highways england

QS2A
Outline Tunnel Design Authority Report

A303 Amesbury to Berwick Down (Stonehenge)

Invitation to Participate in Dialogue

Quality Submission Template A

Outline Tunnel Design Authority Report

TEMPLATE A – Outline Tunnel Design Authority Report	
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1. Strategic Tunnel Requirements

1.0. Summary of the strategic requirements and considerations that have driven the tunnel design, including the customer experience and interface with the Regional Operations Centre (ROC)

The A303 Stonehenge Tunnel design has been developed with the strategic requirements for the tunnel (tunnel capacity & availability, design life & maintenance, tunnel users & dangerous goods, and the fire and life safety approach) and an enhanced customer experience in mind. Careful consideration was made throughout design to ensure the interface with the Regional Operations Centres (ROCs) could be effectively implemented and the tunnel's safe operation could be managed from these locations.

The sub-headings below provide further detail around how the strategic requirements of the tunnel were considered in design and how they will be provided for. This section gives the reader with an overall view of how the tunnel and its approach roads will operate safely and effectively. Setting out how the Badger Team design will comply with the ITPD requirements and provide an enhanced design solution for the A303 Stonehenge Tunnel and its road users.

1.1. Tunnel safety

It is generally accepted that road tunnels designed in accordance with modern standards help to minimise road traffic incidents by virtue of their well-lit environment, protection from the weather and the high level of monitoring and traffic control. Conversely, there is evidence that incident rates near portals, where decisions and distractions from the norm may be present, can sometimes be elevated in comparison to the open road. On balance, overall tunnel safety levels are expected to be comparable to those on the open road.

Where this comparison becomes complex, is in relation to the safety requirements that consider incidents and scenarios where consequences may be elevated in the tunnel environment compared to the open road, e.g., fires. Such events may be regarded as potentially low-frequency but high-consequence, and, statistically, contribute little to the overall statistical tunnel risk. However, such scenarios require special attention in terms of safety objectives. In addition to the general requirement for the tunnel to be as safe as the open road, the safety objectives are to:

- Provide a level of tunnel safety in accordance with the relevant standards, legislation, and good practice for road tunnels on the Trans European Road Network
- Ensure that tunnel safety risk is reduced to as low as reasonably practicable (ALARP)

The approach taken by the Badger Team in design for tunnel safety is structured around the Safety Functions of the tunnel facility, equipment, and operating principles – see also section 5 of this TDA Report on MORs. At a high level, Safety Functions are as follows:

- Maintain safe driving conditions
- Provide incident and hazard detection
- Facilitate emergency evacuation and intervention

By focusing on Safety Functions, it is ensured that the systems and equipment proposed for the tunnel are required to have specific function and performance to meet defined safety functions which can be managed through the operations phase to maximise safety and availability.

1.2. Tunnel capacity

The tunnels design utilises traffic information as provided in Part 2 - Design and Technical Requirements (A303-Proc-PD-009-V2-P2- Design and Technical) for the opening year, 2026 and the design year, 2041. This defines the tunnels capacity not in terms of volume flow but rather fleet composition by vehicle type to inform the design for pollution and smoke control.

1.3. Tunnel availability

The A303 Stonehenge Tunnel is a critical asset on the A303 corridor and as such must be provided with a high level of lane availability. The ITPD (Design and Technical Requirements) defines three clear periods (set out below) during which the tunnel shall have certain degrees of availability, these are "embargo" periods when availability is most critical, "peak periods" when the availability is very important and "off peak" periods when tunnel availability is permitted to be marginally reduced.

These periods are defined by the seasonal fluctuations in route traffic (Solstices, Equinoxes & bank holidays) combined with high commuter and business traffic flows Monday to Friday (06:00 – 22:00). The definition of these periods enables the contractor to plan and coordinate maintenance to support the tunnel's availability during the critical embargo periods, in addition to maximising the tunnel's operational safety level at all times. There will be no planned maintenance activities undertaken during the embargo periods.

Embargo Periods

The tunnel lane availability will be a minimum of 99.9% during the embargo periods which are defined as:

- From 06:00 Friday to 22:00 Monday each week;
- All bank holidays and public holidays of England;
- The Summer and Winter Solstices;
- Vernal and Autumnal Equinoxes; and
- Three (3) calendar days preceding and three (3) calendar days following each bank holiday, each public holiday, each Solstice day and each Equinox day.

Peak Periods

The tunnel lane availability will be no less than 99.0% during peak periods defined as:

- From 06:00 to 22:00 each day;
- Thirteen (13) weeks from 06:00 on the second (2^{nd}) Friday of June to September.

Off Peak Periods

Off-peak tunnel lane availability will be such that the overall annual tunnel availability (including Embargo, Peak and off-peak periods) will be no less than 98%. Off peak periods are defined as any time other than an Embargo or Peak Periods.

1.4. Design life

The tunnel systems and installations will be designed to have a service life of 20 years for Plant Control and monitoring equipment and 25 years for electrical equipment as required by CD 352. Components and materials will be selected to maximise their design life while minimising life cycle costs. The maintenance cycles and procedures for all elements of the tunnel will be defined to support tunnel lane availability requirements.

The tunnel structure itself, including the TSBs and portal/approach structures will be designed to have a service life in excess of 120 years in line with CD 350 requirements for category 5 structures (table 7.1).

1.5. Maintenance and Repair Strategy Statement

The A303 Stonehenge Tunnel will be maintained and repaired to meet the minimum lane availability requirements, maintain the Minimum Operating Requirements and to minimise lifecycle maintenance costs through a proactive asset management approach.

In addition to the reactive and scheduled maintenance activities, a Predictive Maintenance management system will be implemented for the most critical systems. Monitoring the equipment status remotely will make it possible to detect issues before they lead to failures. Damage can be mitigated, maintenance activity can be scheduled, and spare parts can be made available on site. This will allow the service intervals to be adjusted according to efficiency, optimising not only the tunnel availability but also the spare parts stock **(TQ2C2.3),** led during the design stages by our Design Manager, and our Construction/Tunnel Manager through the construction stages into maintenance.

1.6. Trans European Road Network

The A303 Stonehenge Tunnel between Amesbury and Berwick Down forms part of the Trans European Road Network (TERN) and therefore must comply with European Parliament requirements as laid out in EU Directive 2004/96/EC [1].

1.7. Transportation of dangerous goods

The A303 Stonehenge Tunnel is provided as a Category A road tunnel in accordance with the European Agreement on the Carriage of Dangerous Goods through Road Tunnels (known as the ADR) [2]. This categorisation is the least restrictive and requires no restrictions on the passage of registered dangerous goods through the tunnel.

1.8. Tunnel and road users

Access to the tunnel is not permitted to pedestrians or non-motorised users (NMUs) in accordance with CD 352. Alternative routes are provided for pedestrians and NMUs within the scheme as per the DCO requirements.

Automatic detection of NMUs will be installed to provide operators with a warning should a NMU approach the tunnel and allow them to instigate mitigation measures.

1.9. Tunnel category and safety features

The A303 Stonehenge Tunnel is a Category AA road tunnel in line with the determination process provided in CD 352. This categorisation is determined by the tunnel length and the traffic flow (AADT) and determines the key safety provision and structural features to be provided within the tunnel.

The key safety provisions as determined by CD 352 which will be provided in the A303 Stonehenge Tunnel are, Emergency Panels, Escape Routes, Vehicle Crossovers (on the tunnel approaches), Emergency Services Parking, Drainage, Automatic Incident Detection, Tunnel Lighting, Fire Alarm & Smoke Control, Traffic Controls and Signals and Mains Power Failure backup & Emergency Lighting.

Those safety provisions which CD 352 recommends (but are not required) be considered via an operational risk assessment, consultation with emergency services and for compliance with the ITPD, but which are not provided within the A303 Stonehenge Tunnel include, Emergency Stopping Lanes within the Tunnel and Turning Bays within the Tunnel.

These key safety provisions are in line with those recommendations made by the EU Directive 2004/54/EC except for the lack of provision of vehicle refuges. However, CD 352, which is the governing standard for the A303 Stonehenge Tunnel does not require their provision. CD 352 states that vehicle refuges may not need to be provided when their initial cost is balanced against operational needs.

1.10. Fire and life safety

The high-level fire and life safety objectives for the scheme are defined as follows:

- To achieve an acceptable level of safety based on the principles of as low as reasonably practicable (ALARP);
- To minimise tunnel fire risk;
- To protect life, property, and availability of the tunnel;
- Sub-objectives to support these high-level objectives are defined as follows:
  - Detect incidents early and control traffic;
  - Instigate and manage self-rescue evacuation;
  - Communicate with, and advise, tunnel users;
  - Control smoke and limit fire growth;
  - Provide a tenable route for evacuation;
  - Facilitate effective intervention;
  - Protect the tunnel structure and equipment.

1.11. Customer experience and human factors

The tunnel systems and operation have been designed and specified with human factors and the customer experience at its heart. The tunnel lighting option is chosen to provide both functional resilience and high performance but to also enhance the customer experience and safety when driving through the tunnel.

Cornice lighting helps provide perspective to a driver, so their peripheral vision can better interpret the tunnel wall boundaries and minimise the risk of lane drifting. In addition to this safety aspect, the LED lighting mounted along the tunnel shoulders **(TQ2A1.1)** led during the design stages by our Design Manager, and our Construction/Tunnel Manager through the construction stages into maintenance.

provides a visually appealing aesthetic to tunnel users when compared to a centrally mounted solution which also involves a complex supporting structure. Vitreous enamel panels **(TQ4A8)** will be used to clad the tunnel walls up to a height of 4m above the carriageway, this will ensure the tunnel is appropriately bright and will enhance the tunnel walls appearance and the driver experience.

Other human factors considered throughout the design include assessment of the tunnels use by a person of protected characteristics. Careful consideration is given when designing verge widths, emergency egress routes and evacuation strategies, tunnel gradients, kerbs, lighting, and signage as well as cross passage design and spacing to ensure that those with protected characteristics are not discriminated against in the tunnel environment.

A radio re-broadcast system will be installed within the tunnel to provide a means of communicating with in tunnel drivers in case of an incident within the tunnel. This provision will be further spread to cover the tunnel's approaches and beyond so that during normal operation this facility can be used to provide drivers with information about the heritage of the area they are passing through (**TQ2A1.2, TQ2A1.3, TQ2A2.1, TQ2A3.1,** led during the design stages by our Design Manager, and our Construction/Tunnel Manager through the construction stages into maintenance.

1.12. Fixed Fire Fighting System (FFFS)

A Fixed Fire Fighting System (FFFS) is to be provided in line with the ITPD (Design and Technical Requirements) in the A303 Stonehenge Tunnel. The FFFS comprises part of the overall fire and life safety provisions to deliver an integrated design solution for the A303 Stonehenge Tunnel. Alongside the other installed safety systems, the FFFS will provide for the reduction of risk to ALARP.

1.13. Ventilation

Longitudinal ventilation using jet fans arranged in banks near each portal will provide for the control of smoke and hot gases and pollution control within the tunnel. This will maintain a safe operating environment during normal use, keeping in-tunnel pollution to acceptable levels. In addition to normal operation, the jet fans will act as a key fire and life safety system during emergency operation, generating a longitudinal air flow at or in excess of the critical velocity to prevent smoke back layering and maintain a tenable environment upstream of the fire site for tunnel occupants to exit during the self-rescue phase.

For emergency services intervention, the ventilation system will assist in supporting fire brigade operations. The non-incident bore ventilation response is designed to prevent smoke re-circulation between the two adjacent tunnel bores and to provide a net flow through open cross passages upstream of the fire site in order to maintain smoke free access and egress routes.

During contraflow operations, where an emergency could result in their being vehicles on both sides of the fire site, the ventilation system designed for normal, uni-directional traffic operations (longitudinal) will be used to minimise risk to tunnel evacuees. The alternative ventilation solution of providing an extraction-type system to remove smoke from the tunnel at source, is deemed unlikely to pass the test of gross disproportionality, given the additional infrastructure required at the portals, the potential requirement for ventilation shafts, and the probable increase in overall tunnel diameter required.

1.14. Regional Operations Centre (ROC)

The A303 Stonehenge Tunnel will be managed and operated by Highways England from the South West ROC at Aztec West. This operations centre will act as the primary operating centre, with resilient operations provided from the South East ROC at Godstone. Both centres will have provision for TCMS operation.

2. Tunnel Assurance and Stakeholders

This section of the report is not mandatory at this stage of the project (tender stage) and will be updated at detailed design.

3. Standards

3.0. Summary of any proposed departures from standards in the tunnel

There are several proposed Departures necessary to complete the works across the scheme. This section of the report is concerned solely with those Departures required to provide the A303 Stonehenge Tunnel. The four Departures are proposed as listed in Table 1 below.

Table 1 Summary of Departures in the Tunnel

Departure ID	Description	DAS Criticality Scale
100850	Cross Passages at 150m	3
101959	Stonehenge Tunnel: Use of Steel fibres for the Reinforcement of Concrete – Material	4
101950	Stonehenge Tunnel: Use of Steel fibres for the Reinforcement of Concrete – Design	4
TBD	Tunnel Ventilation System is not designed for the full design fire load conditions (FFFS)	-

The EU directive requirement for laybys in bi-directional tunnels might arguably be applicable to the A303 Stonehenge Tunnel when operating in contraflow mode. HE has confirmed in comment response ref QS-3C-20 that "The A303 Stonehenge Tunnel is uni-directional. Bi-directional flow is only permitted during planned overnight maintenance in contraflow. As clarified in PIARC 2016R16EN, there is no requirement for a Vehicle Refuge in a uni-directional tunnel of this length." On this basis, no departure from the EU directive requirements is anticipated.

