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Immersed Tube Tunnel Corridor C2 Report

Grant Thornton

TRIBAL

August 2007

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Version History

Version No.	Date	Change Details	Author	Approver
1	10/08/07	1st Draft	AO/BC/CD	IWD
2	5/09/07	2nd Draft	AO/BC/CD	IWD
3				
4				
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1 C2 Corridor Proposal

1.1 INTRODUCTION

This report outlines the alternative option of an immersed tube tunnel in Corridor C in addition to the bored option taken forward to the STAG Part 2 Appraisal, detailing the type and nature of the proposed construction methodology. It should be noted that since the STAG Part 2 Appraisal, the EU Road Tunnel Safety Regulations 2007 which was in the form of a consultation draft has come into force. This proposed design incorporates the requirements of the regulations.

Where appropriate the associated drawing number has been included at the start of each section.

It is recognised that the development of network linkages for the new crossing option will require significant detailed study of a variety of options and will necessitate detailed traffic, economic and environmental appraisal to ensure the optimum solution is developed. This level of detail is outwith the scope of this study, however to date an overview of options has been undertaken in order to confirm feasibility and explore key issues and likely costs.

In addition the operational characteristics of a replacement crossing will have an impact on the junction layouts and any associated network improvements which would be required.

Finally, a detailed appraisal of the environmental impacts has been undertaken to the same level as the previous STAG 2 appraisal report.

2 Immersed Tube Tunnel – Crossing C2

2.1 DETAILED TUNNEL DESIGN

2.1.1 Introduction (drawing number 49550/T/TC2/01)

The immersed tube tunnel on Corridor C is a uni-directional twin tube tunnel approximately 6.15 km long with ventilation stations located on both banks of the Forth. The southern portal and toll plaza are located immediately to the south of the M9 adjacent to the disused Craigton Quarry. The proposal involves an open cutting to accommodate the toll plaza, with retaining walls forming the approach ramp to the tunnel portal at Chainage 2325. A mined sprayed concrete lined (SCL) tunnel is proposed from the southern portal until Chainage 5150 near Abercorn Point on the southern bank of the Forth. A short ventilation tunnel branches off from the main alignment at approximate Chainage 4700 to the ventilation station which is located near the shore to the south of Wester Shore Wood. At Abercorn Point, a cut and cover tunnel is proposed for approximately 600m in the tidal zone to provide a transition and interface between the land based mined tunnel and the immersed tube tunnel under the deep channel of the Forth. The northern landfall is immediately to the west of Rosyth Dockyard in the former RD57 dry dock site at Chainage 8175 where a short cut and cover tunnel provides a transition between the immersed tube tunnel and the tunnel portal at Chainage 8475. A ventilation station is located adjacent to the portal. This area is also designated for use as a casting basin for the immersed tube units during construction. A retained cut approach ramp to the portal is required for approximately 350 metres with the approach road in open cutting moving northwards. The alignment and profile are shown on Drawing No. T/BC2/01.

2.1.2 Tunnel Cross Section (drawing number 49550/T/BC2/02)

The cross section of the tunnel is defined primarily by the type of tunnelling technique employed. The tunnel is designed to Dual 2 Motorway Standard with two 3.65 metre traffic lanes but does not include a hard shoulder. The extremely high costs associated with the provision of hard shoulders means that there are few examples of continuous emergency stopping lanes in tunnels. A one metre wide verge is required on each side of the carriageway and when combined with a narrow hard strip provides sufficient width to allow for traffic to pass a stranded vehicle (or provide access for emergency vehicles) should an incident occur.

Emergency walkways are required on both sides of the carriageway to enable users to move freely along the tunnel in order to reach a place of relative safety in the event of an incident. Unfenced walkways on the verges are raised 75 millimetres from the carriageway. Headroom standards require that an additional clearance of 0.25 metres is maintained above the vehicle envelope of 5.03 metres to provide protection to ‘soft’ equipment and services from high vehicles.

