would be provided with doors to allow the tunnel airflows to be isolated from each other. The doors are large and comparatively expensive and demand maintenance. There may still be some micro pressure wave issues at the HS2 train speeds.

5.7.12 If crossovers are required it may be highly desirable to provide these at open to air rescue facilities. Any smoke from a fire would tend to rise upwards and passengers might evacuate via a side platform to a protected refuge area. Tunnel cooling would be optimised, infrastructure damage after a fire minimised, the need for cross passage doors eliminated, and potentially improved construction access gained. There is expected to be a need for porous portals on the approach to the crossover/rescue facility, but there may be options to duct such periodic vents to above ground allowing much of the porous portal to be back filled. Further work is required to understand the optimum outcome considering the operational and maintenance demands versus the construction costs and impacts.

5.7.13 It is therefore considered that an open gap structure is required for the Firefighting Points. This is based on the project requirement to design a safe operational railway, ensuring the safe evacuation of passengers under all scenarios.

Tunnel heating

5.7.14 As mentioned previously the principle cause of heating in the Chilterns tunnel is aerodynamic drag and the traction package inefficiencies in converting energy into motion. Tunnel modelling predictions using differing software and prediction methods specific to HS2 Chiltern tunnel indicate that the drag in the longer tunnels may increase by about 50% compared to outside. Warming of longer tunnels is therefore an important consideration.

5.7.15 As described in Section 4.5 of the report, the 13.5km long Chiltern tunnel begins to exceed the maximum temperature criterion of 35°C after about 10km and rises to about 38°C by the time the air leaves the portal. Longer tunnels would result in temperatures tangibly higher than 38°C and for a greater proportion of the tunnel length. This cannot currently be assumed to be acceptable and thus specific measures would need to be included for tunnel cooling should longer tunnels be proposed.

Fan usage

5.7.16 If the trains stop in tunnels during normal operations, the tunnel ventilation fans would likely be required to operate to manage tunnel air temperatures. The increase in length of tunnels theoretically increases the probability of a train stopping in the tunnel during congestion. This potentially increases the usage and wear and tear on the fans and associated equipment and also the probability of an uncomfortable event occurring if the ventilation system at any shaft were not available.

5.7.17 For longer tunnel options it is assumed that the ventilation facilities could be operated to manage the emissions from a diesel powered rail grinding train, albeit that the final technology of the rail grinding train and other heavy maintenance vehicles remains under review. With longer tunnels, the ventilation system would need to operate more frequently in support of such rail grinding activities meaning more maintenance and cleaning of the airways.

Air quality inside trains:

5.7.18 The longer tunnels may affect air quality in the rolling stock. It may be necessary to shut off the outside (fresh) air to the rolling stock when in tunnels to prevent pressure waves affecting the pressure comfort of passengers. This loss of ventilation would cause carbon dioxide (CO2) levels to rise. Whilst the TSIs require a long-term safety exposure limit of 5,000 ppm, there are uncertainties in relation to general air quality at levels above 2,000ppm. Operational practice in aircraft usually results in 1,500ppm of CO2. Levels of around 2,000 ppm might be acceptable in rolling stock based on anecdotal evidence from other long tunnels. Levels between 2,000 and 5,000ppm present a risk in terms of general air quality. If the CO2 level could be controlled to 500 to 600ppm when leaving the stations (outside air is about 400 ppm), the in-car CO2 content may rise to around 2,000ppm at the end of a 20 km tunnel and higher for longer tunnel options. For a crowded car this would increase further and for slower train operations this could increase again.

5.7.19 To achieve even 2,000ppm at the end of the tunnel potentially a supplementary rolling stock ventilation system would be required at the stations to provide a high capacity purge of the carbon dioxide down to a lower starting condition before the journey into the tunnels. It is known that some countries are considering actively controlled pressure ventilation for rolling stock that may allow some ventilation in tunnel when pressure waves were not near the train. This would require a detailed review for HS2. Other countries are understood to have developed a specialised air supply system, possibly from a pressurised reservoir.

5.7.20 Further work would be required to develop mitigation for HS2, but at this time it is recommended to assume that some form of special measure would be required for the rolling stock. Such a special measure might only be achievable on the rolling stock purchased specifically for HS2, potentially affecting the ability for other rolling stock to inter operate in the longer tunnel without risks associated with pressure discomfort or poor air quality.

Crossovers:

5.7.21 If the southern crossover associated with the current maintenance loop at chainage 56+000km is proposed to be located within the long tunnel options, the ventilation system design and ability to control smoke would be strongly affected by the tunnel cross sectional area. If the southern crossover could not be relocated outside the tunnelled section then doors would be required to allow the tunnel airflows to be isolated from each other (as discussed above) which increased construction complexity, maintenance requirements and costs as well as increased capital cost.

Operations:

5.7.22 Journey times would typically be higher for the increased tunnel lengths for speed limit and resistance, but these are offset by the improved flatter vertical alignments.

5.7.23 An operational assessment has identified that none of the proposed longer tunnel options significantly impact the journey time, with modelling indicating increases in both journey time and technical headway in the range of 10 to 15 seconds. Further work would be required to confirm if these small changes to journey time and headway would impact sectional running times and route capacity respectively, which means there remains a risk that the timetable could be affected

5.7.24 Specific journey times associated with each long tunnel under consideration is presented in each individual reports.