4. Tunnel Operating Environment

4.0. Explanation of how the design solutions provide the required tunnel operating environment

The A303 Stonehenge Tunnel is located on the A303 corridor to the South West and as such is part of the improvements Highways England has been making to this route. The dual lane all-purpose trunk road will increase road user safety by dividing the two carriageways with a continuous central concrete barrier to prevent dangerous overtaking manoeuvres. The addition of a second lane to the road in each direction will increase the route capacity reducing congestion and improving the road user experience.

Traffic within the tunnel will normally operate in a uni-directional manner within the national speed limit with no restrictions on the passage of dangerous goods (ADR Category A). The fire and life safety objectives for the scheme are key and the tunnel will be at least as safe as the road network it sits within.

The tunnels operational design will focus on maximising road user safety, providing drivers with accurate information and instructions when they need it, to support correct driver decisions and behaviour. Lane availability is a key metric for the tunnels' operational performance and success but will never take precedence over the safe operation of the tunnel.

The Badger Team's approach to MORs will support the tunnel operator in making decisions to mitigate a fall in the tunnels' safety level, and to ensure that if the minimum level of safety is breached and cannot be recovered, there is a clear instruction that the tunnel must be closed. Fast, automatic incident detection will support effective self-rescue and evacuation of tunnel users in case of an incident, minimising the threat to life and any damage to the tunnel structure. Tunnel ventilation and FFFS will further support these objectives in addition to facilitating a successful intervention by the emergency services.

Utilising Safety Functions as a key principle for the approach to MORs ensures the systems and equipment proposed for the tunnel have the correct function and performance to meet defined safety functions which can be managed through the operations phase to maximise safety and availability. Further detail around Team Badgers MOR principles can be found in the QS2-B submission (doc reference - Badger_210730_QS-2B_Final).

Further details regarding the integration of Team Badger's design solution with stakeholders and emergency services for operation and incident response are outlined in the sections below.

4.1. Stakeholders and operating approach

Highways England will be the A303 Stonehenge Tunnel operator from the ROC at Aztec West with additional provision for resilient operation from Highways England's South East ROC at

Godstone. The maintenance contract for the road between Countess and Longbarrow roundabout (including the tunnel) will last for 5 years and is within the scope of the works contract, beginning at the end of the construction period.

The tunnel will not allow passage of abnormal loads, these will have to be routed via Longbarrow junction, the Packway and Solstice Park to avoid the tunnel and provide the safe routing of over height vehicles. Over height vehicle detection and warning will be provided on the scheme to protect the tunnel structure and limit the likelihood of incidents.

4.2. Incident management and maintenance operations

Incident response and management will require collaboration between the contractor, tunnel operator, emergency services, local authorities, and the environment agency. The combined operations report will be refined by the contractor and will detail the range of situations which could arise and the coordinated response each incident type will require to manage them during the tunnels' operation.

Automatic incident detection systems will be provided for rapidly detecting a stopped vehicle, traffic accident or other incident requiring swift action. On detection of an incident, the tunnel control system will automatically implement a speed restriction within the tunnel and on the tunnel approaches to mitigate the likelihood of further incidents. This will enable the operator to utilise the CCTV network to investigate the incident and activate the necessary incident response plan and any emergency traffic management.

VMS in the tunnel and on the approaches will be used in conjunction with lane control indicators and speed repeaters to manage the traffic around an incident. If traffic in the tunnel has come to a halt the Public Address / Voice Alarm (PAVA) system will be used to communicate with in-tunnel drivers in addition to the radio re-broadcast system (**TQ2A1.3, TQ2A2.1, TQ2A3.1,** led during the design stages by our Design Manager, and our Construction/Tunnel Manager through the construction stages into maintenance).

In case of a fire incident, the tunnel will operate as a self-rescue facility. The automatic incident detection and tunnel control system will assist the tunnel operator in implementing the necessary traffic and incident management plans. The traffic signals (VMS, LCIs and Speed limit repeaters) will display the necessary information to drivers both in the tunnel bores and on the tunnel approaches, clearly instructing them how to proceed (drive slowly out of the tunnel, do not enter the tunnel, evacuate the tunnel following the wayfinders etc). The fire detection and life safety system response will be coordinated as set out in Section 8 of this report. The FFFS will limit the peak fire heat release rate and shield tunnel occupants from dangerous levels of heat radiation. For normal traffic conditions, the mechanical ventilation system will produce a longitudinal air flow at or in excess of the critical velocity to maintain a clear and tenable evacuation path upstream of the incident. Tunnel user evacuation will be supported by wayfinding signs, PAVA announcements and radio re-broadcast. CCTV will allow the tunnel operator to monitor and direct the evacuation as necessary until the emergency services arrive and can take control of the scene from the Silver command centre.

Once control is handed to the emergency services, the tunnel systems will work to assist with their intervention of the incident by means of smoke control, FFFS and monitoring of other key life safety systems.

In case of a tunnel closure as a result of an incident, diversion routes will be implemented to keep the local road network moving. For routine, planned maintenance works the tunnel will be operated in contraflow, running bi-directional traffic in one bore, while the other is closed for maintenance or inspection works. Robust operational plans for diversion routes and contraflow running will be developed at detailed design in consultation with key stakeholders.

4.3. Fire and emergency service access and facilities

Emergency services access to the tunnel includes the provision of cross over facilities at each portal, in addition to traffic management systems at Countess and Longbarrow roundabouts. This will help to prevent access to the tunnel portals being blocked for the emergency services.

There are two fire stations nominated for emergency response to the East portal and two for the West portal. Amesbury and Salisbury fire stations cover the East portal with estimated response times of 5 mins 30 seconds and 18 mins respectively. Salisbury and Wilton fire stations cover the West portal with response times of 16 mins and 20 mins respectively. There are some issues regarding the availability of the second appliance at Amesbury station to deploy to an incident, hence the expected response times for the necessary appliances to attend are between 16 and 20 minutes to the portal, with further time needed to reach the incident inside the tunnel which could be of the same order as the response time (i.e., a further 20 minutes).

These response times have been considered during the specification of the tunnel ventilation system and the FFFS. The FFFS has been specified for a duration of 2 hours, rather than the minimum ITPD requirement for 1 hour, to support the intervention of the fire service. The tunnel ventilation system is capable of generating a longitudinal air flow sufficient to move the smoke and hot gases in either direction along the tunnel bore so that the fire service may intervene from either end of the tunnel. CD 352 requires the jet fans to operate for at least 2 hours withstanding smoke temperatures of 250^{o}C.

Fire hydrants are provided at every cross passage, at the midpoint between each cross passage and at the portals in line with the requirements of CD 352. This ensures the spacing of hydrants is not more than 100m. The exact design specification of pressure and flow rates will be determined at detailed design stage following consultation with the fire service via the TDSCG.

A leaky feeder system is operated within each tunnel bore to facilitate emergency services communications; further consultation will be undertaken at detailed design via the TDSCG to ensure this equipment is specified correctly to provide the necessary channels on which the standard emergency services communication systems operate. The system will be dual fed from both portals to provide communications resilience in the event of cable damage from a fire.

The TDSCG will work closely with first responders throughout the design evolution process to ensure the appropriate facilities and systems they require are provided within the tunnel. This includes during development of the incident response and management plans to ensure integration between all parties.

4.4. Operational command facilities

The tunnel will be operated principally from the South West ROC at Aztec West by Highways England during normal operations with TCMS provision also supporting the tunnels resilient operation from the South East ROC at Godstone.

In case of major incidents there will also be a Silver command centre within each TSB at the tunnels' location (one TSB is located at each tunnel portal). Fire and rescue services incident commanders may use these locations to interact with key tunnel safety systems such as the CCTV, PAVA and ventilation, as well as having a direct communication link to the tunnel operators base at Aztec West and Godstone. Robust operational plans will be developed that ensure incident response between the Silver command centres and the ROCs is fully integrated and effective.

5. Minimum Operating Requirements (MOR)

Please refer to Team Badger's QS2-B submission for details regarding the Outline Minimum Operating Requirements for the Stonehenge Tunnel (document reference: Badger_210730_QS-2B_Final).

6. Operation and Maintenance, Systems, Controls and Co-ordination

6.0. Rationale explaining how the operation and maintenance objectives are achieved in the design solutions for the tunnel and the tunnel approaches

Throughout the development of the A303 Stonehenge Tunnel design, operation and maintenance strategies have been a key consideration. Design decisions taken during the earlier stages of a project can have significant knock-on impacts to an asset's whole life cost, and as such it is important to outline the strategic approach to these activities during the design phase.

The subheadings below provide further detail around the planned operation and maintenance approach and how the tunnel's design solution supports the overall delivery of this strategy. This section provides the reader with an overall view of how the tunnel and its approach roads will be operated and maintained, setting out how the Badger Team design will comply with the ITPD requirements and provide an optimised solution for the A303 Stonehenge Tunnel stakeholders.

6.1. Routine and planned tunnel maintenance (Predictive)

All activities shall be determined and carried out in accordance with the applicable Highways England standards and their requirements.

To determine the maintenance and inspection activities, all structures, individual components, manufactured items, and sub-components to be maintained shall be identified. All manufacturers maintenance requirements shall be incorporated.

The output of this analysis will be incorporated in the Asset Management Forward Plan (AMFP).

For some key systems (lighting, jet fans and the tunnel lining gaskets) appropriate sensors and monitoring will support the Facility Management System to collect data and identify equipment degradation before they are detected as an equipment failure. This will allow to take additional mitigation measures and schedule maintenance intervention, implementing a so-called Predictive Maintenance (**TQ2C2.3** led by our Design Manager and Maintenance Lead).

6.2. Reactive maintenance

The A303 Stonehenge Tunnel will be operated and maintained to minimise as much as possible the need of unscheduled, reactive maintenance. However, this possibility cannot be excluded. If accidentally the MOR are not met, or any unforeseen accidental damage occur, it may be necessary to temporarily close the tunnel. Depending on the specific event, Temporary Traffic Management (TTM) may need to be implemented. Closures extends, methods, and mitigating actions will be detailed in implemented in the AMFP and dedicated procedures.

In addition to minimise the need of reactive maintenance (thought and efficient scheduled and predictive maintenance system), the tunnel design has incorporated mitigation measures to minimize the need of tunnel close if reactive and unscheduled actions are still required.

6.3. Maintenance contractor

The Contractor will be responsible for maintaining all elements of the infrastructure (Affected Property) for the 5 years following the construction period.

A specialized M&O subcontractor will be appointed to fulfil this requirement with the maximum outcome. This solution will also allow to hand-over the subcontract to HE at the end of the 5 years period allowing a seamless transition.

The O&M subcontractor will be in charge to prepare the AFMP and it will be involved in an early design stage allowing to maximize the design outcome.

6.4. Tunnel maintenance objectives

These will be in accordance with CM430 Maintenance of road tunnels, in order to deliver a high performing tunnel asset. The objectives for the maintenance strategy for the A303 Stonehenge Tunnel are to assist in the development of a technical solution that finds the optimal balance of:

- Meeting the availability requirements;
- Meeting the MOR;
- Minimising equipment failures;
- Reducing lifecycle and routine maintenance costs by providing a transparent, efficient, and economic whole of life cost approach to asset management.

6.5. Integration of tunnel systems

The road infrastructure is designed to meet the operating requirements as an integrated design solution. All the systems need to be coordinated and integrated to be able to provide the optimum outcome and to be able to put in place all the solutions considered to mitigate degradation and failures.

Tunnel system integration shall be implemented throughout the whole project life cycle so that all the requirements are properly transferred and implemented in all the disciplines. At the conclusion of the construction and preliminary commissioning phases, it will be considered a Systems Integration phase when it will be proven that all the systems perform as designed and align with the specifications.

6.6. Categories of tunnel maintenance

Maintenance actions may be classified as:

- Routine and planned tunnel maintenance: these include all those activities which are foreseen to be undertaken with fixed intervals (daily, weekly, monthly, quarterly, yearly…). These are listed in the AFMP and will be regularly be updated following the actual inspection outcomes.

- Reactive maintenance: these include all those activities which cannot be scheduled and are caused by unforeseen events and incidents. Infrastructure design includes a certain level of system robustness and contingencies to minimize the need of reactive actions preferring to undertake compensation actions (typically equipment redundancies). However, a minimum level of contingency closure time and reactive maintenance action plans are to be foreseen and implemented to efficiently react to any situation when the MOR cannot be met.

- Predictive maintenance: in addition to the above, computerized facility management systems (logic and artificial intelligence) allow to monitor the equipment status and detect damages before they create a failure. Software, logic and artificial intelligence will be used to support trend analysis and to take mitigation measures, adding a level of mitigation actions. It will allow to minimize further the reactive maintenance rescheduling the intervention during the planned closures (**TQ2C2.3**, **TQ2C3.2** led by our Maintenance Lead).

6.7. Categories of inspection and servicing

Categories of inspections and servicing standards are given in TRMM Volume 2, Part 1 for highways in general and DMRB CS 452 specifically for road tunnel systems. In addition, DMRB CS 450 states the requirements for the inspection of highways structures which will apply to the tunnel and its associated civil structures.

