Engineering Review of the 'HS2 Tunnel Extension' Proposal by LBH for a Tunnel through the Colne Valley

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London West Midlands

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List of acronyms

LBH London Borough of Hillingdon
CVT Colne Valley Tunnel
PBA Peter Brett Associates
AONB Area of Outstanding Natural Beauty
TSI Technical Specification of Interoperability

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 Purpose of Engineering Review

1.1.1 Peter Brett Associates (PBA) has presented an alternative option, the Colne Valley Tunnel proposal, to the existing proposed HS2 scheme through the Colne Valley. This option is promoted by London Borough of Hillingdon (LBH). The Colne Valley tunnel proposal is included within petitions received against the Proposed Scheme.

1.1.2 The Colne Valley tunnel (CVT), as proposed by PBA, would consist of approx. 6.6 km of additional tunnel between a works area/vent shaft in the Ruislip Rail Depot to the HS2 proposed M25/West Hyde portal for the Chiltern Tunnel. The Colne Valley Tunnel would be a separate tunnel drive from the adjacent Northolt Tunnel and Chiltern Tunnel and would replace the proposed at grade and viaduct section of the HS2 alignment through the Colne Valley.

1.1.3 London Borough of Hillingdon have asked HS2 Ltd to consider this alternative proposal. This report provides an engineering and rail systems review of their proposal, based on the information in the PBA document 'HS2 Tunnel Extension: Reducing the Environmental, Social and Economic Burden in Hillingdon', dated December 2014. Some environmental impacts have been noted, but this review is not intended as an investigation of all the potential environmental impacts of the CVT.

1.1.4 It should be noted that the Reference Route as described by PBA in their report is referred to in this report as the Proposed Scheme.

1.2 Findings

1.2.1 A proposal for the Colne Valley Tunnel, if viable, would reduce the surface impacts and disturbance through the Colne Valley from HS2 construction and operation compared to the HS2 Proposed Scheme. It would, however, incur additional cost, construction and operational risks and safety concerns compared to the HS2 Proposed Scheme.

1.2.2 The inclusion of the CVT would obstensibly create a continuous tunnel, measuring approximately 34 km from the Old Oak Common Station to the northern portal of the Chiltern tunnel drive. The length of this underground portion of the route could possibly extend further if the Chiltern tunnel drive is

extended further north to place the portal outside the Area of Outstanding Natural Beauty (AONB).

1.2.3 The complex geometry and size of the proposed Intervention Gap structure, in conjunction with high groundwater in the area, would create a number of technical and logistic challenges to ensure the structure can be constructed, serve as a works area for two tunnelling operations, and be properly maintained over the lifetime of the system. Further investigation would be required to capture the full impact of the structure on the local area and a better understanding of construction costs and programme, to determine viability of the structure.

1.2.4 The report does not discuss disposal of the excavated material arising from the tunnel drive of the Chiltern Tunnel. This material is currently placed locally to form environmental mitigation for the Proposed Scheme. If the CVT was adopted, this mitigation would not be required and these tunnel arisings would need to be removed from site in addition to the excavated material arising from the CVT proposal.

1.2.5 It is proposed that a temporary railhead is constructed within the existing Ruislip Train Depot to provide a location for transportation for equipment and materials to and from the work site via rail or a dedicated road access to a main trunk route. Viability of this location is very dependent on the assumption that London Underground and Network Rail would be able to rearrange their operations to accommodate the construction works and the rail connection between the Chiltern Line and the depot. The existing access road is not considered wide enough to handle the anticipated HGV traffic and is frequently shut down to facilitate railway operations. Improving the existing road access or creating a new road access would require further investigation to determine adequacy for anticipated HGV traffic and the impact of construction traffic on the surrounding highway network.

1.2.6 The proposal only discusses the impacts during the construction phase, there is a further 4 years when the tunnel and rail fit out are undertaken. The Proposed Scheme provides rail heads and sidings to facilitate the transport of materials to the work sites. This arrangement allows reduced handling times of the materials onto the work trains working along the mainline and the sidings ensure that transport trains do not effect existing railway operations. The report does not describe the logistics of installing the rail systems within the proposed tunnel.

1.2.7 The PBA proposal does not discuss railway maintenance impacts from the CVT during the life of the system. Underground structures with long distances between access points would increase duration and costs of maintenance tasks.

1.2.8 The CVT, as proposed, would be part of an overall tunnel of approximately 21 km from one Intervention Gap (Old Oak Common) to another (West Hyde). There is also a 3.7 km distance along the CVT between the Vent Shaft at Highway Farm to the Intervention Gap at West Hyde. The Proposed Scheme guidelines require that access points for rescue personnel to enter the tunnel are no greater than 3 km. Both these distances do not strictly fulfil the safety guidelines incorporated into the Proposed Scheme and may impact signalling headway.

1.2.9 The vertical alignment, as proposed, may be less than one tunnel diameter under the lakes. The risk potential of creating a connection between the tunnel excavation and the surface water features, considering the potential of weathered and fractured chalk and regular cross passage construction, is considered too high for this alignment. In addition the proposed alignment includes substandard vertical alignment which would adversely affect drainage and travel times.

1.2.10 It should be noted that the inclusion of the passive provisions, in the PBA proposal, for the Heathrow spurs would create much more significant issues regarding construction viability than for the Proposed Scheme viaduct

1.2.11 The cost comparison exercise undertaken by PBA does not reflect a realistic assessment of the comparable schemes on a similar basis.

1.3 Issues and Concerns

1.3.1 There is not enough information presented in the PBA proposal to determine if the Colne Valley Tunnel proposal is feasible as outlined or not. There would need to be much more extensive studies and investigations to determine construction feasibility and risk; impacts on operational capacity, maintenance and safety. These studies would need to incorporate and focus on the following items:

- Lowering and modification of the vertical alignment to ensure there is increased cover over the tunnel under the lakes and remove any gradients that would adversely affect drainage and potentially journey times through the Colne Valley.

- Determine if the passenger safety and comfort associated with the Colne Valley tunnel can be addressed so there is no reduction in the ability to provide appropriate safety and comfort for passengers.

- Determine impacts to and from the rail fit out stage of HS2 construction, including: any revised construction methodology, revised construction times, impacts on London Underground and Network Rail Operations and the local areas.

- Determine all potential impacts to all adjacent water abstractions from tunnelling operations and associated construction.

- Determine approximate quantities of excavated material arising from all excavations and impacts to local environment and infrastructure of transporting and disposal of all excavated material.

- Provide and investigate general layouts of the Intervention Gap at West Hyde both for construction phase and final structure to fully capture impacts to the local area, construction cost programme time and rail operations. And further investigate the engineering feasibility and construction costs of deep linear structure of this scale in water bearing ground.

- Provide and investigate general layouts of the Ruislip Rail Depot Works/Vent Shaft for surface and underground works to determine: structural viability of underground caverns, an understanding of logistics issues involving Network Rail and London Underground, logistics regarding getting equipment and material to the underground work site, to fully capture construction cost, programme time and impacts to rail operations.

2 Introduction

2.1 Background

2.1.1 The Colne Valley Tunnel is an alternative tunnel that is promoted by London Borough of Hillingdon (LBH). This report provides an Engineering Review of this proposal, based on the information in the Peter Brett Associates (PBA) document 'HS2 Tunnel Extension: Reducing the Environmental, Social and Economic Burden in Hillingdon', dated December 2014.

2.1.2 This proposal has been developed by PBA and outlines a scheme of approximately 6.6 km of additional tunnel between a works area/vent shaft in the West Ruislip Rail Depot to the HS2 proposed south portal of the Chiltern Tunnel at West Hyde. The CVT would be a separate tunnel drive from the adjacent Northolt Tunnel and Chiltern Tunnel and would replace the proposed at grade and viaduct section of the HS2 alignment through the Colne Valley.

2.1.3 The CVT would connect to the Northolt Tunnel in underground caverns, effectively creating a continuous tunnelled railway from Old Oak Common to West Hyde. This tunnel would essentially be combined with the Chiltern tunnel if the requirement for the Intervention Gap is replaced with a firefighting point, to create a 34 km long tunnel. This 34 km tunnel could possibly be increased in length again if the Chiltern tunnel is extended to beyond the AONB. This review is limited to the PBA proposal, as presented.