Traction Power and Overhead Contact System

5.7.25 For longer tunnel options there is predicted to be an appreciable redistribution (and transfer) of average traction power loading (electrical) from Quainton ATFS to Ickenham ATFS electrical feeding area. The adequacy of the currently proposed Traction Power System Design to support this increase in loading requires further assessment employing multi-train traction power simulation modelling and represents a risk. A possible mitigation to compensate for this would be to relocate South Heath Mid Point AutoTransformer Station (MPATS). The relocation would need to be relocated to a vent shaft or rescue area. In addition, the associated neutral section would also need to be relocated to a vent shaft/rescue area providing sufficient space for the numerous 25kv cables and disconnectors.

Non-Traction Power Supplies

5.7.26 The proposal for non-traction power supplies for the Proposed Scheme includes a bulk intake at the Chiltern tunnel south portal, supplying an HV ring network extending – in the Country direction - towards South Heath Cut and Cover substation at chainage 47+300. From this point onwards, non-interconnected DNO HV intakes are proposed at discrete locations.

5.7.27 Any extension to the present tunnel limits will require amendment of these arrangements and required supply. The additional tunnel ventilation and more shafts potentially operating at the same time, as well as tunnel cooling, are likely to have an impact on the HV power supply, cable sizing and number of connections to the DNO supplies. A detailed review of this would be required.

5.7.28 The following issues would require further detailed investigation should longer tunnels be incorporated into the scheme:

- Achievable supply options for a new substation at the revised northern portal location
- Practicalities of extending the HV ring network further north (including additional cabling costs for both the extension, and overall cabling size for the associated total loads and losses)
- Implications on the ability of the Chiltern tunnel south portal bulk intake to accommodate the additional load demands, inclusive of necessary tunnel cooling.

Construction Programme and Logistics

5.7.29 The key construction issue with the alternative proposals is the restrictive access to the trace increasing the logistical constraints compared to the Proposed Scheme Chiltern tunnel. This will increase risk to the overall rail systems installation. Hence complex logistics planning and access are key and would require risk mitigation to ensure delivery.

5.7.30 Programme considerations have been based on the same rates as described in Section 4.5.

5.7.31 Longer tunnels will result in a longer construction programme if the railway systems fit out was based on the Chiltern tunnel's strategy of installation via the southern portal. However, by providing a compound at the new northern portal locations, fit out could be undertaken from both tunnel ends. Subsequently there will be minimal impact to the railway systems programme for the tunnel options under consideration. However, the resources and worksites would effectively double to achieve this, resulting in a local increase in construction traffic, via road, at the northern portal during railway system installation

5.7.32 Ventilation shafts are stand alone on the programme so the number affects the potential resources required for delivery – the actual duration may extend depending on the additional equipment that might be required from the additional systems requirements. This will affect their independent installation durations but should not impact on overall delivery programme if managed well.

5.7.33 Firefighting Intervention Points: these are new to the Proposed Scheme so have no current programme base. At this stage of development they can be likened to the ventilation shafts and viewed as standalone items. As such they should not be critical but will require additional construction compounds, at the surface and will have more of an interface with installation in the tunnel. They would need to be factored into the testing and commissioning strategy, to determine what additional time and other factors they add to the overall programme.

5.7.34 Where increased temperatures are possible then some of the core installation logic/sequence may need to be addressed and revised to allow for more of the installation of the permanent cooling systems and ventilation early to allow and support early operation to assist in reducing the local tunnel temperatures during construction. This may affect the average installation rates as the number of workfronts/worksites within the tunnel operating at the same time may need to be reduced, or other considerations about durations of shifts and cycling of labour may be required, for health and safety reasons.

5.7.35 A key consideration is that the additional infrastructure/equipment required to support these longer tunnels may result in a lower average installation rates due to the additional works in the tunnel. The potential mitigation for this is to increase the resourcing to mitigate the reduced installation rates, this leads to greater access and logistics considerations and potential space required at the access points.

5.7.36 For all longer tunnelled options the installation from Calvert is not a factor. Any longer tunnel option reduces the amount of systems installation that is possible from Calvert. This reduction is equal to the extension of the tunnel. For the railway systems installation in the tunnel there is no direct relationship with the Calvert south delivery programme.

5.7.37 There is an associated reduction in the amount of material that are delivered by train and a local increase in construction traffic, via road, at the tunnelled section access point. This would be proportionally similar to those provided for the Chiltern tunnel southern portal worksite.

Maintenance

5.7.38 The longer tunnel option increase the plant and equipment required due to the increase in tunnel length and vent shafts. In addition, cooling equipment is required for all longer tunnel options which are not required for the Hybrid Bill scheme. For the 24km long tunnels, rescue areas are required increasing the number of cross passage doors and other life safety equipment that needs to be maintained. Although the ventilation shafts can be safely visited during the day, inspection and maintenance of items such as the cross-passages and the rescue areas will need to be undertaken during the night-time "maintenance windows". The opportunities to work within these maintenance windows is limited due to the quantum of other works that must be undertaken and the number of maintenance trains that will be travelling between the IMD and their worksites every night. Therefore this adds risks to the maintenance strategy.

Costs

5.7.39 Extended tunnels will result in an increased construction cost estimate for railway systems due principally to

- Additional requirements for tunnel systems and new ventilation shafts, including ventilation fans and power equipment to meet additional power demands for shafts and in tunnels; and

- Additional plant/equipment for the introduction of tunnel cooling, to maintain air temperatures within prescribed limits.

5.7.40 The incremental rail systems construction cost for each individual option is described in specific reports.

5.7.41 Although not estimated there would be additional operating costs associated with each option over and above the Chiltern tunnel cost estimate, due to the increased need for tunnel ventilation, smoke control and tunnel cooling, maintaining a rescue area (for the longer tunnels) and a general increase in railway systems plant/equipment within each of the extended tunnel options.