Safety inspections and Safety Patrols will be carried out at weekly and daily intervals respectively. Additional inspections may be carried out if triggered by third party notifications (from TOA, based on CCTV, OMCS). Tunnel equipment will be provided with a status check function in order to reduce site inspections as far as practicable thus Safety Patrols and Inspections will focus on the road-infrastructure status (i.e.: Cladding, Visible Ring elements, Exposed Cableways and supporting structures, Road surface). Inspections will be recorded to allow continuous learning. Patrols will be performed with travelling vehicle, thus eliminating the need of lane closure, and improving inspector safety (still required traffic management actions). Additionally, a HD camera is being investigated allowing an “off-line” detailed inspection and building a so-called Digital Twin. The use of a vehicle mounted 3D digital scanning system, which can operate in the tunnel without the need for tunnel closure, will contribute to effective predictive maintenance and also the inclusion within a digital asset management data set (**TQ4A7 & TQ2C3.3**) led during the design stages by our Design Manager, and our Construction/Tunnel Manager through the construction stages into maintenance, to support future maintenance regimes.

General Inspection: Visual inspections of M&E equipment and a functional check of all emergency and essential systems should be carried out at intervals of one year.

Detailed inspections: Programmes of routine maintenance tasks not requiring urgent execution.

Principal Inspections: Inspections of M&E equipment and an emergency drill function should be carried out in year one, year three, year five and at intervals not exceeding 3 yearly thereafter.

7. Systems Integration

7.0. Approach to the integration of the tunnel systems, including description of the interactions between the different systems, inclusive of the TCMS

The Tunnel Control and Monitoring System (TCMS) will be provided to integrate the various mechanical and electrical systems provided within the tunnel (as described in section 12). It will allow the tunnel to be operated from:

- The South West ROC at Aztec West (primary operating centre)
- The South East ROC at Godstone (resilient operating centre)
- The two tunnel service buildings which will provide Silver Command facilities

The TCMS shall integrate with Highways England's Advanced Traffic Management (Dynac), Incident Management (ControlWorks), Tools for the Technology Operations Capability (T-TOC) (ServiceNow) and the National TCMS.

The TCMS will enable the range of operating functions as outlined in Table 2 below to be delivered:

Table 2 TCMS Operating Functions

No.	Operating Functions
1	Normal operation (including the passage of dangerous goods vehicles)
2	Implement diversion routes
3	Manage prohibited users, livestock, and wildlife
4	Accommodate the safe movement of abnormal loads
5	Prevent over-height vehicles from entering the tunnel
6	Facilitate the management of large-scale public events
7	Monitor and manage tunnel environment conditions
8	Monitor and manage the effects of weather conditions
9	Monitor tunnel and approach road traffic conditions
10	Manage speed of traffic
11	Detect stopped vehicles within the tunnel
12	Manage lane availability in the tunnel and on approaches
13	Support safe maintenance and emergency service access
14	Communicate with road users
15	Implement a contraflow during maintenance in the non-affected bore
16	Safely manage incidents and clear vehicles from the network
17	Prevent traffic from entering a tunnel bore in the event of an incident
18	Quickly close an individual bore or complete tunnel closure
19	Give advance warning to road users of a tunnel incident and bore / tunnel closure

Equipment provision includes Emergency Roadside Telephones, CCTV, Incident Detection, Variable Message Signs (VMS), Lane Control Signals (LCS), Variable Mandatory Speed Limit

(VMSL) Indicators and repeaters, average speed enforcement between junctions and Traffic Signals to close the carriageway in the event of a full tunnel closure. New processes and procedures will be included within the detailed design to meet the configuration and control requirements brought about by the introduction of these new systems.

The various TCMS systems will be integrated using industry open standards (such as DATEX2 or NTCIP) throughout. Where this is not possible, closed contacts, analogue inputs or proprietary industry standards will be used. All communications will be protected using encryption such as SSL transport.

7.1. TCMS interface

The TCMS shall provide the overall operator interface to the tunnel, the operator will be able to view, act upon and acknowledge alarms generated by the mechanical, electrical, and public health equipment in the tunnel and its environs. The TCMS will also allow the operator to take control of signs, the ventilation system, the firefighting systems, and the CCTV system either through automatic, predetermined plans or by means of direct manual control (subject to operator permissions). Where the operator takes manual control of field equipment, the requested operation will be checked against an inbuilt (and protected from unauthorised modification) set of safety rules that will prevent any unsafe operation.

7.2. Integration of tunnel systems

The TCMS will be fully integrated with the operation of the mechanical, electrical, and public health systems in the tunnel. It will provide the user interface that allows the operators to safely manage the tunnel and it also provides detailed logging facilities for audit and training purposes.

8. Fire and Life Safety

8.0. Strategy for fire and life safety for the tunnel and the tunnel services buildings, including justification

The fire and life safety strategy for the tunnel and tunnel service buildings has been designed around the key principals for the fire life safety systems and for the fire life safety of occupants.

The high-level fire and life safety objectives are defined as below:

- To achieve and maintain a level of safety considered acceptable based on the principles of ‘as low as reasonably practicable’ (ALARP) and above Minimum Operating Requirements (MOR);
- To minimise tunnel fire risk;
- To protect life, property, and availability of the tunnel.

The main sources of fire risks in tunnels are vehicle fuel tanks, vehicle contents, and electrical faults. The main hazards to people in the tunnel from a fire are heat and smoke affecting escape in the enclosed environments of tunnels, but which typically produce relatively little hazard in the open air.

Two separate design fires must be defined – one to protect the structure and fabric of the tunnel and the other for the design of the fire life safety systems. From a structural perspective, the tunnel must be able to withstand a significant fire event without collapse.

The design fire size (design maximum peak heat release rate) for in-tunnel safety systems for the A303 Stonehenge Tunnel, in line with expectations for tunnels on major roads allowing the free passage of dangerous goods, is proposed to be 200MW (without interaction of FFFS). This complies with the minimum requirement in the ITPD of 100MW.

With the provision of a fixed firefighting system (FFFS), the design fire size for the tunnel ventilation system may be contained to around 20MW - 50MW total HRR. Considering the energy balance for a suppressed fire case, the convective HRR is expected to be controlled to $25MW_{conv}$ (or lower). The ITPD requires a minimum design fire load of 30MW (unstated as to whether this is convective or total load in the ITPD). It is proposed, therefore, that the ventilation system be designed for, with FFFS, a convective HRR of 30MW. The effectiveness of the FFFS in suppressing the peak HRR will be verified at detailed design stage in line with CD 352 Section 8.

The tunnel fire systems, with the tunnel ventilation, FFFS and emergency communications systems, in the event of fire of the design fire size, are required to a) Detect incidents early to prevent, as far as practical, escalation, and control traffic; b) Instigate and manage self-rescue evacuation; c) Provide for the safety of those that may not be able to self-rescue; d) Control smoke and hot gases and provide a tenable route for evacuation; e) Facilitate effective emergency services intervention and f) Protect the tunnel structure and equipment.

The strategy to ensure the maintenance of safety levels in the tunnels considering system failures, degradation, or other incidents as well as to provide a means to define the requirements for tunnel MEP systems, will follow the MOR principles. Pre-agreed MORs provide the Operator with a clear response action for events that could cause a safety derogation in the tunnel, without recourse to protracted deliberation and uncertainty on the action required. In this way, the MOR serves as a definitive minimum requirement that the Operator must not allow the tunnel to fall below and for which an operation and maintenance strategy may be developed to avoid. This safety approach is described in further detail in the Outline MOR report (document reference: Badger_210730_QS-2B_Final).

8.1. Fire strategies

8.1.1. Tunnel Fire Strategy

The key principles of tunnel operation in case of a fire emergency in the A303 Stonehenge Tunnel are:

- Traffic operations will be managed by an operator at a designated controlled room;
- The in-tunnel fire related systems will draw the attention of the operator to any anomaly and, where appropriate, prompt the operator with the appropriate response (e.g., the switching of portal and lane control signs to red crosses to close a lane to protect a stopped vehicle);
- For response to fire incidents, operator intervention will be facilitated by providing operational plans with pre-defined sets of responses for the relevant tunnel systems;
- For normal traffic conditions the tunnel systems will operate as follows:
    - Automatic incident and fire detection systems will continually monitor the tunnel operations and raise alarms via the Control room systems when incidents are detected;
    - If a fire is manually confirmed by the operator (for avoiding false alarms), the traffic control, evacuation, FFFS and ventilation will be activated automatically;
    - If the operator does not respond to the fire alarm the traffic control, evacuation, FFFS and ventilation systems will be activated automatically after a pre-defined grace period (designed to allow an operator at the control room to intervene if desired before the automatic response).

Figure 1 below is a simplified representation of the points mentioned above, as well as the emergency phase (represented and indicated with dotted lines).

Note that the information provided in this section is subject to further development as well as consultation with the technical approval authority (TAA) and emergency services through the TDSCG.

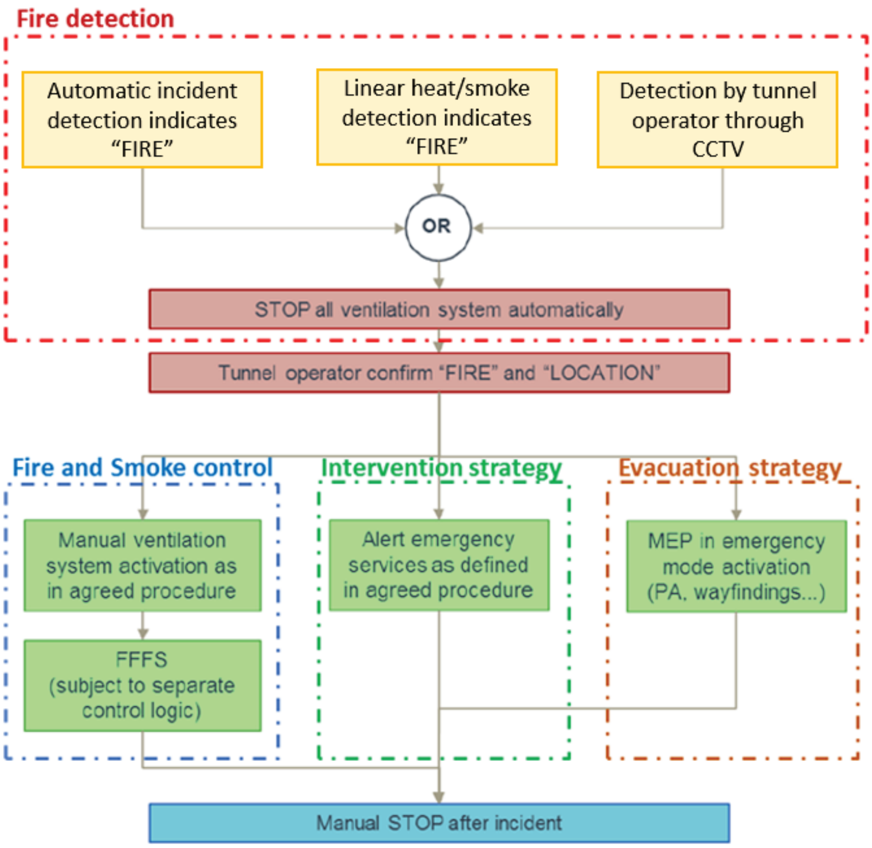

Figure 1 Schematic tunnel operation in case of fire

Fire Emergency Operation

Phase 1: Fire Detection

In normal operation, automatic incident and fire detection systems will continually monitor the tunnel’s operation and alert the Control Room Systems (CRS) when incidents are detected. The following systems will contribute to an effective fire detection:

- Automatic detection systems:
  - Distributed Temperature Sensor (DTS);
  - Smoke detectors
  - Automatic Incident Detection (AID).
- Manual detection systems:
  - Telephone Systems;
  - Radio Systems;
  - CCTV.

If a fire is manually confirmed by the operator (to avoid false alarms), the emergency plan will proceed with the rest of the emergency phases.

Phase 2: Fire and Smoke Control management phase

Fire and smoke control management of A303 Stonehenge tunnel in normal traffic conditions is intended to be achieved by providing sufficient longitudinal ventilation air flow in the event of a tunnel fire to maintain tenable conditions to support the evacuation of users and firefighting operations. In case of congestion or contraflow traffic, the longitudinal ventilation system will be used in the most appropriate way (this will either be to switch the ventilation off and allow natural stratification or to blow gently in one direction as appropriate), which will be confirmed at detailed design.

The following systems contribute on an effective fire and control management:

- Ventilation system (and associated systems);
- FFFS system;
- Manual fire extinguishers.

The operation of these systems depends on fire location and traffic location. This will be further developed in the detailed design stage of the project. Figure 2 below represents the smoke control strategy for a normal traffic scenario.

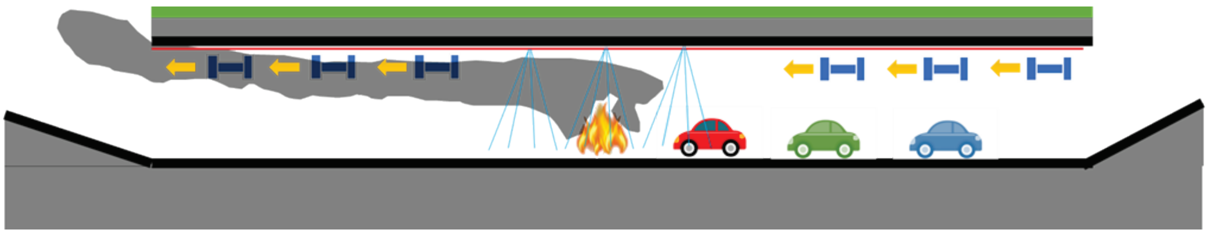

Figure 2 Smoke Control Management Strategy

Phase 3: Evacuation process

The tunnel is to be operated as a 'self-rescue' facility in the early stage of an incident involving a fire. Provisions are therefore required to instigate, manage, and facilitate safe evacuation during a fire related incident. Following detection and the declaration of an emergency fire related incident, the tunnel will enter fire mode and the emergency incident plan will be instigated.