2.2 Colne Valley Tunnel

2.2.1 PBA considered two tunnel alignments:

- Option A - the same horizontal alignment as the Proposed Scheme.
- Option B - this removes the reverse curves required to minimize the length of the viaduct and replaced them with a single curve. This provides a slightly shorter and straighter alignment.

2.2.2 The PBA report determined that Option B was the better tunnelling solution and took it forward for the remainder of the report. Therefore, this Engineering Review will focus the assessment on Option B.

2.2.3 The proposed CVT would be driven from the site of the south portal for the Chiltern Tunnel at West Hyde. The combined portal for the Chiltern and Colne

Valley Tunnels would become an Intervention Gap approximately 1.6 km long, extending from Chainage 31+000 to 29+400. Passive provision is proposed for the Birmingham facing Heathrow spurs at the Intervention Gap. The CVT would be driven a distance of 6.6 km from Chainage 29+400 to Chainage 22+800, where the TBMs would be removed via an offset vent/construction shaft at Ruislip Rail Depot. One ventilation shaft is proposed along the route at Chainage 25+700. When completed, the CVT would be part of one continuous tunnel running from West Hyde to Old Oak Common Station, a distance of approximately 21 km.

2.2.4 The CVT construction/vent shaft at the Ruislip Rail Depot is offset from the tunnel alignment by approximately 200m and is 30m in diameter. It is also proposed to provide the works access for the Northolt Tunnel drive at this shaft and passive provision for the London facing Heathrow spurs is proposed for this location.

2.2.5 A grade separation would be incorporated in the alignment at the Ruislip Rail Depot Shaft to allow the Heathrow spur to pass under the mainline track, this grade separation begins over 3km into the Northolt Tunnel alignment. There is no grade separation detailed for the passive provision at the M25/West Hyde Intervention Gap.

2.2.6 The London Borough of Hillingdon is promoting the CVT as an alternative that would reduce the impact to the local area when compared to the Proposed Scheme, which includes a mixture of cuttings, embankments and viaduct. The Engineering Review of the PBA proposal is based on the following areas:

- Engineering feasibility
- Construction feasibility
- Conformance with HS2 requirements
- Environmental impacts
- Construction impacts on adjacent sections
- Alignment
- Excavated Material Management

- Railway Systems Construction
- Tunnel Ventilation and Smoke Control
- Railway Operations
- Traction Power and Overhead Contact System
- Train Control and Telecoms
- Tunnel Aerodynamics
- Railway Maintenance
- Construction Costs
- Programme Impact

3 Engineering Review

3.1 Introduction

3.1.1 The Engineering Review evaluated the Colne Valley Tunnel proposal against the assessment criteria outlined below.

3.2 Engineering Feasibility

3.2.1 The viability of the CVT is highly dependent on the feasibility of the structures at the starting and ending points of the proposed Colne Valley Tunnel drive. An Intervention Gap is proposed that would combine the Chiltern and CVT portals into one 1.6 km long linear structure that would connect the two tunnels at the start of the tunnel drive. A combined offset works/vent shaft located in the Ruislip Train Depot is proposed for the end of the CVT drive. The PBA proposal provides few details regarding possible geometry of these structures or how they could be constructed. A number of assumptions were made in an attempt to properly evaluate this alternative scheme.

3.2.2 At the start of tunnelling the CVT, an Intervention Gap structure of approximately 1.6 km is envisaged. This Intervention Gap can be used as a firefighting point. The current 2014 version of the TSI requires a firefighting point for every 20 km of tunnel. The length of tunnel in the PBA proposal is 21km to the next intervention/fire fighting point at Old Oak Common station. A firefighting point would be required somewhere along the PBA proposed route. However, an additional firefighting point has not been considered in the PBA proposal between West Hyde and Old Oak Common Station.

3.2.3 This proposed Intervention Gap structure would encompass the passive provision for Heathrow spurs toward Birmingham. This structure would vary in width from 30 to 70 m and be up to 50 m below ground surface. All tunnelling works would be performed from this gap concurrently with the Chiltern Tunnel. A permanent access road to track level, for safety and operational issues, would be required.

3.2.4 The complex geometry and size of the proposed Intervention Gap structure, in conjunction with potential high groundwater in the area, could create a number of technical and logistic challenges to ensure the structure can be constructed, serve as a works area for two tunnelling operations, and be properly maintained over the lifetime of the system.

3.2.5 The proposal includes an offset construction/vent shaft for removal of the TBM's and start of the Northolt Tunnel construction. This shaft would be located in the middle of the currently operational Ruislip Train Depot, approximately 200m from the horizontal alignment. The passive provision for the Heathrow spurs to London is also envisaged at this location.

3.2.6 It is proposed that a temporary railhead is constructed within the existing Ruislip Train Depot to provide a location for transportation of equipment and materials to and from the work site via rail or a dedicated road access to a main trunk route. Viability of this location is very dependent on the assumption that London Underground and Network Rail would be able to rearrange their operations to accommodate the construction works and the rail connection between the Chiltern Line and the depot. The existing access road is not considered wide enough to handle the anticipated HGV traffic and is frequently shut down to facilitate railway operations. Improving the existing road access or creating a new road access would require further investigation to determine adequacy for anticipated HGV traffic and the impact of construction traffic on the surrounding highway network.

3.2.7 At this location, it was assumed that incorporating all the elements of the Colne Valley Tunnel, as proposed, would require the construction of two large underground chambers that would vary in width from 10m to 30m, with a height of up to 14m and a length of approximately 300m. These caverns would be separated by approximately 10m and be between 30 to 40m below ground level.

3.2.8 As the Heathrow spurs would be constructed after the mainline is completed, a section of the spurs would need to be constructed off of these chambers, to an extent that would allow the spurs to be connected in the future without affecting HS2 mainline tunnel operations.

3.2.9 As the works shaft is offset, one or two adits are required to be constructed to access the underground construction site. These adits would access both caverns and would, by necessity, be constructed through the ground arches and pillars supporting the two caverns.

3.2.10 This probable geometry would require careful investigation to determine if it would remain stable during construction and over the lifetime of the system. An underground structure of this magnitude and complex geometry would require substantial programme time and cost to implement.

3.3 Construction Feasibility

3.3.1 The mainline tunnel would comprise 8.8m ID tunnel mainly through chalk similar to the Chiltern Tunnel. A number of specific issues would have to be addressed in order for the CVT to be constructed.

3.3.2 The TBM would have to be designed to excavate chalk and the materials associated with the Lambeth Group. The slurry machine in the PBA proposal is well suited for the chalk but could have difficulty and reduced drive rates within the clays in the Lambeth formation. Alternatively, an EPBM could be used but would be working sub-optimally through the chalk.

3.3.3 The chalk in this area is known to contain karstic features, which would probably require pre-treatment by probing and grouting ahead of the TBM. This could substantially reduce advance drive rates. Also locating karstic features can be problematic and there would be the risk of excavating into a substantial unknown karstic feature, causing significant delays to tunnelling.

3.3.4 The high probability of flints in the chalk would create significant wear on the TBM cutter head teeth, requiring an intervention to change the cutter head teeth sometime during the tunnel drive. The nature of the weathered chalk in this area would make it difficult to access the cutter head in dry conditions. The cutter head could be accessed using compressed air, a time consuming process or by pre-grouting a zone in the chalk into which the TBM could be driven, a costly process.

3.3.5 Launching the TBMs from the West Hyde/M25 location would provide an adequate works area and good access to major highway routes.

3.3.6 The Intervention Gap including passive provision for Heathrow spurs – This element of the Colne Valley Tunnel proposal would be approximately 1.6 km long and up to 50 m deep. The PBA proposal provides little detail regarding the potential layout of the Intervention Gap. The figure below from the PBA proposal provides a suggested layout for the gap structure.