5.8 Programme

5.8.1 Basic programme drivers and assumptions for the long tunnel options, based on the project construction programme, are as follows:

- A TBM average rate of 80m/week;
- Cross passage construction undertaken in parallel with TBM drives, but undertaken some distance behind the face. As a consequence, a period of around a month would need to be allowed for their completion following the end of the tunnel drive;
- The commencement of construction of intervention shafts would be some six months in advance of the tunnel drives. Shafts are assumed to be used for TBM maintenance intervention.

5.8.2 As the Proposed Scheme Chiltern tunnel is on the overall project programme critical path, any increased construction period to that assumed for the construction of Chiltern tunnel would represent a delay to the opening of the railway. Unless the construction methodology assumes additional TBMs running in parallel, or construction of the shafts/gap structures are carried out concurrently, any additional tunnel length construction may result in the delay to the programme.

5.8.3 Longer fit-out periods for tunnel slab track, construction of additional vent shafts and gap structure, tunnel and shaft equipment associated with the rail systems equipment, could all result in the delay to the construction programme currently assumed for the Proposed Scheme. Each long tunnel option would therefore need to be carefully assessed for a detailed assessment of programme implications.

Appendix A

A.1 The Proposed Scheme Plan & Profile Drawings

A.1.1 C222-ATK-CV-DPL-020-000001

A.1.2 C222-ATK-CV-DPL-020-000002

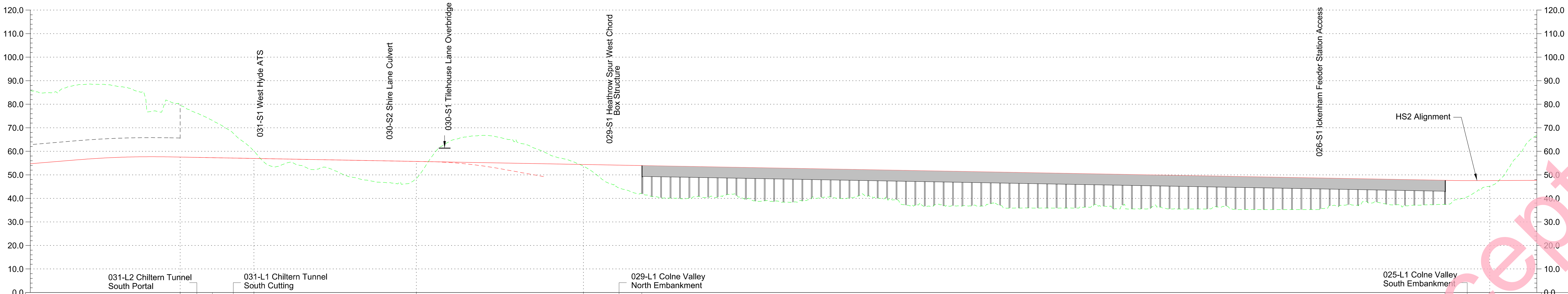
A.1.3 C222-ATK-CV-DPL-020-000003

A.1.4 C222-ATK-CV-DPL-020-000004

A.1.5 C222-ATK-CV-DPL-020-000005

Plan

Scale 1:10000



Route Element ID: 031-L3 Chiltern Tunnel; 030-L1 West Hyde Embankment; 029-L2 Tilehouse Lane Cutting; 025-L2 Colne Valley Viaduct

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Chainage	Existing Level	Proposed Level	Cut and Fill
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31+900	85.0	55.5	-29.5
31+800	88.2	56.4	-31.8
31+700	88.4	57.1	-31.3
31+600	87.2	57.5	-29.7
31+500	76.7	57.7	-19.0
31+400	80.8	57.6	-23.2
31+300	76.5	57.4	-19.1
31+200	71.7	57.2	-14.5
31+100	64.4	57.1	-7.3
31+000	54.8	56.9	+2.1
30+900	55.3	56.7	+1.4
30+800	52.3	56.5	+4.2
30+700	51.5	56.3	+4.8
30+600	48.2	56.1	+7.9
30+500	46.8	56.0	+9.2
30+400	46.2	55.8	+9.6
30+300	56.9	55.6	-1.3
30+200	65.0	55.4	-9.6
30+100	66.6	55.2	-11.4
30+000	65.8	55.0	-10.8
29+900	63.1	54.9	-8.2
29+800	58.9	54.7	-4.2
29+700	55.8	54.5	-1.3
29+600	50.4	54.3	+3.9
29+500	44.5	54.1	+9.6
29+400	42.0	53.9	+11.9
29+300	40.1	53.7	+13.6
29+200	40.1	53.6	+13.5
29+100	40.6	53.4	+12.8
29+000	41.1	53.2	+12.1
28+900	38.7	53.0	+14.3
28+800	38.4	52.8	+14.4
28+700	39.2	52.6	+13.4
28+600	40.6	52.5	+11.9
28+500	40.5	52.3	+11.8
28+400	40.1	52.1	+12.0
28+300	37.5	51.9	+14.4
28+200	36.7	51.7	+15.0
28+100	36.8	51.5	+14.7
28+000	36.9	51.4	+14.5
27+900	37.9	51.2	+13.3
27+800	35.9	51.0	+15.1
27+700	35.9	50.8	+14.9
27+600	35.9	50.6	+14.7
27+500	36.2	50.4	+14.2
27+400	35.5	50.3	+14.8
27+300	35.5	50.1	+14.6
27+200	36.1	49.9	+13.8
27+100	35.5	49.7	+14.2
27+000	35.5	49.5	+14.0
26+900	35.6	49.3	+13.7
26+800	35.2	49.2	+14.0
26+700	35.2	49.0	+13.8
26+600	35.2	48.8	+13.6
26+500	35.8	48.6	+12.8
26+400	37.3	48.4	+11.1
26+300	38.0	48.2	+10.2
26+200	37.2	48.1	+10.9
26+100	37.1	47.9	+10.8
26+000	37.4	47.7	+10.3
25+900	40.5	47.6	+7.1
25+800	45.2	47.6	+2.4
25+700	55.9	47.6	-8.3
25+600	66.6	47.7	-18.9