The requirements of the evacuation strategy are to:

- Direct pedestrians away from immediate danger;
- Segregate pedestrians from traffic;
- Allow pedestrians to self-evacuate in a safe manner.

The following systems contribute to a safe evacuation:

- Same as per "Fire and Smoke Control management phase";
- Lighting systems;
- Evacuation aids;

- Traffic signals;
- Public Address Voice Alarm (PAVA).

Where practicable, a 'green-wave' traffic plan will be implemented to support the timely exit of vehicles from the tunnel ahead (downstream) of the fire incident and from the non-incident tunnel bore. Both tunnels would be closed to further traffic using an appropriate arrangement of variable message and signals at the portals and approaches.

Tunnel occupants unable to pass the fire and stopped upstream of the fire will be directed by the tunnel systems to leave their vehicles and evacuate via the tunnel walkways to the entrance portal or if deemed safe to do so a cross passage to the non-incident bore.

Tunnel verge walkways are 1.2m wide to provide room for wheelchair manoeuvring, such as turning on to the walkway from the roadway and turning into a cross passage from the walkway without difficulty.

Evacuees that pass into the non-incident bore may be directed to the exit portal of that tunnel by egress signs and/or PAVA used by the tunnel operations staff (by means of pre-recorded messages).

Effective longitudinal control of air flow will prevent the back-layering of smoke and hot gases upstream of the fire site. In case of contraflow operations, the ventilation system will be operated to minimise risk to evacuees, working in tandem with the FFFS and evacuation facilities.

Detailed evacuation strategies will be developed in consultation with the emergency services through the TDSCG. Figure 3 below illustrates the emergency evacuation strategy and traffic control with a longitudinal jet fan tunnel ventilation system concept.

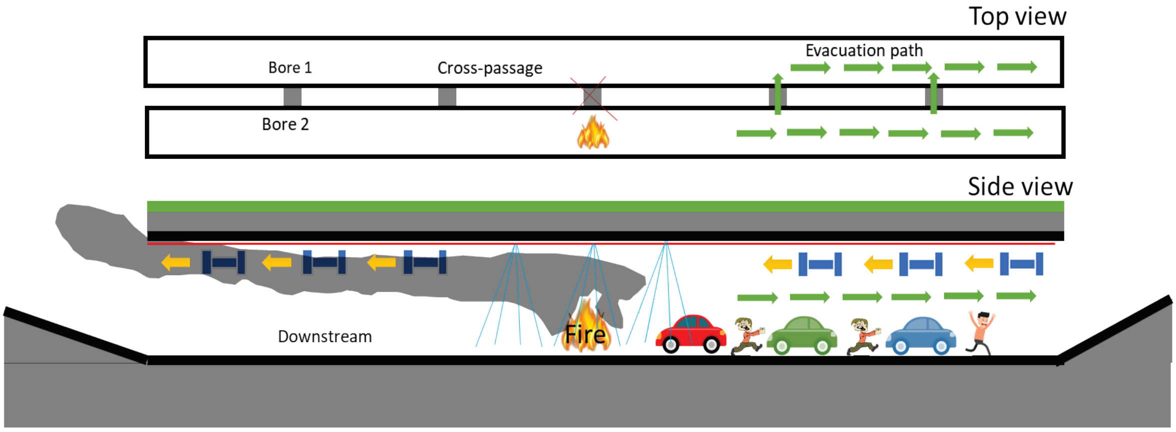

Figure 3 Evacuation Strategy Schematic

Phase 4: Intervention process

Intervention during a fire incident would be expected to be either via the portal(s) or the cross-passages. There are different potential intervention strategies which will be confirmed with the emergency services during detailed design via the TDSCG.

Fire tenders would be expected to assemble at the Rendezvous Point (RVP) before moving to the cross passages to be used for intervention together with other emergency services in the tunnel and at the portals to manage the fire event. Fire tenders will have command and control supported at the control room.

The following systems contribute to a safe intervention:

- Same as per “Evacuation Management phase” safety function; except evacuation aids;
- Smoke Control Panels; Radio Systems;
- CCTV;
- Fire mains and hydrants;
- Command and control support.

Detailed intervention strategies will be developed in consultation with the emergency services through the TDSCG. Special attention will be taken when electric or alternative fuel vehicles are involved for the intervention strategy. Figure 4 below illustrates the intervention strategy for a fire in one of the main bores.

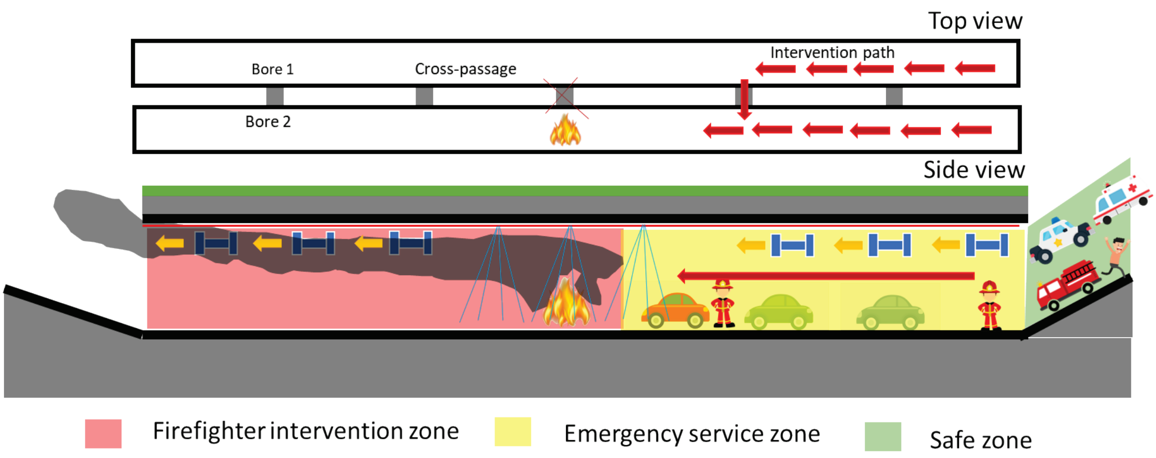

Figure 4 Intervention Strategy Schematic

8.1.2. TSB Fire strategy

The TSBs will be equipped with automatic fire detection systems and alarms to alert occupants to the presence of a fire or other risk to life. Automatic fire suppression systems will be provided in all plant rooms within the TSBs. The TSB will be fire protected for a minimum of 120 minutes with the equivalent minimum 120 minutes protection provided between the TSBs and the invert gallery. All individual rooms with the TSBs will be provided with a means of escape to a place of ultimate safety.

Full audio and visual communications are provided in the TSB in line with the ITPD (Design and Technical Requirements), CCTV, call points, public address / voice alarm, and full mobile phone coverage.

8.1.3. Invert Fire Engineering

Access to the tunnel invert will be managed with a robust operational procedure to ensure the risks associated with the space are ALARP and closely managed. These procedures and restrictions will be developed further at detailed design in consultation with the TDSCG.

For the purposes of tender design, a high-level fire engineering assessment has been developed to provide assurance and direction for the acceptance of this accessible invert solution.

In case of a fire within the invert, those occupants within the space will be alerted to the fire by the automatic fire detection system alarm and be guided to the nearest exit by emergency exit signage. This exit will be via a compartmentalised fire door to ensure the fire cannot spread from the tunnel invert and that once the users have closed the fire door, they will have reached a place of relative safety.

Preliminary work has looked at the provision of a transporting mechanism, be it a tricycle or an electric cart which can assist tunnel invert users.

8.2. Cross-passage spacing and evacuation strategy

8.2.1. Cross passage spacing

Regarding the cross passage spacing, the ITPD (Design and Technical Requirements) lists a departure from Standard CD 352 for an increase of up to 150m the cross-passage spacing as fundamental to providing the works. Preliminary work was conducted by the client's consultant in previous stages of the works to determine if this departure is feasible. Evacuation modelling was used with the adoption of FFFS into the holistic suite of fire life safety measures considered. We understand that this is subject to acceptance by DWFRS and the wider TDSCG.

At tender design stage, TDSCG consultation is not possible and therefore, the acceptance of this cross-passage configuration needs to be further reviewed at the detailed design stage of the A303 Stonehenge Tunnel. It is anticipated that the following actions will be required for its approval:

- Provision of a new Highways England Departure to the contractor based on the CD 352 requirements;
- Quantification of the risk based on the latest tunnel configuration;
- Consultation and agreement with the TDSCG, including the fire service.

8.2.2. Evacuation strategy via the cross passages

Cross-passages will play an important role in case of emergency. When a fire is detected in any of the tunnel bores, the emergency plan will be activated. The operational strategy for the cross-passages during the self-evacuation phase will be focused on assisting the tunnel users to access the non-incident bore in a controlled and safe manner (when the primary evacuation route isn't available for use). Evacuees that pass into the non-incident bore may be directed to the exit portal of that tunnel by egress signs and/or PAVA. Evacuees with reduced mobility, including wheelchair users, would arguably be more likely to use a cross passage to reach a place of relative safety, given potential difficulties in evacuating long distances, particularly on the up-gradient sections of tunnel.

During the intervention phase, the operational strategy for the cross-passage is focused on assisting the emergency services to get access to the incident bore and carry our rescue and firefighting activities. It is not expected that tunnel users and emergency services will typically use the cross-passage at the same time as self-rescue operations should be substantially complete by the time the fire service arrive at the tunnel.

9. Tunnel Ventilation

9.0. Design rationale behind the tunnel ventilation design, including justification

The tunnel ventilation system (TVS) is a longitudinal concept, a total of 28 jet fans per bore arranged in banks of two grouped near each portal to ensure electrical power cable requirements through the tunnel can be optimised. During both normal and contraflow operation the TVS will maintain pollution levels in the tunnel at acceptable levels.

During emergency operation, the TVS will generate a longitudinal air flow at or in excess of critical velocity to control the propagation of smoke within the tunnel for both the self-rescue and intervention phases under the normal operating condition of unidirectional traffic flow.

In case of a fire emergency during congestion or contraflow traffic, the longitudinal ventilation system will be used in the most appropriate way (this will either be to switch the ventilation off and allow natural stratification or to blow gently in one direction as appropriate), which will be confirmed at detailed design.

During normal operation the TVS will be managed by the TCMS, and if the in-tunnel pollutant measuring sensors detect a rise in a monitored pollutant level jet fans will be sequentially activated until the levels fall below specified levels when they will be deactivated. Under free-flowing traffic conditions, the A303 Stonehenge Tunnel will ventilate naturally by means of the traffic generated piston effect, with forced mechanical ventilation for pollutant control potentially necessary during periods such as slow moving or congested traffic.

In the event of a fire emergency, the automatic fire detection systems will put the tunnel systems into an alarm mode with operator confirmation of an emergency mode, activating the jet fans in the direction of traffic flow within the incident bore. The non-incident bore jet fans will also be activated in a configuration that prevents smoke re-circulation between the bores at the portals and also ensures a positive air flow into the incident bore through any open cross passages, maintaining a smoke free evacuation route for tunnel users.

9.1. Design criteria

The TVS will control the pollution level in the tunnel for both uni-directional and bi-directional (contraflow) traffic in line with the PCU/hour capacity figures provided in ASTRA [6]. The design is based on the most onerous period for vehicle emissions, determined by national statistics [2] for fleet technology age to be the year of opening. CD 352 specifies the maximum permissible in-tunnel pollution levels, in addition to EH40 [1] and the latest PIARC guidance [3]. The ventilation system is specified to be reversible.

During a fire emergency involving uni-directional traffic flow within the tunnel bores, the ventilation system generates a longitudinal air flow at or in excess of critical velocity in the direction of traffic to prevent smoke back layering. The system is also capable of producing critical velocity in the reverse direction should the emergency services instruct this.

The target noise level produced by the ventilation system at a plane 1.5m above the roadway should not breach the NR85 level as prescribed in CD 352.

9.2. Pollution and vehicle emissions

The vehicle emission depends on the fleet distribution, road gradient and traffic speed. The fleet distribution data are taken from Section 7 of the ITPD (Design and Technical Requirements) to obtain % distributions for HGVs and PCs. To determine a more refined fleet distribution these data are combined with the latest NAEI data [2] for vehicle categories and technology on a 'rural road' in the opening year, 2026.

This traffic data is then input to the PIARC calculation from Vehicle Emissions and Air Demand for Ventilation [2019R02EN] [5] to obtain the Outside Air Demand (OAD) in order to limit pollution levels within the tunnel in line with the safe exposure limits as set out in CD 352 and EH40 [3].

9.3. Outside air requirements

The tunnel ventilation system will draw outside air in from the portals to dilute vehicle emissions in the tunnel and maintain pollutant concentration levels below safe limits. No intermediate shafts are permitted within the WHS to meet the requirements of the DCO hence the outside air will be supplied by the jet fan longitudinal ventilation system.

The pollution concentration limits used in the monitoring and control of the in-tunnel pollution are taken from CD 352, EH40 and the latest guidance from PIARC [3, 5].

9.4. Proposed ventilation system

The tunnel ventilation system proposed consists of 56 jet fans across both bores mounted in pairs with 100m separation between banks and the portals. This results in four groupings of fans near each portal, stretching 700m into the tunnel with 14 banks total per bore. The fans will be coordinated with other tunnel infrastructure to maximise installation efficiencies and optimise tunnel system integration and operation.

During design of the TVS, the following design parameters are considered:

- Jet fan installation efficiency;
- Tunnel wall friction;
- Jet fan redundancy requirements as per CD 352;
- Jet fan destruction criteria as per CD 352;
- Adverse portal wind pressure as per the ITPD (Design and Technical Requirements).