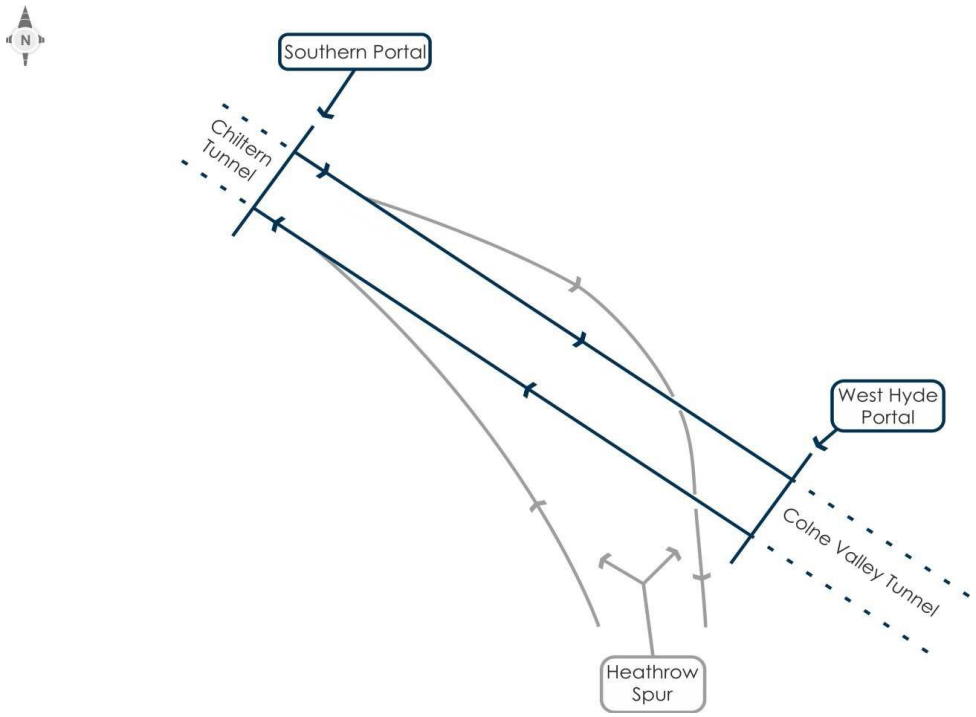


Figure 4.2 from PBA Report

3.3.7 As the spurs are to be constructed after the mainline, this proposed layout would require a bridge/tunnel to be built within the gap that would pass through the retaining wall structure. Both spurs would have to be extended to a distance away that would allow the remaining spurs to be constructed and connected without disrupting mainline operations. This arrangement would substantially increase the size of the final structure at the Intervention Gap, increasing cost, excavated material removal, and construction programme for the CVT.

3.3.8 If the spurs were constructed to enter the southern headwall of the Intervention Gap and then tunnelled over or under the mainline, the Intervention Gap excavation would be reduced. As no specific layout was specified in the PBA report, this layout was assessed for constructability as it minimized the excavation required.

3.3.9 The width of the Chiltern end of the gap structure is approximately 30m to include the two bored tunnels and a pillar of one tunnel diameter.

3.3.10 To account for the passive provision of the Heathrow spurs, the required width of the Colne Valley end of the gap structure must encompass the width of four tunnel diameters (two for the mainline plus two for the inbound and outbound

spurs) plus a soil pillar of a tunnel diameter between all tunnels, creating an overall width of up to 70m. In addition the northernmost tunnel opening invert would be below the other tunnel openings by several metres to allow for that spur to pass under the mainline tracks.

3.3.11 The design of a 50m deep structure probably require the inclusion of an access road from rail level to the surface rescue area. This road would also be used for maintenance and operations access. Given the depth of excavation, and the need to provide access from both portal structures, it would be anticipated that such a route would emerge from it centrally and approximately normal to the main lines.

3.3.12 The form of the excavation for the gap structure would require either a retained cutting, an open cut with engineered side slopes through the chalk and groundwater control, or a combination of the two. For a retained cutting, the width of the excavation would preclude conventional propping and it is expected that ground anchorages would be utilised. However, groundwater levels are currently assumed to be at a depth of about 5m below existing ground level and provision for the required access road would have to made through any retained cutting structure, making it difficult to create a retained cutting that would form a continuous barrier against groundwater

3.3.13 The influence of water during construction and operation could be a significant constraint depending upon rock mass permeability and flow characteristics. Groundwater control could be achieved through grouting of the surrounding ground or constructing a drainage system that would run to a sump that would require pumping over the life of the structure. The drainage system would require regular maintenance and inspection to ensure the structure's drainage is operating correctly. With grouting, it may prove difficult to ensure the grout has permeated the surrounding ground sufficiently to completely cut off the groundwater. Acquiring approval for widespread grouting may be problematic as there is the potential risk of grouting entering the public water supply at the Affinity water SP2 abstraction through the weathered and fractured chalk. A combination of the two methods would probably be required to ensure complete control of groundwater along with any surface water during storm events. Although not unprecedented, a permanent method of dewatering a structure on this scale would be expected to significantly increase maintenance costs.

3.3.14 The construction of the vent shaft at Highway Farm should provide no particular issues compared to other vent shafts on the Proposed Scheme on adjacent tunnels, where constructability issues have been considered. There is adequate space at this location to provide a construction worksite.

3.3.15 There would be a 3.7 km gap from this shaft to the Intervention Gap structure at West Hyde, which would be greater than the maximum shaft spacing of 3 km currently used on the HS2 Proposed Scheme. The only location for another shaft to reduce this shaft spacing would be adjacent to Moorhall Road. Option B alignment crosses Moorhall Road at approximately the same location as the Grand Union Canal. The available land at that location is exceptionally limited, and it would be difficult to locate a construction works area for this shaft.

3.3.16 The construction/vent Shaft site at Ruislip Rail Depot would provide the potential transport links for moving equipment and materials to the site and tunnel excavated material away from the site subject to site logistics and agreement with the major stakeholders in the Depot. This proposed site would be substantially smaller than the railhead provided as part of the HS2 Proposed Scheme, adjacent to Harvil Road, though the continuing need for a railhead for rail systems fit-out is discussed in Section 3.9.

3.3.17 Material and equipment would either be moved by train or by the highway network. The existing road access is narrow and is frequently shut down to facilitate train operations. This access would require significant upgrading, which may not be possible due to space and overhead constraints, to handle the significant HGV traffic anticipated, even with the available train transport. Additional access may be created near the intersection of Austin Lane and Ickenham Road on the south side of the construction works area that would be put in place for the Northolt tunnel drive. This additional access would have its own local impacts that would need to be investigated.

3.3.18 The availability of train paths through the rail depot would need investigation and the feasibility of a connection between the Chiltern Line and the depot. In particular there is a long welding plant that requires movement of up to 90m length of tracks. This impact to operations would not only be during construction of tunnels but during the following four years of the rail fit out.,

3.3.19 The PBA proposal would substantially impact the Ruislip rail depot and its operations. The PBA proposal locates the shaft in the middle of the rail depot. See figure below.