The cost of tunnels generally increases with the cross sectional area. It is therefore important to optimise the cross sectional area to include all necessary functional and safety provisions.

The cross section of an immersed tube tunnel is similar to that of a cut and cover tunnel because the shape can be fabricated to suit the particular requirements of each individual tunnel. The cross section of a SCL tunnel is different, however the method of excavation means that there is significant flexibility in the shape that can be achieved to suit the required traffic envelope and services. In this case, the cut and cover tunnel will be constructed in situ to provide a transition between the shapes of the immersed and mined tunnels and enable continuation of the ventilation and other services.

There is a requirement for cross passages between the two SCL tunnel bores to provide an emergency escape route for tunnel users in the event of an incident. This should be readily achievable as the anticipated ground conditions on the southern shore are suitable for the construction of such cross bores. In the immersed tube tunnel, the units are divided into different cells, used for traffic and services and for ballast purposes. Emergency escape routes are easily incorporated into the design of the units through fire doors in the internal walls. It should be noted that the cross section of a cut and cover tunnel is similar to an immersed tube where the profile can be defined to suit requirements.

Figure 2.1 below shows a typical cross section for a mined SCL tunnel. Figure 2.2 shows a typical cross section of an immersed tube tunnel.

Figure 2.1 – Typical Cross Section for a Mined SCL Tunnel.

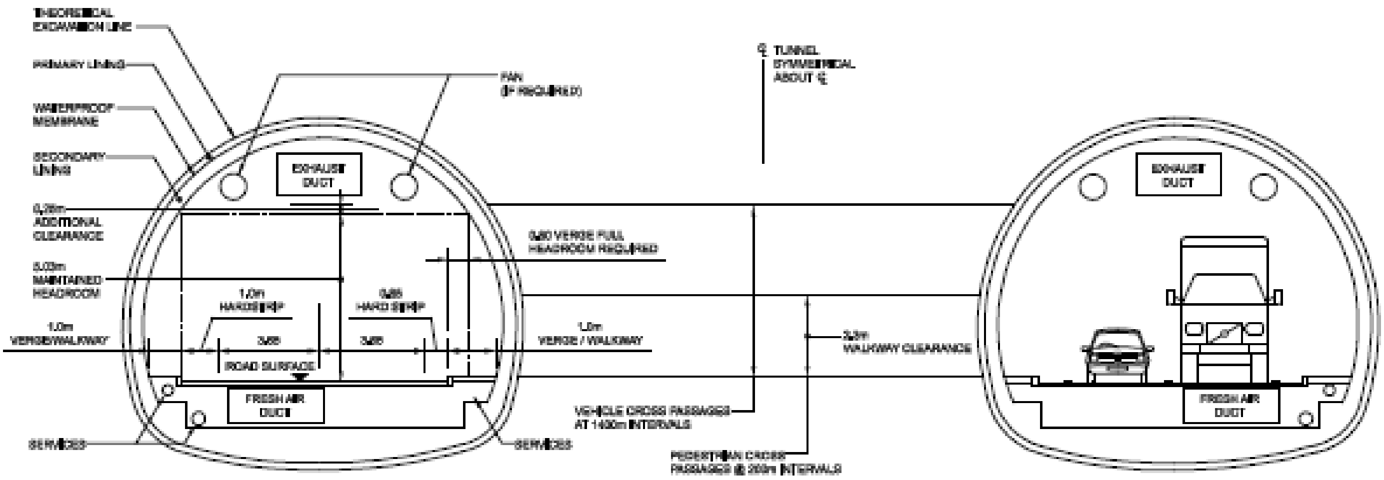
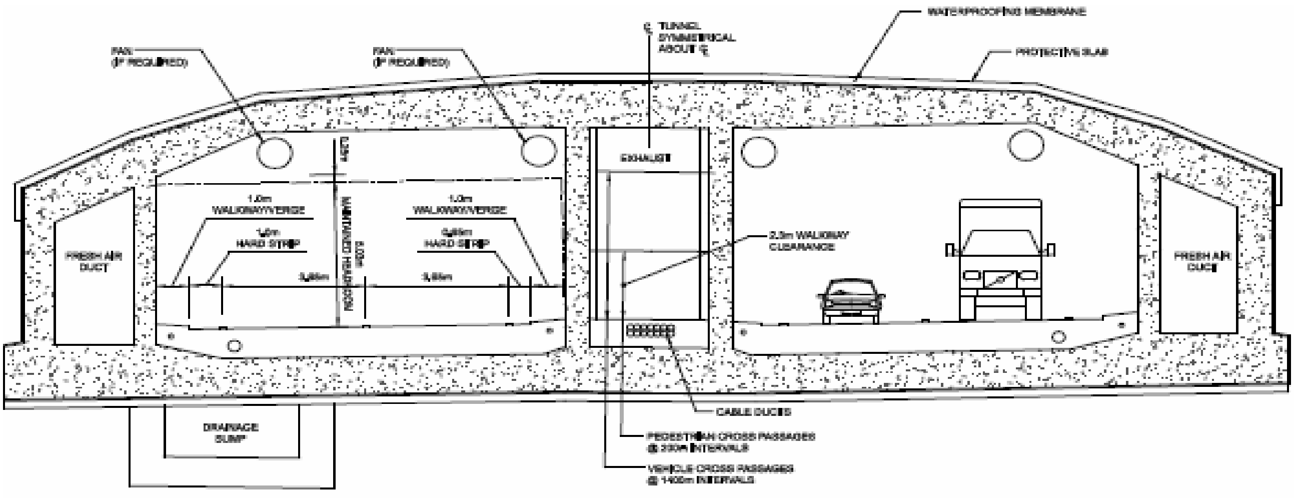