During a fire incident involving unidirectional traffic flow per bore, the jet fans in the non-incident bore will be utilised to generate an airflow through the open cross passages near the incident to support self-rescue and intervention. The non-incident fans will also produce a net positive flow in the non-incident bore to prevent the recirculation of smoke from the incident bore.

Figure 5 Schematic Line Drawing of TVS

9.5. Monitoring and control

The tunnel ventilation system will be automatically controlled during normal operation via a feedback loop monitoring the in-tunnel pollution levels. CO, NOx, and visibility sensors will be installed at both portals and the midpoint of each bore to facilitate contraflow and reverse operation. The fans will be automatically started and operated in steps by increasing the number of jet fans operating when the levels breach the trigger and alarm limits as laid out in CD 352. Air speed sensors will be installed in the tunnel and outside to monitor the speed and direction of air flow to assist with the control of the tunnel ventilation system.

An automatic fire and smoke detection system will be installed within the tunnel, utilising linear heat detectors and smoke detectors combined to provide resilience and dependency in fire detection: smoke detectors will detect a small fire quicker than a heat detector, providing earlier response leading to less damage to the tunnel and its equipment thus a shorter repair time **(TQ2C2.2)** led during the design stages by our Design Manager, and our Construction/Tunnel Manager through the construction stages into maintenance. Upon detection of a fire, the tunnel control system will activate the jet fans in both bores to generate an air flow in the direction of the incident bore traffic flow under unidirectional traffic flow conditions in both bores. The jet fans in the non-incident bore will be utilised to generate an airflow through the open cross passages near the incident to support self-rescue and intervention.

10. Tunnel Lighting

10.0. Design rationale behind the tunnel lighting design, including justification

The tunnel lighting will follow the key standards and best practice guidance requested by Highways England. The tunnel lighting systems will be chosen based upon the following key drivers.

- Health and Safety;
- Driver comfort;
- Capital cost;
- Operating costs;
- Maintenance costs;
- Aesthetic treatment.

The lighting will consist of continuous luminaires parallel to the centreline of the carriageway arranged as two lines cornice mounted on the walls. The LED luminaires will be mounted in an arrangement such that the light appears uniform and continuous, eliminating light flicker to drivers following high sided vehicles **(TQ2A1.5)** led during the design stages by our Design Manager, and our Construction/Tunnel Manager through the construction stages into maintenance.The lighting will be designed to meet BS5489 Part 2 and will be suitable for both single direction (in normal or reverse flow) and contraflow traffic. The tunnel lighting proposal offers significant WLC benefit, please see QS6D Page 8, Section 6 and **TQ4A2**, led during the design stages by our Design Manager, and our Construction/Tunnel Manager through the construction stages into maintenance.

The driver comfort criteria of the tunnel will be Class 3 but with a longitudinal uniformity in excess of 0.7.

Integrated architectural LED lighting will be provided to illuminate the tunnel cladding panels and enhance the visual experience for tunnel users **(TQ2A1.1)**; these will have a specific mode which can be activated in the event of an incident to supplement the tunnel safety systems and aid vulnerable users in the evacuation of the tunnel by giving a visual indication of the nearest evacuation point thus improving safety in the tunnels **(TQ1C1.1 & TQ1C3.1),** led by our Design Manager and supported by our HSW Manager**.** In addition to the LED lighting, projectors will be mounted at the tunnel mid-point to display images on the tunnel walls and further enhance the tunnel user experience **(TQ2A1.2)**.

10.1. Lighting Zones

The length of the lighting zones within the tunnel is determined by the maximum permissible speed of traffic within the tunnel, hence the zone lengths have been prescribed as follows:

Zone	Length (m)
Threshold	215

Transition	500
Interior	2,450
Exit	120

10.2. Monitoring and control

The lighting system will have a full lighting control system following the DALI2.0 protocol which will enable switching, dimming and luminaire diagnostics to be controlled and communicated to the TCMS. Emergency lighting testing regimes will be enabled through the control system.

The lighting within the threshold zone will be determined by the ambient brightness condition external to the tunnel portal and will be controlled using photometers. During the early design stage, we are going to use climate-based daylight modelling to better predict the L20 value earlier in the design process and hence optimise the threshold lighting.

The night lighting will be achieved by providing a lower output via the lighting control system.

10.3. Emergency lighting

The mains-failure lighting will be provided by a sub-set of the interior lighting powered through a number of dedicated lighting UPS units, located within the TSB plantrooms. Evacuation lighting will be provided in accordance with BS EN 16276. The evacuation lighting will be supported from the same UPSs.

11. Tunnel Drainage

11.0. Design rationale behind the drainage design in the tunnel and on the tunnel approaches, including justification

The tunnel drainage system operates independently of the schemes other drainage networks. All drainage inflows beyond the tunnel portals are managed by the highway drainage system. Therefore, the tunnel drainage network has been designed with the following tunnel inflow volumes in mind:

- Tunnel wall washing after a fire (1 bore only);
- Tunnel wall washing (2 bores);
- FFFS discharge (2 hours) (NB, this increase in supply duration beyond the ITPD minimum requirement has been allowed for within the design of the drainage system);
- 1 hour of fire hydrant discharge at a maximum of 1500 litres/minute (CD 352);
- 1 tanker spillage;
- Allowance for lining infiltration;
- Allowance for water carried in by vehicles.

These flows are in line with CD 352 recommendations for wall washing and fire hydrant discharge, in addition to the FFFS performance determined flow rate and vehicle and lining inflows based on previous project experience. The carriageway has a 2.5% crossfall to channel flows into the slot drains located at the off side of the carriageway and along the gravity drainage pipe to the low point sump where the flow is pumped out of the tunnel up to the diverter valve.

11.1. Tunnel drainage schematic

The drainage schematic below shows the working in-tunnel drainage design solution for the A303 Stonehenge Tunnel. During normal tunnel operations the diverter valve connecting the mid-tunnel sumps to the impounding sump will divert all tunnel inflows to the highway's drainage network. The majority of this inflow is assumed to be clean water resulting from vehicle run off as they pass through the tunnel and a small allowance for ground water infiltration through the tunnel lining.

In case of the collection of 'contaminated' water in the mid-tunnel sumps, the divertor valve shall switch to direct all tunnel inflows into the impounding sump. This will prevent any hydrocarbons or other possible contaminants from entering the local water environment as a result of tunnel wall washing, tanker spillage or other incident. As a precaution and to protect the local ecosystems, the divertor valve shall fail safe, by diverting all flows to the impounding sump. Further work regarding automatic control of the divertor valve will be conducted at detailed design, including automatic incident detection of spillages and other incidents.

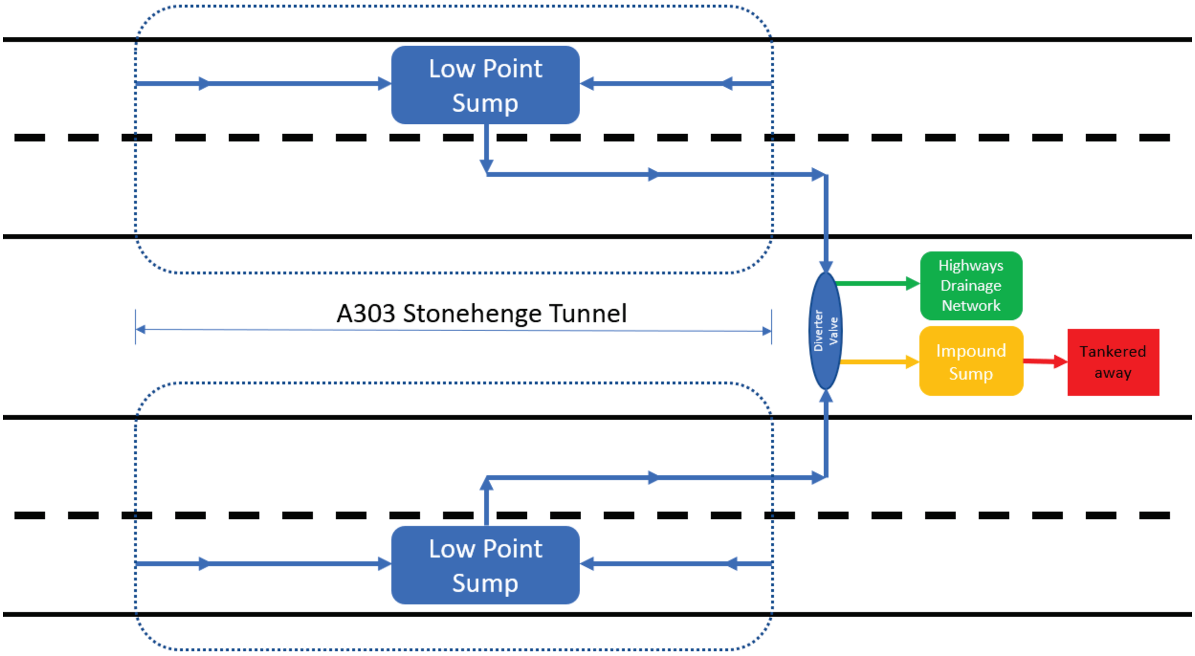

Figure 6 Tunnel Drainage Schematic

11.2. Surface water on tunnel approaches

The highways drainage network will capture all surface run off water at the portals, eliminating any requirement of the tunnel drainage network to manage these flows. A small allowance has been made within the tunnel drainage network specification for rainwater carried into the tunnel by vehicles and for the possibility of overlap between the small area of road at the portal and the final highways drainage outfall. This is prudent to ensure the tunnel drainage network isn't overwhelmed in case of a rare rainfall event.

11.3. In-tunnel surface water

All water hitting the carriageway within the tunnel bores will flow in the direction of the carriageway crossfall and down the gravity drainage system. Between the kerb/slot/linear drain there is a fire trap to prevent flames from spreading into the carrier pipe which will run in the tunnel invert to the low point sump.

The in-tunnel drainage system has been designed with spillage collection in mind, as this is a critical factor in case of a flammable or hazardous spillage. The longer a spillage sits on the carriageway the likelihood of ignition and other consequences increases.

11.4. Groundwater inflow

At the bottom of the invert below the gallery walkway there is a gulley to funnel any groundwater inflows through the lining into the low point sump where it can be pumped up to the highway's drainage network under normal operations.

11.5. Typical cross-section

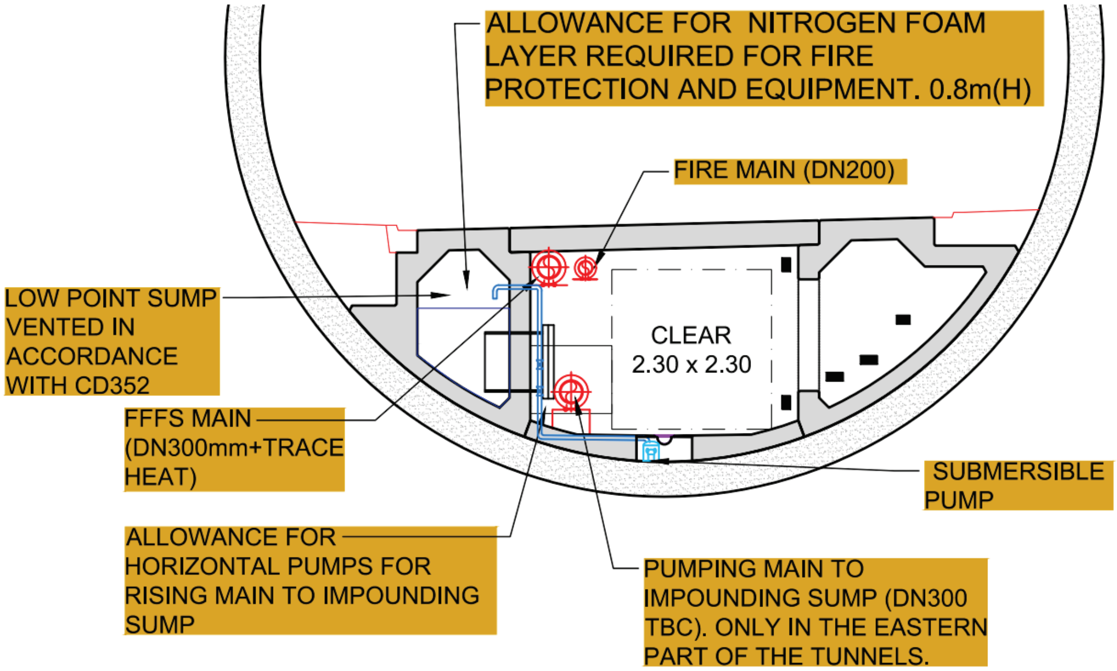

Figure 7 Cross Section at Low Point Sump (CH.9137.65)

11.6. Low-point sump and pumping station

The low-point sump will be 50m^3 in volume with a length of 34m. It has been sized according to CD 352 requirements. It has been sized to support the tunnel drainage system to contain all the inflows outlined in the tunnel drainage summary above (11.0).

The low point pumping station shall comprise two pumps in a duty/standby configuration. The pumps will be ATEX rated to ensure they can continue pumping in the presence of hydrocarbons to prevent pooling on the carriageway in case of an incident. This enables the low point sump to act as a holding area from where inflows to the tunnel drainage system can be periodically collected and pumped to the impound sump.

The low point sump will be equipped with foam blanket and ventilation systems in accordance with CD 352 to ensure there is no chance of vapour build up or ignition within the sump.

There will be access to the low point sump and pumping station via the invert gallery. This will support servicing and rodding to any components as necessary in addition to sludge deposit removal from the sump.