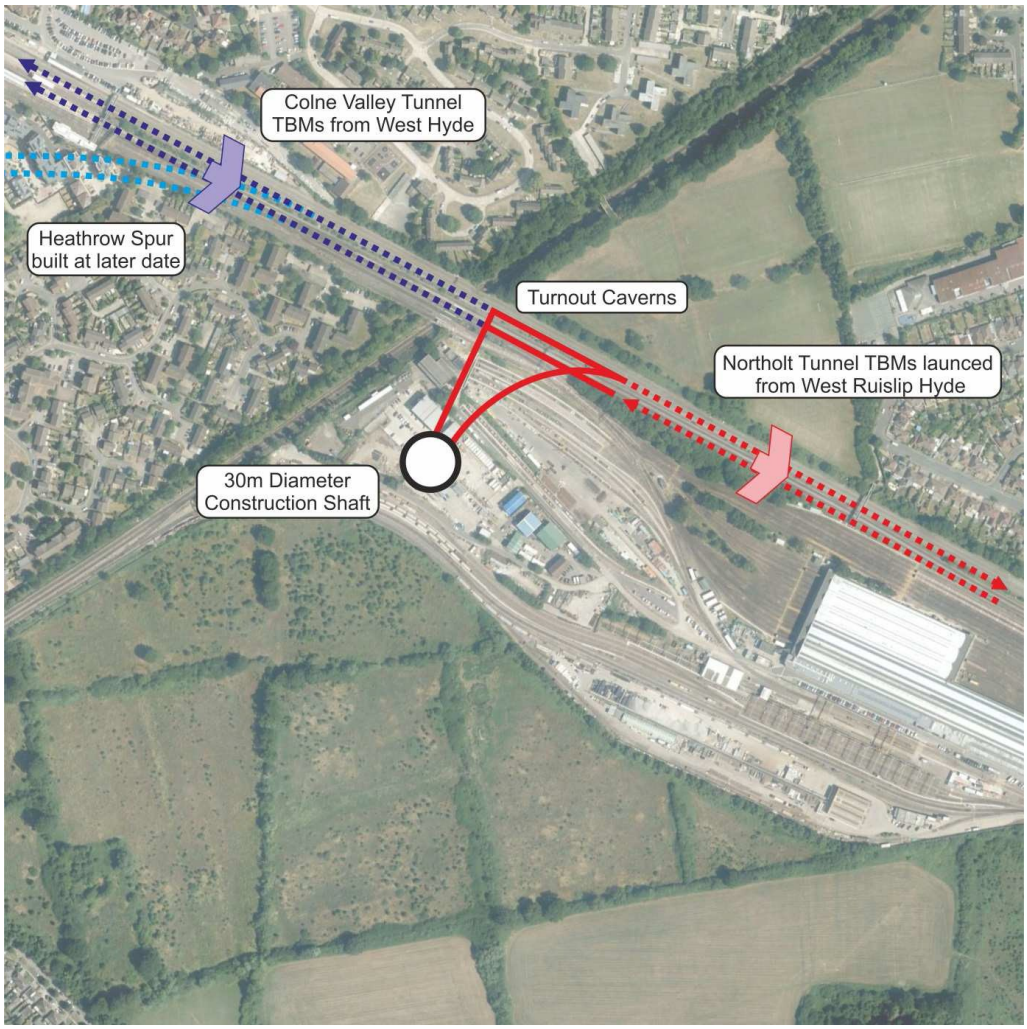
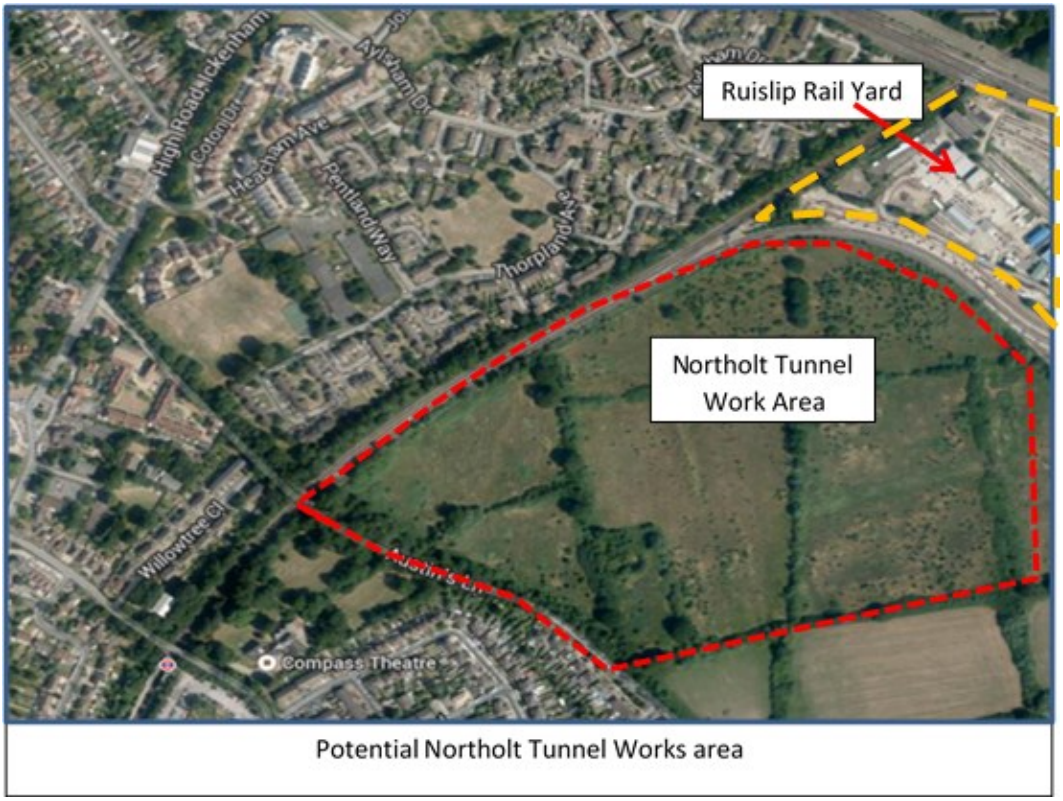


Figure B2 from PBA Proposal

3.3.20 Provision would have to be made by Network Rail and London Underground to tailor their operations around the proposed construction. Substantial realignment of the yard tracks would be required to facilitate movement of construction equipment and materials and to add a spur to the Chiltern mainline.

3.3.21 This offset shaft is proposed to accommodate the reception of the Colne Valley Tunnel TBMs and the tunnelling operations for the Northolt Tunnel. Additional

land adjacent to the yard would have to be acquired/utilized to accommodate the works for the tunnelling operations. See figure below.



Potential Northolt Tunnel Works area

3.3.22 The PBA proposal assumes that the Northolt Tunnel Works area would be moved from the Proposed Scheme location at Harvil Road. The area available for a works site at the Harvil Road site is approximately 332,000 m^2. The available area adjacent to the Ruislip Rail yard would be approximately 210,000 m^2, which is about 63% of the Harvil Road site. A percentage of this reduced site would have to be allocated to the CVT contractor for removing the TBM and constructing the caverns for the passive provision for the Heathrow spurs.

3.3.23 This reduced site would now have to accommodate a work site performing two different types of construction, TBM driven tunnels and SCL construction, to maintain the overall HS2 programme.

3.3.24 As figure B2 above indicates, the PBA proposal also proposes that passive provision for London facing Heathrow spurs are included as part of this structure. As part of incorporating the passive provision for the spurs at this location, a grade separation alignment is proposed to accommodate the spur

passing under the mainline track. No specific details regarding the internal geometry required to accommodate the above constraints have been provided and therefore a number of assumptions have been made to asses this element of the PBA proposal.

3.3.25 Two internal geometry layouts would be generally possible for the caverns to fit the passive provision for the spurs, a very large cavern or two smaller caverns.

3.3.26 A very large cavern would accommodate:

- The entry of the two 8.8m ID bored tunnels,
- The turnouts which diverge to both directions, and
- The exit point for four 8.8m ID bored tunnels with a specified minimum separation.

3.3.27 In order to minimise cavern dimensions, the alignment of the mainline tracks could be brought closer together but even with this adjustment, such an option is unlikely to be feasible as the cavern span would be in excess of 50m.

3.3.28 The provision of two smaller caverns, which, noting the 21m separation of the tracks should be achievable with a thickness of a soil pillar of some 10m width between them. The PBA proposed grade seperation of the spur tunnels, these caverns would be at two different elevations. The ground condition and thickness would need to be assessed in detail to ensure that conditions of stability can be created, noting that the caverns would be construction by excavators in a staged sequence. A principal issue would probably be related to groundwater which is currently identified to be at a level of about +40mOD consistent with the surface level of the lakes with the track level proposed at 0m OD.

3.3.29 The two smaller cavern structures would have a maximum height of some 12m to 14m, a maximum span of approximately 30m and a length of some 300m. After this point the spur tunnels are separated from the mainline tunnels by at least one tunnel diameter as the alignment climbs over or under the mainlines.

3.3.30 Adding to the complexity of this structure is the construction of the adits from the construction shaft to the two caverns. The adits would be constructed first and would extend to both caverns, one adit would have to pass over or under

one of the caverns. Both caverns would then be constructed from the adits. The TBM's would be brought in through the adit where they would be turned and set to start the Northolt Tunnel. To allow space for the TBMs to be moved and turned these adits would probably be a minimum of around 11 m ID.

3.3.31 Constructability issues arise regarding whether adit in the ground between, over or under the two smaller caverns would destabilise the caverns when they are fully completed.

3.3.32 The Northolt Tunnel TBMs may have to be assembled and the CVT TBMs would have to be disassembled in the caverns within a restricted space.

3.3.33 The CVT layout presents multiple challenges in design and construction and would take substantial programme time to construct. A more detailed study/preliminary design would be required to determine if the proposed Ruislip construction/vent shaft could be constructed.

3.4 Conformance with HS2 Requirements

3.4.1 The Colne Valley Tunnel proposal has the distance from the Old Oak Common Station, an intervention area, approximately 21km from the Intervention Gap at West Hyde. The revised alignment would require review to ensure the tunnel length would maintain a safe environment for passengers and be in conformance the safety and ventilations guideline presently adopted in the HS2 Proposed Scheme

3.4.2 As stated earlier the spacing between the Highway Farm shaft and the Intervention Gap at West Hyde would be approximately 3.7km, greater than the typical 3km shaft spacing adopted on the Proposed Scheme, and with consequential impact on ventilation requirements and train headway/capacity.