Figure 2.2 – Typical Cross Section for an Immersed Tube Tunnel



2.1.3 Alignment (drawing number 49550/T/BC2/01)

The horizontal alignment of the tunnel is constrained by a number of factors including but not limited to the location of the portals (and toll plaza on the south side), the need for ventilation stations on both shorelines and the required connections to the highway network and their performance against the objectives of the Forth Replacement Crossing Study.

The alignment is driven by the use of an immersed tube as the proposed construction technique. With this in mind, it was essential for the landfall on both banks of the Firth to avoid environmentally sensitive areas. The alignment was chosen to run immediately to the east of the areas designated as SPA, SSSI and RAMSAR. This corresponds to landfall adjacent to the Rosyth Dockyard on the north which was also identified as a suitable on-line casting basin for the immersed tube units. The southern landfall is at Abercorn Point.

It was recognised that large construction compounds are required at the portal locations on the north and south near Rosyth Dockyard and Craigton Quarry respectively, and that sufficient space and available access would be required.

The northern portal is located immediately to the west of Rosyth Dockyard in the former RD57 dry dock site with an approach ramp linking the tunnel to the A985 and to Junction 2 of the M90 further to the north-east. The northern ventilation station is located near the portal to extract the polluted air near the tunnel exit.

It was concluded that the southern portal and toll plaza should face east to achieve better connections with the highway network. The northern side of the M9 was considered but the gradient of the tunnel in this configuration was prohibitive and with the proximity of Duntarvie Castle, there was insufficient space for the toll plaza and the highway connections. The chosen location is directly to the south of the M9 adjacent to the disused Craigton Quarry. The southern ventilation station is located on the southern bank of the Forth to the south of Wester Shore Wood.

The vertical alignment is derived from maintaining a minimum of three metres of cover above the immersed tube tunnel under the Forth. The depth of the Firth and the need to rise to make the highway network connections mean that the gradient is maintained at a maximum of three per cent on each shoreline, which is the recommended maximum gradient for road tunnels that form part of the Trans-European Road Network. As mentioned above, the preliminary design considered locating the southern portal and toll plaza on the northern side of the M9, however the gradient of the tunnel in this configuration was excessive and given the location of Duntarvie Castle, there was insufficient space for the toll plaza and the highway connections.