11.7. Impounding sump

The tunnel impounding sump location will be in the East TSB. The impounding sump is sized to contain the total volume of all inflows listed in Section 11.0 giving it a capacity of 1,650 m^3. Its location will allow for safe and easy emptying using bowsers, without compromising the safety of A303 road users.

The impounding sump will be provided with ventilation, fire detection and a foam blanket system. It will also support the easy removal of sludge deposits and access for other maintenance.

No pumps are provided within the impounding sump, but it will be equipped with level sensors to signal high water levels, this will be connected to the TCMS and relayed to the ROC at Aztec West.

12. Communications and Technology

12.0. Design rationale behind the communications and technology design in the tunnel and on the tunnel approaches, including justification

The communications and technology general arrangement will be as per drawings HE551506-BGR-HOS-SWGN000Z-DR-TE-0101 to HE551506-BGR-HOS-SWGN000Z-DR-TE-0105 (QS-6A) and will comply with the requirements of CD 352. The general principle will be that all safety critical functions will be provided by a redundant pair of communications networks that are interleaved along the length of the tunnel. The two bores will be independent copies of the M&E systems implementation to enable isolation of the two bores in case of a catastrophic incident or works affecting a single bore. All equipment will be selected for a long life in the aggressive environment of the tunnel, thus materials such as stainless steel will be preferred for in-tunnel equipment. The system will be controlled via the TCMS as described in Section 6 by an operator in the Highways England South West ROC at Aztec West. For reasons of maintainability and future enhancement, where possible all equipment will interface to the TCMS using a TCP/IP interface and all control and monitoring messages will be made using open protocols such as DATEX 2 and NTCIP. The general approach to the layout of the M&E plant will be to minimise the amount of it in the tunnel bore by moving it to the Tunnel Service Building, the cross passages, and the accessible invert.

Equipment provision includes Emergency Roadside Telephones (at 50m intervals throughout the tunnel on the nearside of the carriageway; 75m intervals on the offside of the carriageway (at the midpoint between each cross passage); in the entrance to the cross passages , as well as within the interior of every cross passage; and at the places of relative safety at each of the portal entrances), CCTV, Incident Detection, Variable Message Signs (VMS), Lane Control Signals (LCS), Variable Mandatory Speed Limit (VMSL) Indicators and repeaters, average speed enforcement between junctions and Portal Lane Control Signals supported by the Portal Variable Message Sign to close the carriageway in the event of a full tunnel closure.

The tunnel communications network will be implemented over an Internet Protocol (IP) communications network provided by the National Road Telecommunications Service (NRTS). We will define which standards are to be implemented during the detailed design. The details in this section are the preliminary design and will be further developed during the detailed design. NRTS will provide high integrity, high bandwidth connections to each Service Delivery Point (SDP) which will be located at appropriate points. In order that the roadside technologies may be connected to the NRTS communication network, the locations, quantities, and transmission requirements of each device is to be identified to allow the circuit provision. NRTS will be requested to provide, install, terminate, and test its own transmission equipment and cabling up to the SDP. We will provide power, cabinet space and cabling beyond the SDP that connect to the works, including any cables that interconnect these systems that are beyond the SDP.

12.1. Tunnel approaches

Roadside devices on the tunnel approaches will be controlled over an IP communications network provided by NRTS. The Average Speed Enforcement Cameras however will operate using encrypted data packages over the mobile data network to the Evidence Recovery Control Unit (ERCU) at the local Safety Camera Partnership office. There are two Variable Message Signs (VMS) signs on the approaches to the junctions to warn of tunnel closures, restrictions, and congestion.

CCTV coverage is provided on the tunnel approaches through to the tunnel portals providing 100% coverage. Additional CCTV will be provided around and within the tunnel services buildings for security with extra cameras at the tunnel portal for traffic management.

Temporary Traffic Management Signs are provided in the verge and central reserve on the approach to the crossover points within Longbarrow and Countess junctions. These signs are in place to manage lane closures and vehicle speeds in advance of crossovers setup for tunnel contraflow operations. In addition, illuminated LED road studs will be provided to guide vehicles through the crossovers. Average speed cameras will be installed to enforce the reduced speed limits (i.e., 40mph) set between the junctions and tunnel portals, and also within the tunnel. Variable Mandatory Speed Limit (VMSL) indicators will have speed limit repeater indicators installed between the junctions and the tunnel portals to reinforce the speed limit.

The Longbarrow and Countess junctions will be provided with traffic signals at the roundabouts.

In order to facilitate the safe implementation of contraflow operation, S-A-B Gates will be installed at the crossovers. The S-A-B Gates will be operable by hand without the need for any tools and will improve safety for maintenance personnel and the public during the start and end of contraflow operation (**TQ2C1.3**, **TQ1C2.1**, led by our Maintenance Lead and supported by our HS&W Manager).

12.2. Tunnel equipment

Tunnel Equipment will consist of the following:

- Variable Message Signs;
- Lane Control Signs (including portal signals and speed limit repeater signals);
- Public Address / Voice Alarm;
- Emergency Telephones;
- Emergency wayfinding signs;
- CCTV;
- Automatic Incident Detection Systems;
- Speed Enforcement.

The tunnel safety assessment supports the need for VMS. The VMS will be regularly spaced through the tunnel providing a continuum of information, without causing driver overload. The VMS will be placed at the portal and at 600m intervals throughout the tunnel. The 600m spacing will ensure that the driver is reminded of key safety message not less than once every 34 seconds at the lowest regularly used speed limit.

Lane Control Signals capable of displaying Lane Closed (Red X), variable mandatory speed limits and Lane Open (Green arrow) aspects are provided to separately control traffic in each running lane and employ contraflow working when required. Inter-visibility of signals is important to ensure that the road user can see at least one set of signals beyond them. Software interlocking on these Lane Control Signals will be provided to avoid the need for one-off modified equipment. We are proposing that in line with the driver experience on the Smart Motorways, an open lane will be represented with a speed limit whilst a closed lane (including for contraflow) will be indicated by a Rex-X. When the tunnel is being used in contraflow, the Red-X will be supported by a VMS message such as "`Contraflow Stay in lane`".

A public address / voice alarm and emergency wayfinding systems will be provided to guide evacuating road users with telephones provided in line with the ITPD Volume 2 Part 2 to allow motorists to contact the tunnel operator in an emergency. Low light CCTV pan tilt and zoom cameras will be provided at 100m centres along the tunnel. At each cross passage, a fixed camera viewing the cross passage will be provided in the tunnel bore to view people standing in the cross passage's recessed entrance and there will be an ultrawide-angle camera within the cross passage.

12.3. Tunnel incidents and emergencies

Tunnel incidents will be detected by one or more of the AID (and integrated Stopped Vehicle Detection system) system, smoke detectors or the DTS. These will be alerted to the operator who will be prompted to take action. The suggested action and the proposed incident class will be as follows:

Table 3 Incident Classification and Suggested Actions

Alarm source	Operator prompt / incident class
AID system only	Alert operator to an incident in the tunnel Move relevant PTZ cameras to view incident location Propose a reduced speed limit Classify incident as Incident
DTS or Smoke Detectors only	Alert operator to possible fire in tunnel Move relevant PTZ cameras to view incident location Prompt operator to confirm fire If confirmed, propose raising lighting level to incident level and activate ventilation system in current configured direction – classify as emergency and propose closing the tunnel. If not confirmed, take no action, and classify as incident
Any two of Smoke detector, DTS and AID	Alert operator to likely fire in tunnel Move relevant PTZ cameras to view incident location Propose closing the tunnel, raising lighting level to incident level and activate ventilation system in current configured direction – classify as emergency

If the operator fails to respond to the prompt, after a configurable time out, the TCMS will automatically implement actions that are not subject to direct operator confirmation. Fire detection (heat) detectors will also be installed in all the cross passages and plant spaces.

12.4. Speed Enforcement

Within the tunnel and on the approaches, speed enforcement will be provided by the average speed enforcement system. There will be two average speed enforcement zones covering the tunnel and its approaches. One will cover each of the tunnel approaches up to the portals in the East and West, and one will cover the tunnel itself. These zones will have modes of operating for both normal and maintenance operation.

12.5. Tunnel closure

Upon the need to close the tunnel in an emergency, the lane control signals at the relevant portal(s) will be set to the Red X aspect with flashing red lanterns. This will be supported by the Portal Variable Message Signs. Before the closure is introduced, the fixed text message sign (FTMS) elements of the advanced direction signs at the Countess and Longbarrow junctions will be changed to show that the tunnel is closed and that all traffic should divert to the local streets at the junction. The slip roads will be closed completely using cones and temporary signage.

12.6. Tunnel technology monitoring and control

The tunnel technology equipment will be monitored by the TCMS. This will be accomplished by the field equipment carrying out regular self-tests and reporting the results to the TCMS supervisor process. In addition, the TCMS will regularly poll / monitor for heartbeat signals all equipment to detect any complete failures. For certain mechanical equipment (such as FTMS, dampers, valves and fans) the TCMS will automatically carry out regular test activations and or duty changes to ensure that mechanical elements do not stick and that they respond correctly (e.g., dampers reach a closed or open position when demanded or that fans reach a predefined speed within a certain time of operation). The Reliability, Availability and Maintainability of the Communications and Traffic Control systems will be sufficient to achieve the functional safety requirements determined by the Tunnel Systems Safety Case. The systems will be hardened to meet the general cybersecurity guidance published by the National Cyber Security Centre and the Cabinet Office and to meet the findings of the information security systems assessment carried out in accordance with BS ISO 27001.

12.7. Communication network within the tunnel

The core communications network is the responsibility of NRTS; however, we will work with them to develop a reliable and resilient service. There will be a Service Delivery Point for each item of IP connected field equipment. For field equipment that does not utilise IP communications, we will provide a local PLC interface to connect to this field equipment.

There will be a number of field equipment circuits that provide a power over Ethernet facility to simplify the field wiring in the tunnel. This may be provided by secondary PoE power injectors in the cross passage.

12.8. Communication network outside of the tunnel

The core communications network outside the tunnel is the responsibility of NRTS, however we will work with them to develop a reliable and resilient service. All roadside equipment will be connected to an appropriate NRTS Service Delivery Point.

12.9. Future proofing of tunnel technology

We will provide a minimum of 25% spare capacity in the following areas to permit future expansion of the system. The following facilities will have 25% spare capacity:

- TSB rack space;

- UPS capacity;
- Transformer capacity;
- Power supply ways in power distribution boards;
- Ducts and cable trays.

13. Mechanical and Electrical and Public Health

13.0. Design rationale behind the mechanical and electrical supply and distribution design, including justification

Team Badger’s design rationale for the mechanical and electrical supply and distribution design, including the justification behind the design parameters used is detailed below. These topics have been broken down into their respective discipline sub-headings to provide clarity and to support the readers effective interaction with the document.

13.1. High Voltage (HV) distribution

Two incoming distribution network operator (DNO) HV power supplies are being procured by Highways England and one will be made available at each TSB: The DNO switchgear associated with these supplies will need to be incorporated into the design of the TSB. The contractor will develop HV and LV distribution system designs that are compatible with the incoming supplies provided. The distribution system designs will be DNO compliant customer HV distribution networks suitable for supporting the TSB HV/LV electrical substations.

The HV system shall be configured so that all tunnel systems can remain fully operational with a failure of either incoming HV electrical power supply, and so that any individual incoming main or interconnecting circuit breaker can be isolated without affecting the safe operation of the tunnel.

Two independent HV Ring Circuits, “A” and “B” supply will be provided through the tunnels. HV “A” and “B” supplies will be available at both TSBs. Either supply will be capable of powering the entire tunnel, if required. Normally, the tunnel load shall be shared between the “A” and “B” incoming supplies.

The HV cables associated with the “A” and “B” supplies will be routed in separate tunnel bores for maximum security. The incoming HV power supply to the transformers at the East end are derived from Ratfyrn Primary substation at 11kV. The incoming HV power supply to the West end are derived from Salisbury BSP (Bulk Supply Point) at 33kV before being transformed to 11kv by a transformer at the West TSB. Note that the distribution through the tunnel will be at 11kV. The DNO equipment requirements will be incorporated into the design of the TSB and will ensure that it is not possible to parallel connect the two supplies.

13.2. Low Voltage (LV) distribution

HV power shall be transformed down to 400 volts at the main TSB HV/LV electrical substations for final distribution to plant and equipment via Low Voltage Switchboards. Each TSB Plant Room will contain an LV Switchboard for distributing power to serve LV plant and equipment.

Each LV switchboard will be fed from a separate transformer and a bus bar or cable link will be installed between the LV Switchboards located in separate rooms. The transformers will be sized to provide power to both sides of the Switchboard in the event of loss of “A” or “B” supply. The automatic Change-over connection at the LV Switchboards will allow for one transformer to be out of commission and isolated, and all circuits to be connected to the remaining functioning transformer. To minimise the risk of a complete failure of services in any section of the tunnel, luminaire circuits and other electrical loads such as the jet fans will be connected alternately to the “A” and “B” supplies as far as practical. Cables and containment from both supplies will be routed separately to minimise the risk of loss of both circuits simultaneously.

13.3. Backup power supply

Permanent generators will not be provided because of the independence of the two incoming supplies. However, provision will be made to permit transportable generating equipment to be connected to the tunnel electrical distribution system in the event of a planned network outage.

13.4. Uninterruptable Power Supply (UPS)

Uninterruptable Power Supply (UPS), which uses battery power to maintain supplies without a break to connected equipment in the event of mains power failure, are required to be installed at both TSBs. This would provide power to all essential items of plant such as communications equipment and the tunnel Emergency Lighting. Each UPS (lighting and communications) will have autonomy for two hours.