3.4.3 Emergency safety response teams may be hampered by the offset configuration of the finished tunnel vents shaft at Ruislip Rail Depot. The potential impact to emergency crew operations would require investigation to determine conformance to HS2 safety requirements.

3.5 Environmental Impacts

3.5.1 The PBA report states that only approximately 15 hectares of agricultural land (including construction areas) would be affected as opposed to 362 hectares that would be disturbed for the Proposed Scheme. The Intervention Gap at

West Hyde, as described earlier, would be an excavation of 50m deep that would incorporate a permanent access road and probably engineered slopes. The permanent structure would extend for 1.6 km and could extend over 100 m in sections. That permanent impact would be 15 hectares at this one site alone.

3.5.2 Taking into account that the site would be the location of two concurrent tunnelling projects, the construction areas would significantly add to the agricultural land that is affected at the West Hyde Intervention Gap. Additionally the works area for the ventilation shafts required for the tunnel along with the probable disturbance of farmland adjacent to the Ruislip train depot would further increase the agricultural land disturbance.

3.5.3 It is assumed that the total disturbed agricultural land cited in the PBA report for the Proposed Scheme includes areas where the excavation arisings would be disposed. The PBA report further assumes that excavation arisings from the CVT would be commercially reused and would not be disposed of locally. This assumption cannot be guaranteed and it should be assumed that tunnel arisings from the CVT would need to be transported to a disposal site, which would be compatible with current assumptions used for the proposed scheme.

3.5.4 The report does not discuss disposal of the excavated material arising from the tunnel drive of the Chiltern Tunnel. This material is currently placed locally to provide environmental mitigation for the Proposed Scheme. If the CVT was adopted, this mitigation would not be required and these tunnel arisings would also need to be removed from site.

3.5.5 A more detailed review of the required area for all construction and disposal sites associated with the tunnel would need to be performed. This would provide a better scope of the surface disturbance both permanent and during construction, as it is considered that the PBA proposal, as currently presented, significantly underestimates these impacts.

3.5.6 The Colne Valley Tunnel alignment is located in close proximity to the potable water abstractions points. The PBA proposal states that the abstraction would be unaffected by the alignment being considered but further investigation would be required to ensure there is no impact. Should there be a requirement for a vent shaft at this location to comply with the 3km shaft space requirement, the potential impact to the abstraction would be further increased.

3.5.7 The PBA proposed tunnel routes pass close to two of the largest source protection zone (SPZ) 1 (TH177 and TH027) in the area. The CVT is within SPZ 1 of these two sources. Both Public Water Supply abstractions are thought to be fed by large fissures in the Chalk, which supply most of the water for these supplies.

3.5.8 Construction of the CVT has the potential to contaminate groundwater through the production of turbidity (particulate) or the release of other contaminants and affect surface water features and both PWS abstractions (TH177 and TH027). It is aassumed that contaminants will be controlled at source. However, these measures cannot eliminate turbidity and it is likely that Affinity Water would have to temporarily close their sources to avoid impact on PWS. This impact is also identified in the Proposed Scheme due to piling for the Colne Valley viaduct The effect magnitude and duration on groundwater sources is considered similar under the Proposed Scheme and CVT.

3.5.9 Vent shafts and cross passages would be required for the tunnelling option, which would require groundwater dewatering. In the Colne Valley groundwater is thought to support local surface water features, such as the River Colne and lake SSSIs. Therefore, groundwater dewatering may have a temporary impact on water levels in the local surface water bodies. Where possible, water could be recharged back to ground in the vicinity of the abstraction in attempt to minimise any impact.

3.5.10 This groundwater dewatering activity could also have a short term temporary impact on the PWS and private abstractions, where these are located close to the route.

3.5.11 The CVT alignment is intersected by or adjacent to the following physical elements.

- Lakes formed in the abandoned gravel pits (ch27+000 to ch29+000), the depths of which are not known, but geological long sections suggest the base of the gravels, excluding any chalk solution or erosional features, are at approximately 30mOD.

- The Grand Union Canal (ch27+000), the construction of which may be critical, particularly where it runs immediately adjacent to / through the lake, and especially the canal lining type (whether puddle clay, concrete or other) and condition.

3.5.12 Because of the potential of faulting and weathering of the chalk, the vertical alignment should ideally maintain a distance of two tunnel diameters below the lakes to lessen the risk of any interconnection between the lakes and the tunnel excavation. The PBA proposed vertical alignment indicates an elevation of approximately 13mOD. If the bottom of the lakes are at the 30m OD as could be assumed from above, that would leave less than a tunnel diameter between the lakes and the tunnel excavation.

3.5.13 An available cover of less than a diameter of the tunnel would present a significant risk of the tunnel excavation connecting with the lakes.

3.5.14 The PBA proposal would have the majority of construction traffic at two locations, the West Hyde Intervention Gap and the Ruislip Vent Shaft. Both these location would service two concurrent tunnel drives. While the PBA proposal places all this traffic on main highway routes, those roads would experience very large increases in HGV traffic and associated environmental impacts. There has been no consideration of the traffic impacts on the highway network that would be caused by the removal of all tunnel excavated material.

3.6 Construction Impacts on Adjacent Sections of the Proposed Scheme

3.6.1 The PBA proposal requires that the Chiltern Tunnel drive and the CVT drive share the same construction works area. While the works area required for the Intervention Gap should be adequate to provide enough works area for both drives, access to the sites would be shared. Considering the amount of HGV traffic that would be required for both sites, logistics would have to be investigated to see if such an arrangement remains feasible.

3.6.2 The Ruislip Construction/Vent Shaft location proposes a reduction of available area for the Northolt Tunnel construction works while also accommodating ancillary construction works for the CVT. The new available works area would require investigating to determine if there would be enough space to facilitate all the envisaged construction works.

3.6.3 Grade separation is proposed to incorporate the passive provision for the London facing spurs as the method of passing the spur under the mainline tunnel. The Proposed Scheme has the London facing spurs join the mainline track at approximate Chainage 25+000. The PBA proposal has these spurs joining the mainline at approximate Chainage 23+000, a difference of approximately 2 km. This change in location does not necessarily affect the cost and programme

of the CVT, but would increase the costs and programme of constructing the Heathrow spurs.

3.6.4 The PBA proposal assumes that changes would be made to the Northolt and Chiltern Tunnel vertical alignment to accommodate the CVT vertical alignment. This change in vertical alignment would extend for several kilometres into each adjacent tunnel within the Proposed Scheme. The impact of this change is more evident in the Northolt Tunnel alignment where the proposed grade separation extends to the first ventilation shaft. The full impact to the adjacent tunnel drives would have to be evaluated if the PBA proposal was taken forward.

3.7 Alignment

3.7.1 As stated earlier the proposed CVT alignment is probably less than one tunnel diameter below the various lakes. To minimize the potential for adverse impacts to the lakes from tunnelling, the alignment should be lowered to at least 0m OD, providing cover equal to two tunnel diameters as it passes under the lakes and canal.

3.7.2 A high level review of the alignment long section drawings in the PBA proposal for options BI and B2 has been undertaken to determine if the track alignment complies with HS2 requirements. It is assumed the design speed throughout the CVT section would be 320kph. Potential non-compliances requiring derogations are identified as follows:

3.7.3 There is a 1974m length flat section (0% gradient) in the tunnel from Chainage 24+000m to 25+900m for both options. This is non-compliant with the minimal gradient for drainage purposes (0.5% desirable or 0.2% limiting) and is located at a low point in the tunnel vertical alignment.

- Short section of 90,000m radius vertical curve at Chainage 26+000m for both options and a further vertical curve of 60,000m radius at Chainage 29+700m for Option B1. Both are greater than the maximum permitted radius (40,000m limiting value increasing to 56,000m where required on 400kph sections of line). The minimum element lengths of both curve are also short, being just within the limiting value at 320kph.

- Shorter than limiting length horizontal transition curves at Chainage 25+400m and 29+000m (both 165m length) on both options.