Design Speed: 320km/h

Profile

Scale H 1:10000 V 1:1000

METRES @ 1:10000 — 0, 100, 200, 500, 1000

METRES @ 1:1000 — 0, 10, 20, 50, 100

Rev	Description	Drawn	Checked	Con App	HS2 App
P10	Condition B. Code 1. Fit for hybrid bill submission	TB 03/10/13	SS 04/10/13	JN 04/10/13	
P09	Interim Preliminary Design Condition B - CP2	TB 10/09/13	SS 10/09/13	JN 10/09/13	
P08	Interim Preliminary Design Condition B	TB 26/06/13	SS 26/06/13	JN 26/06/13	
P07	Initial Preliminary Design Condition A	TB 16/04/13	SS 17/04/13	JN 17/04/13	
P06	Initial Preliminary Design Condition B4	TB 26/03/13	SS 26/03/13	JN 26/03/13	

Legends/Notes:

- Depot, station, headhouse or portal building
- Tunnel portal
- Electricity substation
- Land drainage area
- Ecological mitigation pond
- Balancing pond
- Replacement floodplain storage
- Woodland habitat creation
- Wetland habitat creation
- Grassland habitat creation
- Landscape mitigation planting (scrub / woodland)
- Grassed areas
- Sustainable placement
- Public realm
- Engineering earthworks
- Landscape earthworks
- Rail alignment formation
- Returned to suitable development use
- County boundary
- Borough / District boundary
- Community forum boundary
- Watercourse diversion
- Existing watercourse
- Ditches - new
- Hedgerow habitat creation
- UT Main utility works
- Existing public right of way (PRoW)
- New, diverted or realigned PRoW
- Stopped-up PRoW
- Tunnels external extent
- Rail alignment
- HS2 Access road
- Noise fence barrier
- 10+000 Chainage (e.g. 10+000)

Registered in England
Registration No. 06791686
Registered office:
Eland House,
Bressenden Place,
London, SW1E 5DU

Creator/Originator	Atkins
HS2 Security Classification	INTERNAL
Zone	Country South
Design Stage	hybrid bill submission
Drawing Title	Main Line Sheet 20 of 49 Chainage 25+600 to 32+000
Project/Contract	Country South Design
Discipline/Function	Civil
Drawn	TB
Checked	SS
Approved	JN
Date	18/10/2012
Scale	AS SHOWN
Size	A1
Drawing No.	C222-ATK-CV-DPL-020-000001
Rev.	P10

Plan

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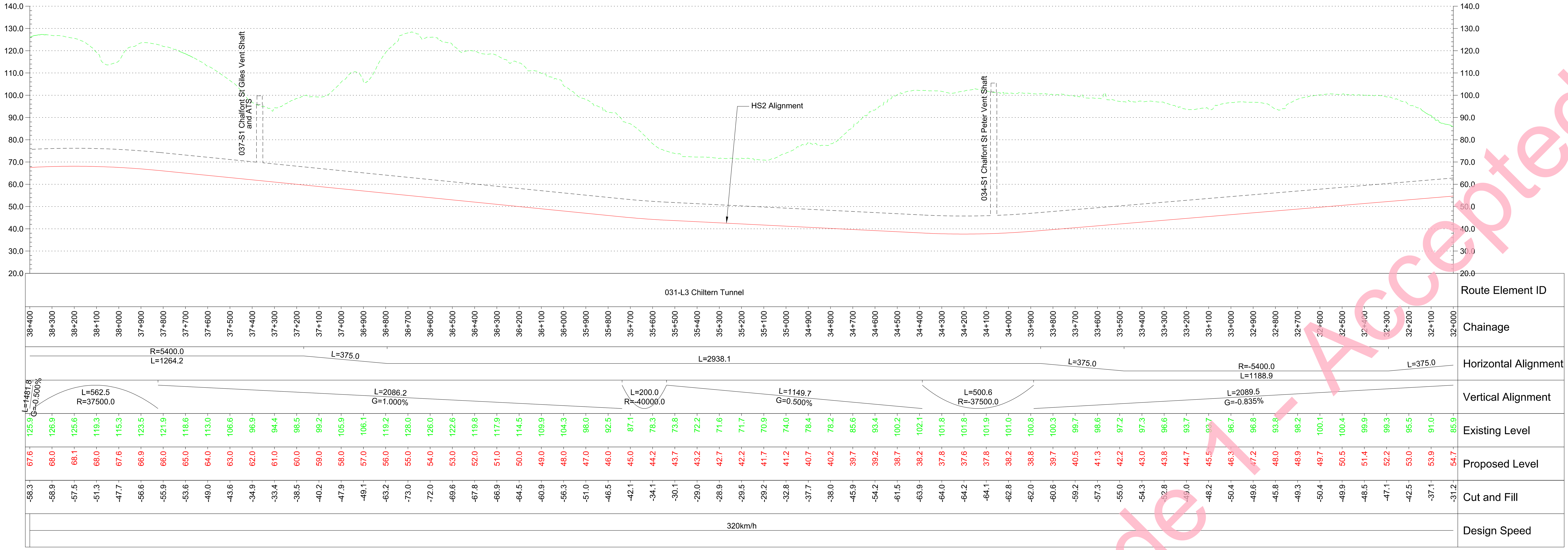

Profile

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Rev	Description	Drawn	Checked	Con App	HS2 App
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P08	Interim Preliminary Design Condition B - CP2	TB 10/09/13	SS 10/09/13	JN 10/09/13	
P07	Interim Preliminary Design Condition B	TB 26/06/13	SS 26/06/13	JN 26/06/13	
P06	Initial Preliminary Design Condition A	TB 16/04/13	SS 17/04/13	JN 17/04/13	
P05	Initial Preliminary Design Condition B4	SHN 26/03/13	SS 26/03/13	JN 26/03/13	

Scale with caution as distortion can occur.