13.5. Fire hydrant system

The fire hydrants within the A303 Stonehenge Tunnel are provided in line with CD 352 requirements for maximum flow rates and supply duration. Their exact specification will be confirmed at detailed design in consultation with the Fire and Rescue Service with regards connections and fittings. They will be located at the cross-passage doorways within the tunnel, the midpoint between each cross passage and at the tunnel portals to support emergency services intervention.

The volume of water to be supplied will be housed in the portal structures with two pumps in a duty/standby arrangement to supply the water at the desired flow rate and pressure. The fire main will be routed through the tunnel invert. Trace heating will be provided where necessary to prevent any issues due to low ambient temperatures in the invert.

13.6. Fixed Fire Fighting System (FFFS)

Different FFFS systems are available on the market, the preferred solution will be evaluated during the detailed design. Team Badgers design has been space proofed for either solution.

The FFFS main will also be routed through the tunnel invert, with the section valves readily accessible for maintenance and servicing. The distribution pipework from the section valves passes up the sides of the tunnel bore to the nozzle arrays above the carriageway.

The FFFS main will include trace heating to prevent any blockages forming in case of cold ambient temperatures. Trace heating will not be provided downstream of the section valves as this pipework will be normally dry. The distribution pipework will have space provided around the traffic envelope to accommodate it including the necessary bracketry and fixings.

The water storage tanks and pumps will be located within the portal cut and cover sections. It is proposed for resilience that the water supply is split across the two portals, with two separate tanks of one hour duration each provided at the portals. The tanks will be provided with fire service quick fill valves in case an extended duration of supply is needed.

14. Tunnel Services Buildings

14.0. Design rationale behind the general arrangement and design of the tunnel services buildings, including justification

The Tunnel Service Buildings are located at road level at the entrance to each portal. They are cut and cover structures to blend them into the landscape and minimise the visual impact on the WHS. All structures will be fully integrated into the design vision for the scheme, with attention paid to the transition at the tunnel portals and end of the retained cuts. Driver experience and impact on the WHS are also key considerations throughout the design of the project.

The TSBs will be provided to house all plant and equipment as required in the ITPD Design and Technical Requirements Section 16. Automatic fire detection will be provided throughout the TSBs in conjunction with appropriate structural fire resistance and fire protection up to 120 minutes. Additionally, automatic fire suppression will be provided in all plant rooms within the TSBs. All rooms within the TSB will contain ventilation and air conditioning systems as necessary to maintain the safe and effective operation of the TSBs. Full coverage of the TSBs and surrounding areas will be provided for in terms of mobile phone service, CCTV surveillance, intruder and fire alarm systems, PAVA systems and lighting for both normal usage and during a power failure.

Silver Command control rooms will be provided in both TSBs with full access for local control and operation of the TCMS. The Silver Command control rooms will support the Emergency Services in their management of incidents and emergencies by providing access to view the operational status and condition of the tunnel, its systems, and provide communication with the ROCs.

To improve availability and allow safe maintenance access to the in-tunnel MEP equipment without shutting a lane/bore, an under-road gallery space will be provided in the tunnels. This will be connected to the TSB, the cut and cover tunnel sections at each portal and at selected cross passages / equipment rooms in the main bored tunnel. The gallery has been sized with a clear width of 2.3m x 2.3m and will not exceed classification beyond a low-medium risk confined space. Access will be via staircase at the portals and at the nominated cross passages, along with access holes in the TSBs for lifting in equipment/spares and casualty evacuation should an incident occur in the gallery. As it is proposed to use the space between the two bores in the C&C portal section for FFFS water tanks, pumps and ancillaries, access to that space will also be provided. It is proposed to have the floor of that space be at the same level as the under-deck gallery, this will allow step free access which will allow a more efficient use of the space.

14.1. Tunnel Invert

The design for the tunnel invert features an accessible underdeck gallery, within which MEP systems will be installed to provide ease of access for maintenance and inspection. MEP equipment is kept largely out of the cross passages to support a larger than standard 2m clear width for evacuation. Access to the tunnel invert is possible at either end of the tunnel bore (via the TSBs), where a dedicated plant room which supplies ventilation and other auxiliary systems to the space will provide a stairway into the invert. In addition to these locations, access between the invert and the tunnel bores will be provided at three intermediate locations along the tunnel’s length via dedicated cross passages, as seen in Figure 8 below. These access points are located approximately 1km from either end of the tunnel, and at the tunnel low point (for access to the in-tunnel sump).

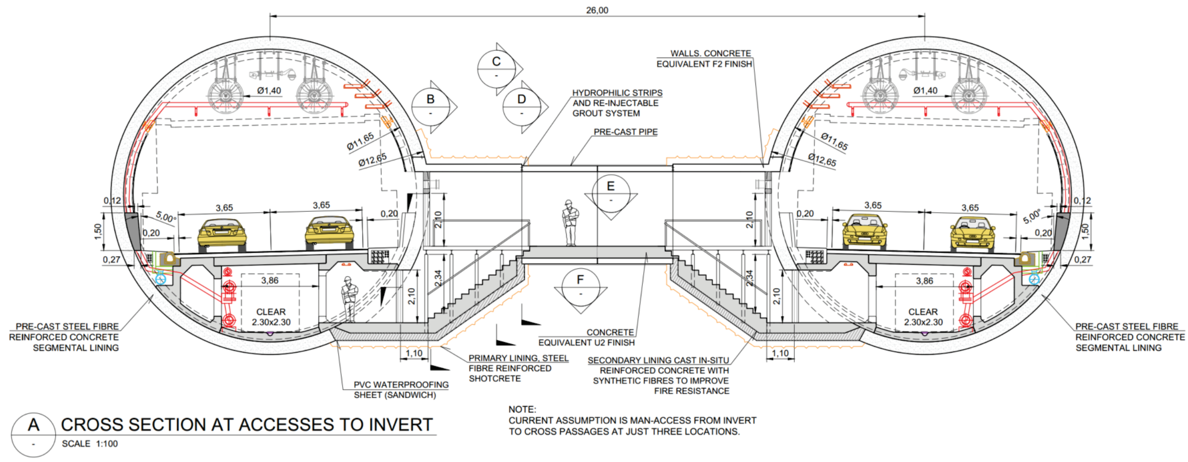

Figure 8 Intermediate Access to the Tunnel Invert

The space will have a dedicated walkway with a minimum unobstructed headroom and width of 2.3m each. A permanent mechanical ventilation system will be provided in addition to fire compartmentation from the traffic space and a dedicated vehicle for maintenance, inspection, and evacuation purposes. Safe secondary means of escape will be provided as outlined above and illustrated in Figure 8. Lighting will be provided along the length of the gallery, with communications panels located at either end of the invert as well as periodically along the invert.

The space will be classified as a confined space in line with the Confined Spaces Regulations. The internal useable area below the suspended road deck will be provided to ensure the operational risk does not exceed a classification as a low-medium risk confined space under the National Occupational Standards (EUSC01-EUSC02).

15. Tunnel Space Proofing and Geometry

15.0. Design rationale behind the proposed geometry and space proofing including in the tunnel, cross passages, plant rooms (where specified), tunnel services buildings, portals and on the tunnel approaches

The route will be comprised of a Dual 2-Lane All-Purpose Carriageway (D2AP) with the in tunnel carriageway widths complying to CD 127 as shown in Figure 11. The route will have a 70mph national speed limit. During contraflow operations for planned maintenance the speed limit will be reduced to 40 mph or as necessary.

The 3.285km A303 Stonehenge Tunnel comprises two bores, each carrying two lanes of traffic in unidirectional flow.

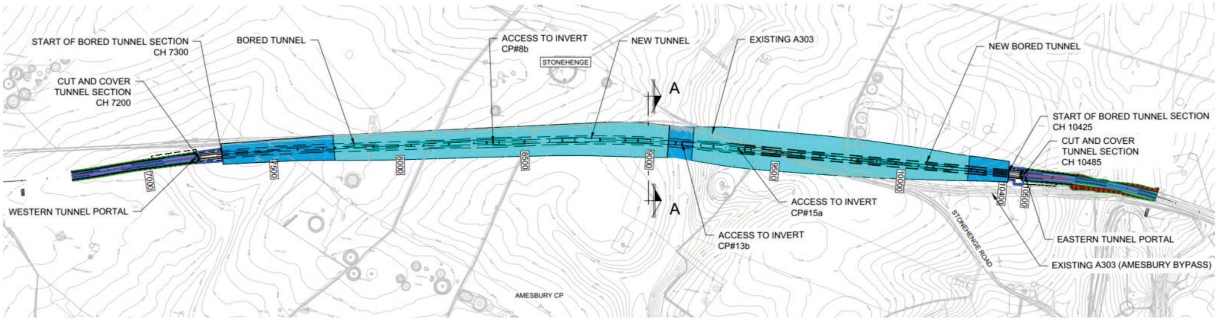

Figure 9 Tunnel Alignment

The A303 Stonehenge Tunnel comprises three distinct tunnel sections, as follows:

- CH 7+200 - CH 7+300: Western Portal: A 100m Cut & Cover tunnel providing the transition from the western approach road to the deeper bored tunnel portal.
- CH 7+300 – CH 10+420: Bored tunnel: A 3,120m tunnel constructed using a closed face Tunnel Boring Machine (TBM).
- CH 10+420 – CH 10+485: Eastern Portal: A 65m Cut & Cover tunnel providing the transition from the deeper TBM portal to the eastern approach road.

The twin tubes of the TBM bored tunnel will be connected by 22 Emergency Evacuation cross passage tunnels. Three additional cross passages are proposed to provide safe intermediate access between the main tunnel bore and the underdeck gallery.

An under-deck gallery configured with two pre-cast elements and a roof slab will provide space for the sump at the low point of each bore and the pumps. Other services such as the tunnel gravity drainage system, pumping pipe to the impound sump, FFFS main and valves, Fire hydrant main and busbars.

15.1. REDACTED

15.2. Emergency evacuation and cross-passage space proofing

Cross-passages are required to provide emergency evacuation to the non- incident bore. A provisional agreement has been secured for departure (ID 100850) for an increase in cross-passage spacing to 150m.

CD 352 specifies that cross passages shall be fitted with double swing self-closing doors, with each door leaf required to be a minimum 914mm. Team Badger's design is compliant with this requirement providing a 2000mm door. Figure 12 below shows section views at the door and centre of the evacuation cross passages.

The escape route through the cross passages has a pedestrian space 2.0 m x 2.3 m as per the latest requirements. With the space proofing requirements for both emergency evacuation and M&E provision, emergency evacuation cross passages have been sized at 3.34m ID plus 10cm for tolerances.

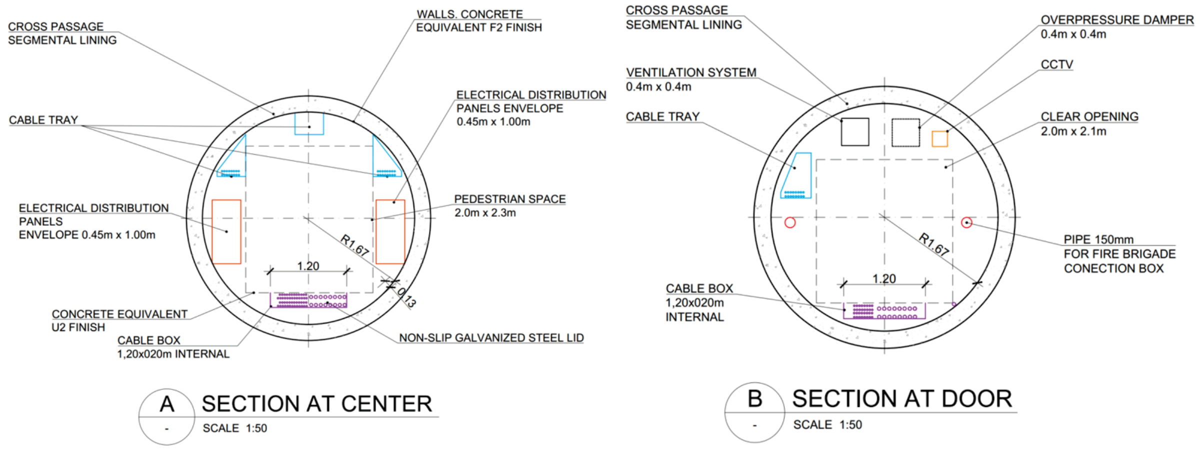

Figure 12 Sections of Evacuation Cross Passage at the centre (L) and the door (R)

15.3. Low-point sump space proofing

The low point sump volume was determined based on the CD 352 minimum sizing requirements. Combining this volume with the proposed design for the tunnel invert it was determined that sufficient space was available to house the low point sump and the pumping equipment.

15.4. Tunnel portals and approaches

The tunnel portals and approach structures were space proofed in accordance with the maintained headroom and widths provided through the bored tunnel as shown above in Figure 11.

16. Tunnel Design and Constraints

16.0. Summary of the geotechnical constraints considered in the design

The geology and ground water profile along the tunnel alignment will have a dominant influence on the design of the tunnel and construction. Both the method of construction and the spoil properties will be dependent on the conditions encountered.

Artificial ground and superficial deposits are only anticipated within the portal areas as thin cover and the majority of tunnel will be within the Seaford Chalk Formation. Within the Seaford Chalk Formation, the tunnel is anticipated to be primarily within the Cuckmere and Haven Brow Beds. The Seaford Chalk Formation is typically described as extremely weak to weak medium to high density white, slightly brown stained, chalk with occasional black speckling and with fractures infilled by white or brown silt. Sponge beds, hardgrounds, thin wispy marls and flint bands are also typically encountered. Additionally, localised phosphatic chalk deposits are encountered in the Seaford Chalk Formation between chainages 7600 and 9400m. Lateral variation in ground conditions along the tunnel alignment are anticipated due to variations in lithology, discontinuities (e.g., due to weathering or faulting) and regional dip.