3.7.4 The following items are also noted as being within Limiting Values but outside the Desirable values:

- Various short vertical elements with less than desirable minimum lengths.
- Various short horizontal elements with less than desirable minimum lengths.
- Various sections where the minimum gradient for drainage purposes is 0.2% (Limiting) rather than 0.5% (Desirable minimum).

3.7.5 It is noted that a number of vertical curves and horizontal curves are coexistent, which is non-compliant with the first preference for vertical and horizontal alignment combinations. It would be necessary to check the detailed alignment models and cant values/deficiency to determine whether this complies with the second or third preferences within the standard.

3.7.6 The 5400m radius horizontal curve from Chainage 32+100m to 33+400m would appear to require either limiting cant or limiting cant deficiency (e.g. 150mm cant and 75mm cant deficiency).

3.8 Excavated Material Management

3.8.1 The PBA proposal for the CVT makes two statements about the excavations arising from the tunnel:

- The excavation arising would be only 900,000 tonnes and,
- The only cost for disposal would be transport costs.

3.8.2 The volume of excavation arisings from twin tunnels forming the CVT would be approximately 975,000m^3. Hard chalk is 2.5 tonnes/m^3. Assuming the chalk is quite porous and weathered (1.5 tonnes/m^3), excavations arisings from the tunnel alone would be approximately 1,500,000 tonnes.

3.8.3 In addition, the tunnel excavated material arising from the drive of the Chiltern Tunnel would be removed at the south portal for the Proposed Scheme and these are placed locally as environmental mitigation. As the PBA proposal would reduce this mitigation, most, if not all, of this material would also be required to be removed from site. This quantity of the Chiltern tunnel excavated material is approximately 2,000,000m^3.

3.8.4 Adding to that is the quantity of material which would be excavated for the Intervention Gap, which equates to approximately 5,000,000m3 of excavated material due to the long length of the structure proposed on the PBA proposal. With the further addition of the volume of excavated material associated with the vent shafts, it would indicate that the total excavations arising from the PBA proposal are grossly underestimated.

3.8.5 Based on the PBA proposal, the total quantity of tunnel excavated material arising at the location of the Intervention Gap would be approximately 7,975,000m^3. Removal of this quantity of material on the highway network, if required, equates to a total number of approximately 1,876,470 two way lorry trips. There is likely to be concerns raised by the Highways Agency at this volume of HGV traffic joining the M25 via the temporary slip roads. Disposal may need to be phased over a much longer period than the actual construction works, extending local construction impacts.

3.8.6 The PBA proposal, in making the assumption that all excavated material disposal would be commercially reused is optimistic. Considering the quantity of material arising from the CVT drive concurrently with the Chiltern Tunnel drive there may be difficulty in finding appropriate disposal locations for all the excavation arisings from both tunnel drives, thus probably increasing the cost of disposal.

3.9 Rail Systems Construction

3.9.1 The proposal only discusses the impacts during the construction phase, there is a further 4 years+ when the rail fit out is performed. The Proposed Scheme provides rail heads and sidings to facilitate the transport of materials to the work sites. This arrangement allows reduced handling times of the materials onto the work trains working along the mainline and the sidings ensure that transport trains do not effect existing railway operations. The PBA report does not describe the logistics of installing the rail systems within the proposed tunnel.

3.9.2 The key construction issue with the PBA proposal is the restrictive access to the trace increasing the logistical constraints compared to the Proposed Scheme.

3.9.3 The Proposed Scheme strategy is for the tunnel fit out to be undertaken from the Chiltern tunnel south portal. There is no description within the PBA report of how it has been assumed that the CVT, as well as the Chiltern and Northolt Tunnels would be fitted out. It is assumed that this alternative proposal would

require the use of the Ruislip Vent shaft, which would not be possible without significant modifications to the vent shaft proposal or the Intervention Gap structure. These would increase the logistical complexity as well as add time to the construction programme. This would become a key rail systems worksite which would result in a construction and logistics constraint with the civil engineering needed to be completed prior to rail systems work being commenced. The site from which the rail system fit out is undertaken would need to be designed to provide adequate access to crane equipment and material to track level.

3.9.4 The implications of the above to the programme, compared to the Proposed Scheme, cannot realistically be assessed without further information on a proposed strategy for the PBA proposal.

3.10 Tunnel Ventilation and Smoke Control

3.10.1 The current 2014 TSI specifies a maximum spacing of 20 km between firefighting points for tunnels longer than 20 km, the PBA proposed combined CVT and Northolt tunnel is 21 km long. The spacing is based on the use of Category B rolling stock (section 4.2.1.7 of the TSI relating to 'safety in railway tunnels 18/11/2014). The PBA proposal does not include a firefighting point within the the 21 km length of the combined CVT – Northolt Tunnel. This firefighting point would have the capability to provide a safe environment for all passengers in the event of a fire. This would be a subterranean facility, with local ventilation exhaust and supply, or an open facility.

3.10.2 The remainder of the tunnel ventilation system should be consistent with other HS2 tunnels and adopt longitudinal tunnel ventilation shafts at 2 to 3km spacing. The signalling system would allow one train to enter each tunnel bore between the ventilation shafts if this ventilation shaft spacing is adopted. The proposed shaft spacing of up to 3.7km is irregular which may make airflow balances more challenging to achieve and may have an impact on signalling and ability to meet the train technical headway. Further detailed study would be required.

3.10.3 Tunnel heating is a key consideration for longer tunnels at these speeds. The aerodynamic resistance of long tunnels generates heat which is mitigated for by the cool air drawn in at the portal. Based on the prior analysis of the 13.4km long Chilterns tunnel, it is considered likely that tunnels longer than 13km would cause temperatures to rise in excess of HS2's 35°C summertime criterion. Warmer tunnels may be acceptable depending on the degree, but could begin to

have implications for maintenance workers and for the sizing of the rolling stock air conditioning. They could also affect the ability to control temperatures during train congestion and if too warm may affect tenability during any in-tunnel evacuation. The life of tunnel based equipment is also negatively affected by warm conditions. It is therefore likely that cooling would be required. Cooling could be by either relief air shafts integrated into the ventilation shafts, or by mechanical means, most likely from cooling pipes in tunnels. The use of relief air shafts may be possible, but the sizes required might cause aerodynamic effects issues as the trains pass. Further detailed study would be required to understand whether a reasonable design could be developed to balance the needs of achieving cooling but minimising aerodynamic effects. The shaft designs would need to change and potentially be larger to accommodate the optimised relief air paths. Without this analysis it is recommended to account for the need for cooling pipes near the portals, as adopted on the Channel Tunnel. Pipe loops, concentrated near the portals, would pass up and down the tunnels served by air cooled chillers plants potentially located at the ventilation shafts. This would therefore require a total of four cooling installations located at the portals and vent shafts.

3.10.4 The open rescue station (Intervention Gap) potentially allows for cool air to enter the second downstream tunnel, but careful design would be required to ensure that hot air from one portal can dissipate and cool air can be drawn into the second tunnel. If this cannot be achieved there may need to be localised extraction of the hot air at the rescue station. Regardless of the provision of ventilation, passive measures such as dividing walls extending some distance from each portal are likely to be required to prevent transfer of hot or smoky air from one bore to the other. Considering the overall length of the tunnel, the fire authorities may request a special purpose vehicle at this location for more rapid tunnel access which would require additional track and maintenance facilities within a larger excavation. Further consultation would be required on this matter.

3.10.5 The proposed caverns and turn-outs present significant challenges for the tunnel ventilation system. The spur tunnels are likely to require jet fans within them to both control smoke in the event of a fire in these tunnels, and also to manage the air leakage to and from these tunnels in the event of a fire in another part of the tunnel complex. There may also need to be jet fans at the turn-out cavern location. If at high level these would be a unique configuration and potentially challenging to maintain. The potentially large cross sectional area of the turnout

may make it impracticable to control smoke at this location. It may need to be accepted that smoke control can only be achieved in the connected tunnel bores and not the turnout.

3.10.6 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 (CO_2) 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 CO_2. 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 CO_2 level could be controlled to 500 to 600ppm when leaving the stations (outside air is about 400 ppm), the in-car CO_2 content may rise to around 2,000ppm at the end of the proposed longer tunnel for the case of 50 people per car. For a crowded car this would increase further and for slower train operations this could increase again. 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. Other countries are understood to have developed a specialised air supply system, possibly from a pressurised reservoir.

3.10.7 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 captive rolling stock, potentially affecting the ability for other rolling stock, including classic compatible rolling stock to operate in the longer tunnel without risks associated with pressure discomfort or poor air quality.