Legends/Notes:

- Depot, station, headhouse or portal building
- Tunnel portal
- Electricity substation
- Land drainage area
- Ecological mitigation pond
- Balancing pond
- Replacement floodplain storage
- Woodland habitat creation
- Wetland habitat creation
- Grassland habitat creation
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- Stopped-up PRoW
- Tunnels external extent
- Rail alignment
- HS2 Access road
- Noise fence barrier
- 10+000 Chainage (e.g. 10+000)

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Zone	Country South
Project/Contract	Country South Design
Design Stage	hybrid bill submission
Discipline/Function	Civil
Drawing Title	Main Line, Sheet 21 of 49, Chainage 32+000 to 38+400
Drawn	TB
Checked	SS
Approved	JN
Date	18/10/2012
Scale	AS SHOWN
Size	A1
Creator/Originator	Atkins
HS2 Security Classification	INTERNAL
Drawing No.	C222-ATK-CV-DPL-020-000002
Rev.	P09

Code 1 - Accepted

Plan

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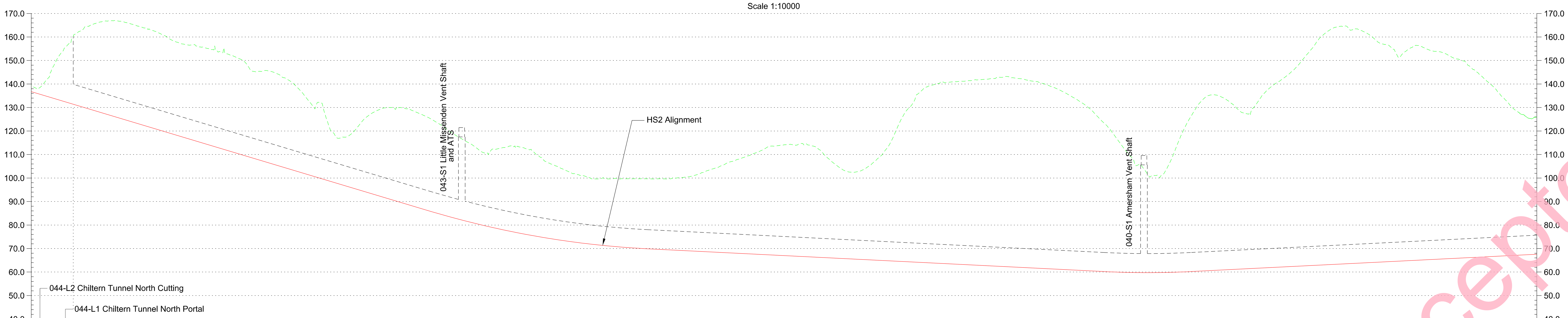

Route Element ID: 031-L3 Chiltern Tunnel

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Chainage	Existing Level	Proposed Level	Cut and Fill
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44+700	148.8	133.7	-15.1
44+600	162.2	130.7	-31.5
44+500	166.5	127.7	-38.8
44+400	166.2	124.7	-41.5
44+300	163.4	121.7	-41.7
44+200	158.5	118.7	-39.8
44+100	156.2	115.7	-40.5
44+000	153.8	112.7	-41.1
43+900	150.0	109.7	-40.3
43+800	145.7	106.7	-39.0
43+700	141.3	103.7	-37.6
43+600	130.3	100.7	-29.6
43+500	117.0	97.7	-19.3
43+400	123.3	94.7	-28.6
43+300	129.8	91.7	-38.1
43+200	129.5	88.7	-40.8
43+100	125.1	85.7	-39.4
43+000	118.4	82.9	-35.5
42+900	112.2	80.4	-31.8
42+800	112.8	78.1	-34.7
42+700	112.6	76.1	-36.5
42+600	106.4	74.3	-32.1
42+500	101.9	72.8	-29.1
42+400	99.7	71.6	-28.1
42+300	99.6	70.7	-28.9
42+200	99.8	70.0	-29.8
42+100	99.6	69.5	-30.1
42+000	100.6	69.0	-31.6
41+900	103.9	68.5	-35.4
41+800	107.8	68.0	-39.8
41+700	111.6	67.5	-44.1
41+600	114.1	67.0	-47.1
41+500	114.1	66.5	-47.6
41+400	107.2	66.0	-41.2
41+300	102.5	65.5	-37.0
41+200	108.4	65.0	-43.4
41+100	125.4	64.5	-60.9
41+000	138.3	64.0	-74.3
40+900	140.7	63.5	-77.2
40+800	141.6	63.0	-78.6
40+700	142.5	62.5	-80.0
40+600	142.3	62.0	-80.3
40+500	140.2	61.5	-78.7
40+400	136.0	61.0	-75.0
40+300	129.5	60.5	-69.0
40+200	118.8	60.0	-58.8
40+100	105.3	59.8	-45.5
40+000	100.8	59.8	-41.0
39+900	120.8	60.1	-60.7
39+800	134.9	60.6	-74.3
39+700	131.9	61.1	-70.8
39+600	130.4	61.6	-68.8
39+500	140.9	62.1	-78.8
39+400	149.8	62.6	-87.2
39+300	161.6	63.1	-98.5
39+200	163.7	63.6	-100.1
39+100	160.0	64.1	-95.9
39+000	153.4	64.6	-88.8
38+900	156.3	65.1	-91.2
38+800	153.4	65.6	-87.8
38+700	149.0	66.1	-82.9
38+600	140.1	66.6	-73.5
38+500	129.6	67.1	-62.5
38+400	125.9	67.6	-58.3