16.1. Summary of the hydrogeological constraints considered in the design

Regional Hydrogeology

The Preferred Route traverses the Chalk Group bedrock outcrop which is classified by the Environment Agency (EA) as a Principal Aquifer, and in the study area, supports private and public water supply and base flow within rivers. The alluvium and head deposits present in the river valleys crossing the scheme are classified as Secondary A aquifers. These are capable of supporting water supplies at local scale and can form an important source of base flow to rivers.

Although the Chalk matrix is a highly porous medium, its intrinsic permeability is very low. The main aquifer groundwater flow characteristics are derived as a consequence of the fracture distribution, which provide secondary permeability for groundwater flow. The majority of the groundwater flows in the Chalk occurs in the upper layers of the Chalk where the natural seasonal water fluctuation has enhanced the fracture distribution. Topography also controls transmissivity in the area with high transmissivity occurring within valleys and decreasing towards the interfluves.

Regionally groundwater in the Chalk aquifer flows in a generally southerly direction with flow at high groundwater levels converging towards the River Till in the west of the study area and towards the River Avon in the east of the study area, creating a groundwater divide between the two rivers. The groundwater discharges naturally as baseflow to the Rivers Avon and Till.

Groundwater Levels

The preliminary GIR (pGIR) (Environmental Statement Appendix 10.1) shows groundwater monitoring data from ground investigation boreholes installed in 2001 near the tunnel section of the proposed mainline alignment covers the 2001-2006 period. Additional groundwater level monitoring boreholes were installed in 2017. Telemetry monitoring started in the additional groundwater level monitoring boreholes from April 2017 and is currently ongoing. Additional long-term groundwater level data is available from EA monitoring boreholes. The location of groundwater monitoring boreholes was presented in the pGIR.

Groundwater levels are discussed in a series of reports produced for submission as part of the Development Consent Order. These reports were produced to cover the Groundwater Pumping tests and the groundwater Risk Assessments.

- Stonehenge Area Pumping Test 2018 Interpretative Report (TR010025-8.22);
- Implications of 2018 Ground Investigations to the Groundwater Risk Assessment (TR010025-8.23);
- Groundwater Monitoring 2018-19 Conceptual Model Review (TR010025-8.24).

The Pumping Test Interpretative Report identified that seasonal fluctuations in the groundwater level tend to be less in the dry valleys (between 8m and 10m), than below the topographical divides (about 15m) as the storage capacity is usually greater beneath dry valley systems, than in the interfluve areas. Boreholes located close to the active rivers in the groundwater discharge regions show a limited seasonal fluctuation (about 2m).

16.2. Summary of the environmental factors considered in the design

Ecology

There are a number of important designated sites in the vicinity of the scheme, including the River Avon Special Area of Conservation (SAC), Salisbury Plain SAC and Special Protection Area (SPA), both of European importance, and the River Till Site of Special Scientific Interest (SSSI). The River Till SSSI also forms part of the River Avon SAC. Other important nearby sites include the Parsonage Down SSSI and National Nature Reserve (NNR) and the RSPB reserve at Normanton Down.

Water Environment

Groundwater is contained within the chalk which underlies the proposed scheme; the chalk is designated as a principal aquifer (a rock that readily allows the storage and flow of groundwater). The majority of the proposed scheme would-be built-in areas of no or very low probability of flooding
although localised areas, such as the River Till valley, have a higher risk of flooding.

Landscape & Land Use

The scheme is situated in an open rolling landscape, with small towns, villages, and farms within a pattern of ridgelines and valleys including the River Till valley. The land use is predominantly agricultural, with areas of residential and military properties and tourism. The existing
A303 is a busy transport link which has a significant adverse effect on the character and tranquillity of an otherwise largely rural landscape.

Noise & Vibration

Road traffic noise from the A303 affects the setting of the WHS, particularly in the vicinity of Stonehenge. The existing A303 passes close to residential properties at Amesbury and Winterbourne Stoke and the high existing noise levels along the A303 through Winterbourne Stoke are reflected in the designation of two ‘Noise Important Areas’ (areas identified by the government as being most exposed to noise) in the vicinity.

Air Quality

Air quality in the area around the scheme is considered to be good. This is confirmed by the fact that there are no Air Quality Management Areas (AQMAs) close to the proposed scheme, with the nearest being in Salisbury, approximately 6 miles (approximately 10 km) south of Amesbury. AQMAs are areas which the local authority has identified as requiring management to achieve desired air quality objectives. Notwithstanding this, air quality within Winterbourne Stoke and the northern edge of Amesbury is currently affected by traffic on the A303.

16.3. Summary of the heritage factors considered in the design

Team Badger’s design solution, in line with the DCO requirements limits the impact on the WHS and surrounding features.

The site currently contains numerous examples of Scheduled Monuments which all combine to form the main ‘presence’ of the World Heritage Site. Preserving their structure and setting is of paramount importance as the value of the site is derived from their intrinsic value.

To limit effects on the WHS, minimising land take for the temporary and permanent works is a focus of Team Badger’s solution. The tunnel works has significant impact on the land take in addition to that required by the tunnel alignment and at the portals. This is especially apparent west of the WHS, where multiple fields required for the temporary construction staging area. This site will house the project highways and tunnel construction compounds and personnel. It will also provide land for material storage, production plants and spoil treatment facilities.

17. Tunnel Construction

17.0. Justification of the proposed construction methodology for the tunnel and tunnel approaches

The following challenges have been considered in the selection of the most appropriate tunnelling technique;

- Health & Safety;
- Geology & Groundwater;
- Hydrogeology;
- Minimum disturbance of surface features above the tunnel;
- Minimum disruption to Environmental and Heritage influences;
- Final use of arisings.

A closed-face Tunnel Boring Machine (TBM) is considered to be the best option for tunnelling as it provides greater control on settlement and removes the necessity of dewatering during the main tunnel construction. Closed-face tunnelling also removes the exposure of worker and unsupported ground interface. This interface is considered one of the highest safety risks in tunnelling.

A major advantage of the closed-faced machine is that it significantly reduces face loss, compared to open-face techniques. In addition, a closed face machine can navigate water bearing strata without the need for dewatering. Based on the hydrogeological model, the TBM can be expected to navigate both dry and water bearing chalk. The length of tunnel under water or partially under water will be dependent on the high or low water tables that have been recorded between winter and summer seasons, therefore adding to the complexity in machine choice.

Therefore, a closed-face TBM will be used to construct the main reinforced concrete segmental primary lining. The tunnel drives will be serviced from a compound at the new Longbarrow Junction to the west outside of the WHS.

Further details on TBM selection and drive strategy can be found in the QS-3B submission.

The cover at the portal’s areas will be 0.5 diameter and may need to be grouted in advance before TBM launch. During the main bore construction, any ground treatment in advance of tunnelling is to be undertaken from inside the tunnel face as surface works to provide the bored tunnel are not permitted by the Scope.

The west and eastern TBM tunnel portals are located at chainage ch7+300m and ch10+420m respectively. The geometry of the tunnel portals is defined by the size of the tunnels, the required bore spacing, the cover required and the launching technique.

The TBMs will launch and complete their drives through a cast in situ concrete wall that will form part of the completed cut and cover tunnel. These will incorporate a soft eye where the reinforcement will be GRP to facilitate machine excavation.

17.1 REDACTED

17.2. REDACTED

17.3. Cut and cover tunnel sections

The cut and cover portals will be constructed as in situ reinforced concrete boxes, ground support during excavation will be provided by soil nailed walls which will be excavated in stages with individual walls no greater than 10m. The soil nails will form part of the permanent works and will resist the ground loads, while the in situ concrete box walls will resist the water loads and any surface surcharge loads. Once the box has been completed and reached minimum strength the structure can be backfilled back to required final ground level.

The TBM will be assembled and driven from the Western Portal, it will then be recovered at the East portal after the first drive and returned to the West for the second drive. The requirements of the TBM launch gantry and systems, as described in Badger's QS-3B submission, have determined the size of both cut and cover portal structures, which are larger than required by the final traffic flow. Given concerns around long term fixing inspection and durability it is not proposed to use false ceilings or similar to reduce the final size of the portals.

The outer retained cut in the west will be soil nailed, with a water retaining in situ concrete wall and invert for ~500m before the portal to ensure that there is no ground water ingress/flooding of the highway during extreme rainfall events. This is not a concern at the eastern portal as this structure is soil nailed with an in situ concrete wall which will be primarily cosmetic to achieve the finish required by the design vision. At both portals the lower 1.5m of the in situ concrete wall will serve as the impact barrier/VRS.

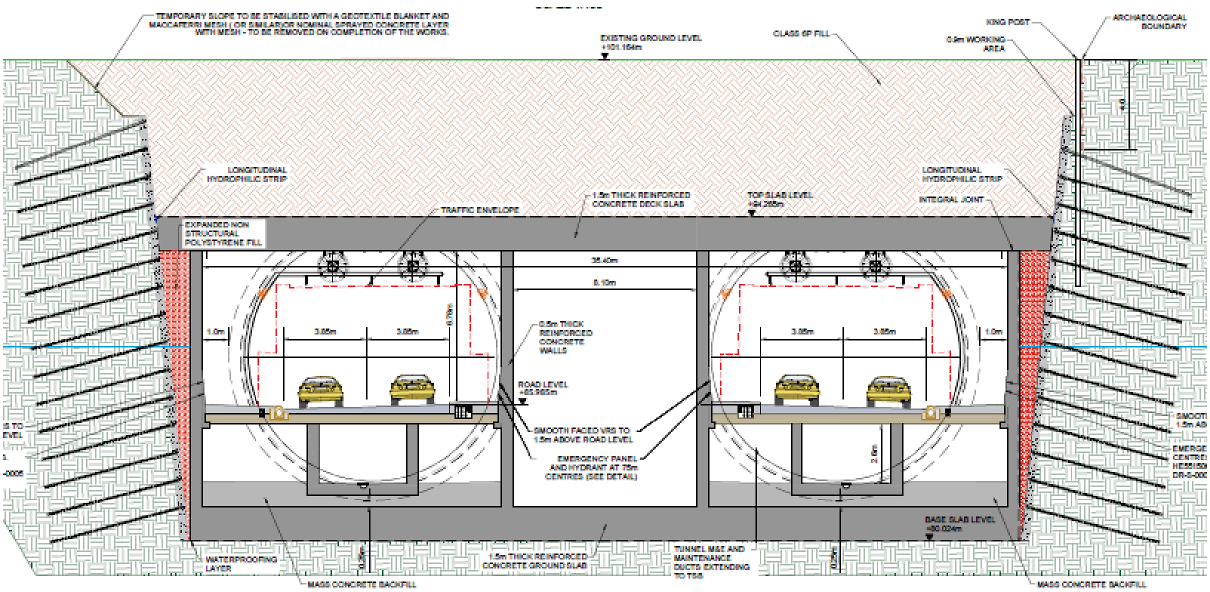

Figure 15 Section of Western Tunnel Cut & Cover at Bored Tunnel (CH.7300.00)

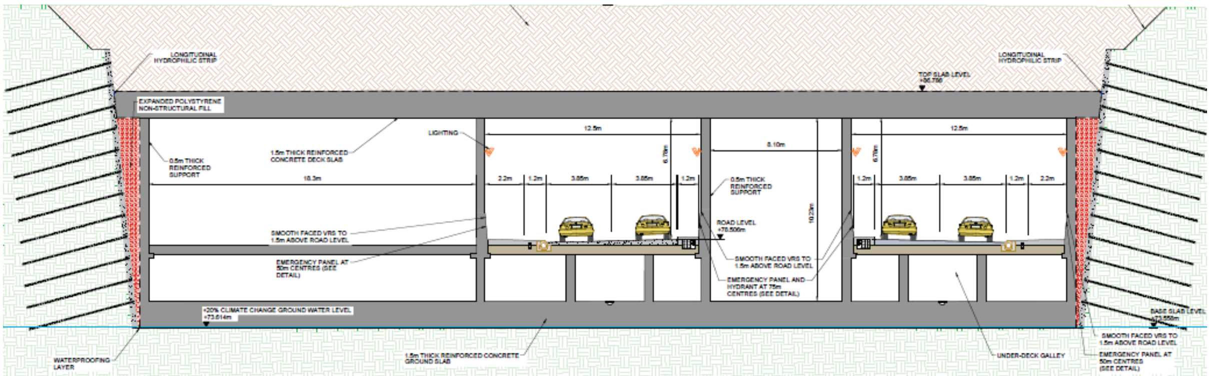

Figure 16 Section View of Eastern TSB and Carriageway (CH.10460.00)

18. References

[1] European Commission (2004). Directive No. 2004/54/EC of the European Parliament and the Council on the Minimum Safety Requirements for Tunnels in the Trans-European Road Network.

[2] Legislation – UK (2009). The Road Tunnel Safety (Amendment) Regulations 2009

[3] [Online]. Available: https://www.hse.gov.uk/pubns/priced/eh40.pdf. [Accessed 28 7 2020].

[4] [Online]. Available: https://naei.beis.gov.uk/data/ef-transport. [Accessed 8 12 2020].

[5] PIARC, "Road Tunnels: Vehicle Emissions and Air Demand for Ventilation," 2019.

[6] ASTRA, "Ventilation des tunnels routiers - Choix du système, dimensionnement et équipement," 2008.