3.11 Railway Operations

3.11.1 An assessment has not been undertaken to determine the implications of journey time between the Proposed Scheme and the alternative proposal. However, it is anticipated that there would be a material difference, due entirely

to tunnel resistance increases (*) due to a significant increase in air mass movement for the combined tunnel.

3.11.2 However, a high level review of the aerodynamic implications of the PBA proposal suggests a potential requirement for a speed limit due to pressure waves generated when trains pass through the Heathrow spur caverns (refer to 3.13.2). Although this has not been analysed, this could have potentially significant implications to the journey time and timetable robustness regardless of the potential increases to the tunnel resistance.

(*) Tunnel resistance increases have been estimated on the basis of drag co-efficient increase due to the combined tunnel length increasing. Detailed analysis of this tunnel would be required to determine the exact effects.

3.12 Traction Power and Overhead Contact System

3.12.1 There would be an appreciable increase in traction power requirements due to the overall additional (two-track) tunnel running and the effective increase in both CVT and Chiltern tunnel lengths (the former which is significant), this being as a result of the increased train resistance forces. The adequacy of the currently proposed traction power system design in being able to support this increase in loading has yet to be assessed and presents an appreciable risk.

3.12.2 A particular issue would be that the current scheme has Ickenham ATFS (Auto Transformer Feeder Station) located adjacent to the open route portion. This has numerous high voltage cable connections between the ATFS and the overhead contact system for each of the two tracks. Therefore, these would require cable shaft(s) to be provided between the ATFS at surface and the tunnels or an 'at-surface' cable route to the proposed shaft at Highway Farm and the shaft size increased to allow for the additional traction power cables.

3.12.1 There are factors related to the neutral sections in the overhead contact system in the area of Ickenham ATFS which would need further consideration. A neutral section is the arrangement of the overhead contact system where the source of power changes from one feeder station to another. Additional space is required at a neutral section which may be problematic to achieve and may require additional tunnel adits.

3.12.2 A proposed site for the relocation of Ickenham ATFS has not been explored within the PBA report. If the ATFS moved closer to the National Grid substation

it potentially introduces the risk of hazardous voltage from electrical faults at the 275kV substation being transferred to the ATFS and railway, which is a risk that was not present for this site previously; this would be subject to further detailed evaluation.

3.12.3 The proposed Intervention Gap would likely impact on the layout for the West Hyde Auto Transformer Station location at Chainage 31+00 and may require additional lateral land-take.

3.13 Train Control and Telecoms

3.13.1 The high level review has not identified any significant technical issues with the alternative proposal with respect to train control or telecoms.

3.14 Tunnel Aerodynamics

3.14.1 The greater length of tunnels, if the PBA proposal was adopted, would require increased mitigation of micro-pressure waves ("sonic boom"). Mitigation could be achieved by increasing the length of perforated hoods at both ends of the Intervention Gap and at the northern end of Chiltern tunnel. Further work would be required to define the length, which as a first estimate could be in the range 200-300m.

3.14.2 Where there is a requirement for caverns, such as that which may be required for the London facing Heathrow Spur junction, train speeds through the cavern may have to be restricted and this would apply to the main line in addition to the spur (refer to 3.11.2). Further work would be required to define the maximum acceptable speed and how this would have an impact on journey times.

3.15 Railway Maintenance

3.15.1 The PBA proposal states that having a continuous tunnel from the Old Oak Common to the Chiltern Tunnel would create a more economical maintenance strategy. Inspecting and maintaining tunnels can only be done at very limited times when the trains are not running. Surface feature, such as viaducts and bridges can be inspected in part during normal operations.

3.15.2 Considering the length of the proposed tunnels, a significant amount of the time available for maintenance and inspection could be taken up travelling to the site. The PBA proposal makes reference to options for maintenance loopsand stabling of trains (e.g PBA report paragraphs 2.2.15 and 4.27), however, the report

makes no firm recommendation. The provision of maintenance loops within the West Hyde intervention gap would significantly increase excavation volumes.

3.15.3 Inspections and maintenance tasks for the CVT would take substantially longer with than for the HS2 Proposed Scheme and cost more over the life of the system. Specific issues are noted below.

3.15.4 Single bore caverns as may be required for Heathrow Link spurs or caverns with barriers to manage smoke movements would cause significant maintenance problems, particularly when the high-speed switches require replacing. In addition, there would also be a need to undertake a review of how any bespoke jet ventilation fans are maintained. The current proposal for servicing jet fans specified in the Proposed Scheme is via specialist multipurpose vehicle (MPV) and serviced off-site. This may not be possible in the cavern.

3.15.5 There would need to be a safe way of inspecting the HV Feeder Cables from ATFS/ATS in their dedicated shafts. There would need to be system redundancy included so that individual cables can be replaced as necessary without impacting on train services.

3.15.6 The current working assumption for the use of Engineering Trains in the Proposed Scheme is that all engineering trains and on-track plant would be diesel powered as the overheads would need to be isolated to undertake maintenance work. The impact of the extra length of the tunnel on the ventilation and heat requirements would need consideration to understand any implications.

3.16 Construction Costs

3.16.1 As part of the report (Section 6.4), PBA have undertaken an elemental high level cost comparison between the HS2 Reference Route and the Colne Valley Tunnel Option B proposed within their study. This high level cost comparison indicates a potential cost increase of approximately £64.03 million over the Proposed Scheme (£68.93 million over the Proposed Scheme excluding the Heathrow Spur turnouts).

3.16.2 Appendix E to the PBA report provides limited breakdowns to both PBA's assessment of the comparable cost of the HS2 Reference Route for the section under consideration and the estimate they have prepared for their proposed

alternative. This is accompanied by a short further commentary on the sources of information used and approach adopted in preparing these costs.

3.16.3 PBA have made references to costs being based upon those "Published in Estimate of Expense Jan 2013". An "Estimate of Expense" was published in November 2013 as part of the hybrid Bill and it is assumed that this is the document that PBA are referencing.

3.16.4 This costing review has currently been confined to the "Civil Engineering" and associated works costs and has not looked at the Rail systems element.

3.16.5 PBA have stated that their estimates relate only to the infrastructure and facilitating works required and that no allowance has been made for the cost of property acquisitions, relocation of facilities, social costs or compensation. It not stated however whether their estimates are complete in terms of design, Contractors Preliminaries and Overheads and Profit. For the purposes of this exercise it has been assumed that they are included.

3.16.6 The first items that are identified as an issue is the Heathrow spur junctions (PBA Items 10 and 19). In both cases PBA have made an assumption that this would represent "qtr of Retaining walls in Country South Item 3.3.3." and this has given a figure of £30.81 million for each junction, which is a conservative approach which is an overestimate of the costs of these elements.

3.16.7 PBA have included a number of high level "Budget allowances" within their estimate (Items 20 to 26) which would appear excessive.

3.16.8 Item 21, the diversion of this gas main is not now an item required in the Proposed Scheme as the viaduct foundations etc. have been adjusted to avoid the need for its diversion. This now omits the allowance of £3 million by PBA.

3.16.9 Item 22, C3 estimates for these works have been received from the Utility provider and are less than the £15 million allowed by PBA.

3.16.10 It is also unlikely that the other utility works required in that section are going to amount to the £10 million allowed in PBA Item 23.

3.16.11 Item 25, PBA have quoted an allowance for mitigation/planting works of £23 million based on a response to a Freedom of Information (FoI) request. The £10 million allowed for further mitigation/planting works in Item 26 is probably excessive as there is little additional work that is significant in that area.

3.16.12 The most significant factor in reducing the apparent cost differential between the Proposed Scheme and the PBA options is the inclusion of an additional "below the line" (Item a) cost of £60 million within their assessment of the Proposed Scheme costs of an item for "removal of contaminated material at Park Lodge Farm and deposition into new engineered landfill". This item is currently not included within the Proposed Scheme cost estimate. It has been included following the assumption made in section 7.6 of the PBA report that "The "sustainable placement" of material in the (area?) proposed by HS2 is unacceptable and LBH believe that mitigation is required".

3.16.13 A large uncertainty in PBA's proposal is how the extended tunnel drive would be serviced from their Ruislip Depot access shaft and the adequacy of that provision. It is not evident in the allowances made within PBA's estimate (Item 3) exactly what is included for, in terms of the access shaft, passive provisions for the spurs and associated adits needed to provide access from the railhead to the tunnel construction.