Design Speed: 360km/h; 320km/h

Profile

Scale H 1:10000 V 1:1000

METRES @ 1:10000: 0, 100, 200, 500, 1000

Rev	Description	Drawn	Checked	Con App	HS2 App
P09	Condition B. Code 1. Fit for hybrid bill submission	TB 03/10/13	SS 04/10/13	JN 04/10/13	
P08	Interim Preliminary Design Condition B - CP2	TB 10/09/13	SS 10/09/13	JN 10/09/13	
P07	Interim Preliminary Design Condition B	TB 26/06/13	SS 26/06/13	JN 26/06/13	
P06	Initial Preliminary Design Condition A	TB 16/04/13	SS 17/04/13	JN 17/04/13	
P05	Initial Preliminary Design Condition B4	SHN 26/03/13	SS 26/03/13	JN 26/03/13	

Legends/Notes:

- Depot, station, headhouse or portal building
- Tunnel portal
- Electricity substation
- Land drainage area
- Ecological mitigation pond
- Balancing pond
- Replacement floodplain storage
- Woodland habitat creation
- Wetland habitat creation
- Grassland habitat creation
- Landscape mitigation planting (scrub / woodland)
- Grassed areas
- Sustainable placement
- Public realm
- Engineering earthworks
- Landscape earthworks
- Rail alignment formation
- Returned to suitable development use
- County boundary
- Borough / District boundary
- Community forum boundary
- Watercourse diversion
- Existing watercourse
- Ditches - new
- Hedgerow habitat creation
- UT Main utility works
- Existing public right of way (PRoW)
- New, diverted or realigned PRoW
- Stopped-up PRoW
- Tunnels external extent
- Rail alignment
- HS2 Access road
- Noise fence barrier
- 10+000 Chainage (e.g. 10+000)

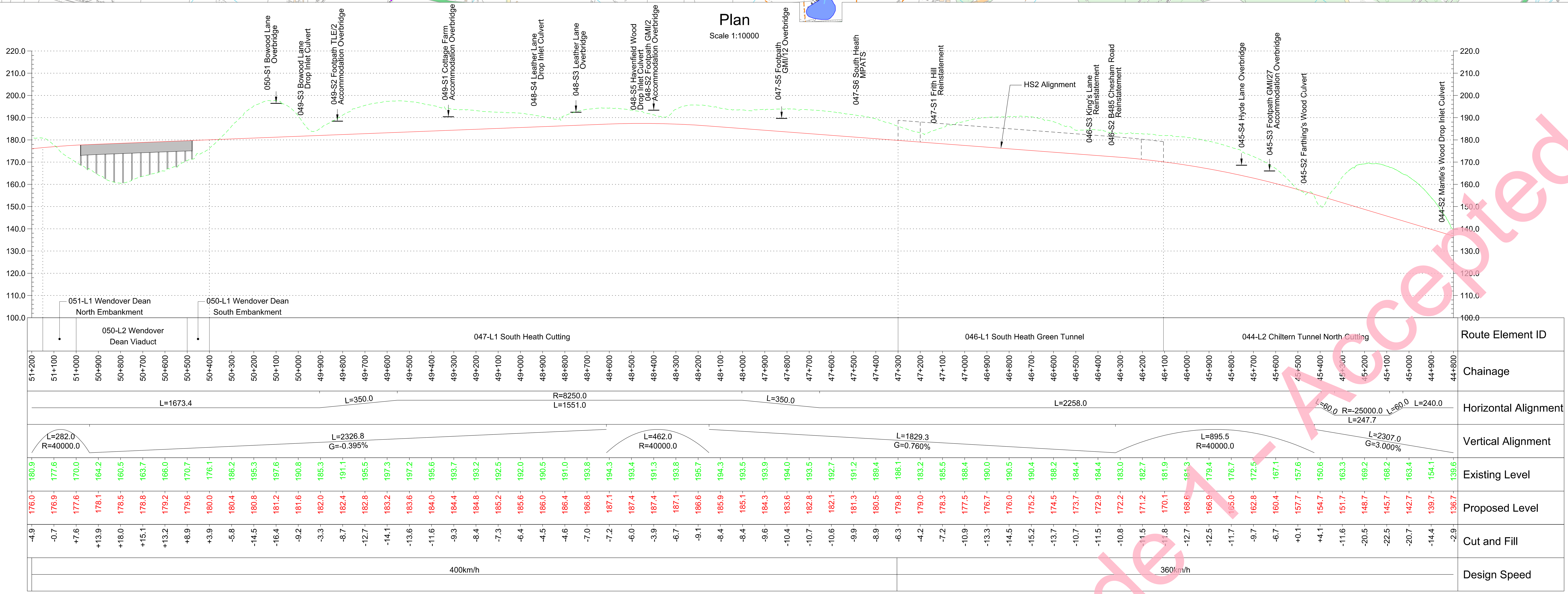
Registered in England
Registration No. 06791686
Registered office:
Eland House,
Bressenden Place,
London, SW1E 5DU

Creator/Originator	Atkins
HS2 Security Classification	INTERNAL
Zone	Country South
Design Stage	hybrid bill submission
Drawing Title	Main Line Sheet 22 of 49 Chainage 38+400 to 44+800
Project/Contract	Country South Design
Discipline/Function	Civil
Drawn	TB
Checked	SS
Approved	JN
Date	18/10/2012
Scale	AS SHOWN
Size	A1
Drawing No.	C222-ATK-CV-DPL-020-000003
Rev.	P09

Code 1 - Accepted

Plan

Scale 1:10000



Profile

Scale H 1:10000 V 1:1000

METRES @ 1:10000 0 100 200 500 1000

METRES @ 1:1000 0 10 20 50 100

Rev	Description	Drawn	Checked	Con App	HS2 App
P09	Condition B. Code 1. Fit for hybrid bill submission	TB 03/10/13	SS 04/10/13	JN 04/10/13	
P08	Interim Preliminary Design Condition B - CP2	TB 10/09/13	SS 10/09/13	JN 10/09/13	
P07	Interim Preliminary Design Condition B	TB 26/06/13	SS 26/06/13	JN 26/06/13	
P06	Initial Preliminary Design Condition A	TB 16/04/13	SGB 17/04/13	JN 17/04/13	
P05	Initial Preliminary Design Condition B4	TB 26/03/13	SS 26/03/13	JN 26/03/13	

Scale with caution as distortion can occur.

Legends/Notes:

- Depot, station, headhouse or portal building
- Tunnel portal
- Electricity substation
- Land drainage area
- Ecological mitigation pond
- Balancing pond
- Replacement floodplain storage
- Woodland habitat creation
- Wetland habitat creation
- Grassland habitat creation
- Landscape mitigation planting (scrub / woodland)
- Grassed areas
- Sustainable placement
- Public realm
- Engineering earthworks
- Landscape earthworks
- Rail alignment formation
- Returned to suitable development use
- County boundary
- Borough / District boundary
- Community forum boundary
- Watercourse diversion
- Existing watercourse
- Ditches - new
- Hedgerow habitat creation
- UT Main utility works
- Existing public right of way (PRoW)
- New, diverted or realigned PRoW
- Stopped-up PRoW
- Tunnels external extent
- Rail alignment
- HS2 Access road
- Noise fence barrier
- 10+000 Chainage (e.g. 10+000)

hs2

Registered in England
Registration No. 06791686
Registered office:
Eland House,
Bressenden Place,
London, SW1E 5DU

Creator/Originator: Atkins

HS2 Security Classification: INTERNAL

Zone: Country South

Design Stage: hybrid bill submission

Drawing Title: Main Line — Sheet 23 of 49 — Chainage 44+800 to 51+200

Project/Contract: Country South Design

Discipline/Function: Civil

Drawn	Checked	Approved
TB	SS	JN

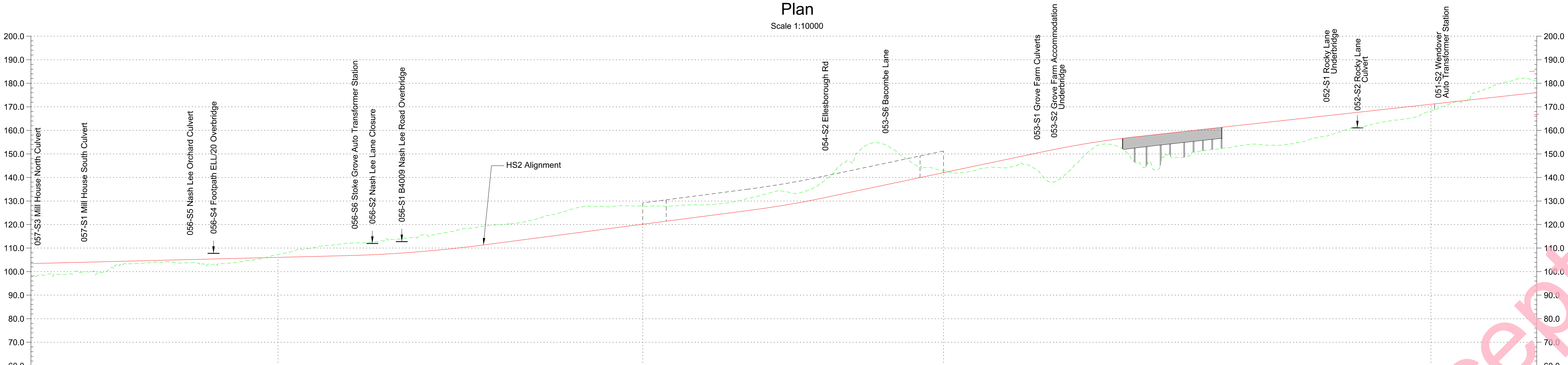
Date	Scale	Size
18/10/2012	AS SHOWN	A1

Drawing No.: C222-ATK-CV-DPL-020-000004 — Rev.: P09

Code 1 - Accepted

Plan

Scale 1:10000



Route Element ID: 056-L1 Stoke Mandeville South Embankment (57+600 – 56+550); 055-L1 Wendover North Cutting (56+550 – 55+000); 053-L2 Wendover Green Tunnel (55+000 – 53+720); 053-L1 Small Dean North Embankment; 052-L1 Small Dean Viaduct; 051-L3 Small Dean South Embankment; 051-L2 Rocky Lane Cutting

Horizontal Alignment: L=2780.0; L=300.0; R=-10000.0 L=208.5; L=75.0; R=-8250.0 L=3391.5; L=75.0; R=-10000.0 L=208.5; L=300.0; L=1673.4