3.16.14 A major issue is noted on the assumptions made in respect of material disposal from the additional tunnel bore. PBA have, in considering the cost of disposal of the additional material from the Colne Valley Tunnel (Item 13) allowed only £5 million based on the statement/assumption that this would reflect "transport cost only as material available for commercial use". Whilst such an opportunity may well exist it would need to be proven to justify its inclusion. This approach is contrary with that assumed in the development of the Estimate of Expense which is that such material is assumed to have no commercial value.

3.16.15 The disposal of excavated material adding only a further £5m to PBA's Option B2 estimate, assuming it only being a transport cost, is not justifiable. At this stage it could only represent an aspiration or opportunity and should not form the basis of the estimate. If that material needed to be disposed of commercially to off-site pits/landfill, the cost of its disposal is likely to be in the order of £20-25 million.

3.16.16 There has been no account for the cost of transportation and disposal of the Chiltern tunnel and Intervention Gap excavated material arising from the construction, as discussed in section 3.8 of this report. This could increase the total of the PBA Option B2 by approximately a further £100 million.

3.16.17 From the limited exercise undertaken and described above, it is suggested that the PBA assessment of the Proposed Scheme cost is excessive and could be reduced by between £40 and £60 million in respect of the physical works. If the item allowance for removal of contaminated material is also omitted, that reduction could increase to £100-120 million.

3.16.18 Conversely, the estimate for their Alternative B proposal should, to be consistent in approach with the HS2 Proposed Scheme, be increased by between £20 and £30 million for disposal of the excavated material from the additional length of tunnel proposed.

3.16.19 The effect of these adjustments would be to increase the differential between the Proposed Scheme and PBA Option B2 schemes to anything between £120 and £215 million. However, this excludes the additional cost associated with the disposal of the Chiltern Tunnel and Intervention Gap excavated material, which would further increase this differential by approximately £100 million.

3.17 Rail Systems Costs

3.17.1 A high level rail systems (including tunnel ventilation) construction cost estimate indicates that the incremental cost of the PBA proposal over and above the HS2 Proposed Scheme would be approximately £50 million.

3.17.2 Further costs would be incured for any additional equipment for tunnel cooling as further work is required to identify a feasible solution.

3.18 Programme Impacts

Civil Works

3.18.1 In order to maintain the construction programme the Chiltern Tunnel and Colne Valley Tunnel construction contractors would use the Intervention Gap/works area concurrently. This would have to be investigated in more detail regarding feasibility around logistic issues, particularly the ability to adequately process and remove two concurrent tunnel excavations efficiently.

3.18.2 The complex construction of the Ruislip construction/vent shaft could affect the programme of the Northolt Tunnel and the CVT for the following reasons:

- Construction time for Construction/Vent Shaft;
- Moving materials and equipment from surface to track Level;

- CVT TBM removal would have to wait untill the Northolt tunnel was completed; or

- Northolt tunnel will cease operations to allow CVT TBM removal.

3.18.3 Because of the longer length of the Chiltern Tunnel, its construction would have to commence from the West Hyde Intervention Gap sooner than the Colne Valley Tunnel. The extent and depth of the gap would require significant construction time to construct the Intervention Gap to the point where the construction could start for the Chiltern tunnel. This scenario would require careful examination to determine potential impacts to the Chiltern Tunnel construction programme.

Rail Systems

3.18.4 The key construction issue with the PBA proposal is the restrictive access to the trace increasing the logistical constraints compared to the HS2 Proposed Scheme. This will increase risk to the overall rail systems installation. Hence complex logistics planning and access are key to the delivery and would require risk mitigation to ensure delivery.

3.18.5 The Proposed Scheme strategy is for the tunnel fit out to be undertaken from the Chiltern tunnel south portal. There is no description within the PBA report of how it has been assumed that the CVT, as well as the Chiltern and Northolt Tunnels would be fitted out. It is assumed that this alternative proposal would require the use of the Ruislip Vent shaft, which would not be possible without significant modifications to the vent shaft proposal or the Intervention Gap structure. These would increase the logistical complexity as well as add time to the construction programme. This would become a key rail systems worksite which would result in a construction and logistics constraint with the civil engineering needed to be completed prior to rail systems work being commenced. The site from which the rail system fit out is undertaken would need to be designed to provide adequate access to crane equipment and material to track level. Short rails (60ft /18m) may have to be lowered to the floor of the gap for track installation using the temporary rails, with re-railing and the S&C fit-out undertaken from the temporary railhead, once the track is completed.

3.18.6 The revised access to the HS2 trace also adds issues to the construction and logistics. The access through the Intervention Gap would require longer to

install. In addition a review is required to ensure sufficient gauge to ensure delivery of the high speed S&C.

3.18.7 The implications of the above to the programme, compared to the HS2 proposed scheme, are as follows (the following are approximate durations and further work would be required to fully understand the programme implications):

- 1 month due to the logistics constraints reducing the number of overlapping activities.
- 1 month (worst case) to fit out of the Intervention Gap.
- 1 month for the logistical and additional installation complexity.
- 1 month for the additional tunnel systems installations between 24 to 31km (this is a slower operation than for open route).

3.18.8 Due to the above rail systems issues the overall construction programme is likely to extend by 4 to 5 months for the alternative proposal compared to the HS2 Proposed Scheme.

4 Conclusions

4.1.1 It is clear that a tunnel option across the Colne Valley would provide overall environmental benefits compared to the HS2 Proposed Scheme viaduct during operation. However, certain elements would remain similar, with the continual need for land take at the West Hyde Intervention Gap and the need for power supply at Ickenham in particular.

4.1.2 Construction works will be mainly focused on the West Hyde Intervention Gap and construction site and Ruislip railhead and associated tunnel construction activities, both of which would be extensive work areas over extended periods and which would require land for earthwork handling. There would also be construction sites required for the Moorhall Road and Highway Farm vent shaft.

4.1.3 The PBA proposal for a tunnel focuses on the engineering requirements and presents them in detail. However, the Engineering review of the PBA proposal concludes that it does not adequately investigate a number of issues, including:

- Impacts to rail operations, including tunnel ventilation, traction power, maintenance, travel times and passenger comfort.
- The viability of the vertical alignment.
- Impacts from the movement and disposal of several million tonnes of excavated material.
- Technical feasibility for passive provision for the Heathrow Spurs.
- Environmental impacts, particularly at the SPZ 1 water abstraction sites.
- Need for additional geotechnical information, particularly in weathered areas of the chalk under the various water features.
- Complete costs of underground civil works.
- Programme impact to overall HS2 system construction.
- Cost and programme impacts on adjacent projects and facilities (Ruislip Rail Yard).
- The complete surface impacts of the proposed Colne Valley Tunnel.

- Impacts on rail fit out construction costs and programme.

4.1.4 The technical, logistic and operational issues regarding the West Ruislip ventilation/construction shaft have not been explored in enough detail to determine feasibility. These issues include but are not limited to: improvement of access roads, long term logistics associated with rail fit out and maintenance of system, impact to existing train operations, impact to existing yard operations particularly the long welded rail plant, adequate space for construction works, long term impact to local area, impact to rail fit out operations, impact to Northolt tunnel construction and stability of underground caverns that are several metres below the water table and are in a geologic formation that is known for karstic features.

4.1.5 Potential disturbance to the two SPZ1 abstraction sites adjacent to the CVT have not been fully explored to the point where the impact from the tunnel construction is reasonably understood.

4.1.6 In general, a more detailed analysis of the Colne Valley Tunnel proposal would be required to evaluate all potential impacts to the Colne Valley area and to capture all potential operational, maintenance, construction costs, risks and programme impacts to the overall HS2 system, from beginning of construction to rail fit out through the life of the system.

4.1.7 Cost considerations of the PBA proposal indicate rather than the suggested £6o million additional cost of tunnelling under the Colne Valley, construction costs could range between an additional £220-£315 million, plus additional rail systems cost of approximately £50 million.

4.1.8 Based on the present assessment of the PBA proposal, it is clear that there would be significant additional risk to the construction programme, extensive additional measures required to provide appropriate fire safety requirements and additional traction and ventilation requirements, some of which would be difficult to implement effectively. These would all further escalate the already substantial cost difference of the Colne Valley Tunnel proposal over the HS2 Proposed Scheme.