Vertical Alignment: L=1519.4 G=-0.250%; L=587.9 R=-56000.0; L=1138.1 G=-1.300%; L=319.9 R=-40000.0; L=926.1 G=-2.100%; L=399.8 R=40000.0; L=1672.3 G=-1.100%; L=282.0 R=40000.0

Design Speed: 400km/h (57+600 – 55+000); 360km/h (55+000 – 53+720); 400km/h (53+720 – 51+200)

Chainage	Existing Level	Proposed Level	Cut and Fill
57+600	98.4	103.4	+5.0
57+500	98.8	103.7	+4.9
57+400	99.9	103.9	+4.0
57+300	99.7	104.2	+4.5
57+200	103.5	104.4	+0.9
57+100	103.8	104.7	+0.9
57+000	104.0	104.9	+0.9
56+900	103.7	105.2	+1.5
56+800	103.4	105.4	+2.0
56+700	104.4	105.7	+1.3
56+600	106.0	105.9	-0.1
56+500	108.2	106.2	-2.0
56+400	110.1	106.4	-3.7
56+300	111.5	106.7	-4.8
56+200	112.3	107.0	-5.3
56+100	113.1	107.4	-5.7
56+000	114.2	108.1	-6.1
55+900	115.5	108.9	-6.6
55+800	117.2	109.9	-7.3
55+700	119.0	111.0	-8.0
55+600	119.9	112.3	-7.6
55+500	121.2	113.6	-7.6
55+400	123.8	114.9	-8.9
55+300	126.6	116.2	-10.4
55+200	127.6	117.5	-10.1
55+100	127.9	118.8	-9.1
55+000	127.8	120.1	-7.7
54+900	127.7	121.4	-6.3
54+800	128.3	122.7	-5.6
54+700	128.6	124.0	-4.6
54+600	129.9	125.3	-4.6
54+500	132.3	126.7	-5.6
54+400	134.1	128.2	-5.9
54+300	134.4	129.9	-4.5
54+200	140.8	132.0	-8.8
54+100	148.1	134.1	-14.0
54+000	154.8	136.2	-18.6
53+900	149.3	138.3	-11.0
53+800	144.1	140.4	-3.7
53+700	142.3	142.5	+0.2
53+600	142.7	144.6	+1.9
53+500	144.2	146.7	+2.5
53+400	145.5	148.8	+3.3
53+300	140.6	150.9	+10.3
53+200	141.5	152.9	+11.4
53+100	151.3	154.6	+3.3
53+000	153.8	156.1	+2.3
52+900	146.1	157.3	+11.2
52+800	145.2	158.4	+13.2
52+700	148.5	159.5	+11.0
52+600	151.6	160.6	+9.0
52+500	152.7	161.7	+9.0
52+400	154.2	162.8	+8.6
52+300	153.6	163.9	+10.3
52+200	155.1	165.0	+9.9
52+100	157.5	166.1	+8.6
52+000	160.6	167.2	+6.6
51+900	162.5	168.3	+5.8
51+800	164.4	169.4	+5.0
51+700	166.1	170.5	+4.4
51+600	170.1	171.6	+1.5
51+500	172.7	172.7	
51+400	178.2	173.8	-4.4
51+300	181.2	174.9	-6.3
51+200	180.9	176.0	-4.9

Profile

Scale H 1:10000 V 1:1000

METRES @ 1:10000 — 0 100 200 500 1000

METRES @ 1:1000 — 0 10 20 50 100

Rev	Description	Drawn	Checked	Con App	HS2 App
P09	Condition B. Code 1. Fit for hybrid bill submission	TB 03/10/13	AK 04/10/13	JN 04/10/13	
P08	Interim Preliminary Design Condition B - CP2	TB 10/09/13	AK 10/09/13	JN 10/09/13	
P07	Interim Preliminary Design Condition B	TB 26/06/13	SS 26/06/13	JN 26/06/13	
P06	Initial Preliminary Design Condition A	TB 16/04/13	SS 17/04/13	JN 17/04/13	
P05	Initial Preliminary Design Condition B4	SHN 26/03/13	AK 26/03/13	JN 26/03/13	

Legends/Notes:

- Depot, station, headhouse or portal building
- Tunnel portal
- Electricity substation
- Land drainage area
- Ecological mitigation pond
- Balancing pond
- Replacement floodplain storage
- Woodland habitat creation
- Wetland habitat creation
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- Existing watercourse
- Ditches - new
- Hedgerow habitat creation
- UT – Main utility works
- Existing public right of way (PRoW)
- New, diverted or realigned PRoW
- Stopped-up PRoW
- Tunnels external extent
- Rail alignment
- HS2 Access road
- Noise fence barrier
- 10+000 Chainage (e.g. 10+000)

Registered in England
Registration No. 06791686
Registered office:
Eland House,
Bressenden Place,
London, SW1E 5DU

Zone	Country South
Project/Contract	Country South Design
Design Stage	hybrid bill submission
Discipline/Function	Civil
Drawing Title	Main Line — Sheet 24 of 49 — Chainage 51+200 to 57+600
Drawn	TB
Checked	AK
Approved	JN
Date	18/10/2012
Scale	AS SHOWN
Size	A1
Creator/Originator	Atkins
HS2 Security Classification	INTERNAL
Drawing No.	C222-ATK-CV-DPL-020-000005
Rev.	P09

Code 1 - Accepted

Appendix B

B.1 Chiltern Tunnel Simple Programme

17/10/2014
Updated 07/01/15

Extended Chiltern Tunnel - Simple Programme