2.1.4 Construction and Ventilation Shaft Sites (drawing number 49550/T/GC2/01)

To minimise disruption and land take, ventilation stations have been located at the same sites as the proposed construction compounds for the immersed tube/cut and cover works which are near each shoreline. A further construction compound is located at the southern portal where permanent above ground structures are required.

The northern portal is located at the northern landfall immediately to the west of the Rosyth Dockyard in the former RD57 dry dock site. This area is also the proposed fabrication site for the immersed tube tunnel units. The site has berthing facilities and a significant adjacent landholding. The Fife Structure Plan 2002 (Approved) & 2006-2026 (under consideration by Scottish Ministers) has outlined plans for this site, however it also states that if the land is required for the construction and operation of a new Forth Crossing, then it would be safeguarded. This site is 330m by 660m and is believed to provide sufficient space for an on-line casting basin for units which would be up to 35m wide and 120m in length.

Rosyth Dockyard could also be considered as a suitable fabrication site for the units as there are a number of dry docks currently used for ship refitting that would only require minor modification. The portal area also forms an ideal site for the northern ventilation station. A fully transverse ventilation system has been assumed for this tunnel in accordance with Clause 2.9 of Annex I of the Road Tunnel Safety Regulations 2007. Therefore it is assumed that a vent station is required at the northern portal to provide fresh air supply and removal of polluted air.

The landfall construction compound on the southern shore is situated south of Wester Shore Wood. It is approximately 500m by 600m and is reasonably level between 30-40m AOD. A new access road is required from the construction site to the local road which joins up to the A904. The permanent ventilation structure can be located on this site (combined with an underground vent adit tunnel from the mainline) and the adjacent wooded area may be used to reduce the visual impact of this structure. A possible alternative is to construct a ventilation shaft on the alignment of the mainline tunnel in the open field south of Abercorn Cottages, however this means further disruption with another worksite required and the permanent ventilation station located in a designated landscape area.

Considering the extremely steep topography between the construction compound and the tidal area at Abercorn Point where the cut and cover works need to be carried out, significant earthworks may be required to construct an access track down to the tidal zone. The access track needs to traverse a heavily wooded, sloped area containing the Midhope Burn valley at approximately the location of the existing Nethermill Bridge. It may be possible to carry out some of the excavation works in the tidal zone by dredging from the Firth side and the spoil transported away by barge rather than by land.

It should be noted that this construction site is immediately adjacent to the SPA, SSSI and RAMSAR designated shoreline of Wester Shore Wood. The access track and cut and cover works in the tidal zone are in Ancient Woodlands and Designated Landscape areas of Deer Park. The works would cause severe temporary disruption to the whole Abercorn Point area.

The proposed southern portal construction site is adjacent to the disused Craigton Quarry. The site is bounded on the northern side by the M9 and on the southern perimeter by the railway line. The approximate dimensions of the site are 780m by 300m. Access to the site could be from a point on Beatlie Road. Alternative methods of spoil disposal using Union Canal or the adjacent railway line are feasible and disused quarries in the surrounding area could be backfilled or used as temporary stockpile sites.

2.2 GEOTECHNICAL INFORMATION

Previous studies have focussed on data collection in Corridor D where a bridge option has been promoted. As would be expected the studies are useful in understanding the context but provide no information with respect to the specific constructability and risk issues related to tunnelling.

For this proposed tunnel corridor there is no detailed site specific or generic data that informs the designers of hazards to be avoided in setting tunnel alignments. Further extensive site investigations would be needed to address specific perceived risks.

Investigation of the limited geotechnical data available indicates that the tunnel must negotiate limestone, shales, sandstones and coal measures on the southern bank of the Forth. It is likely to encounter soft alluvial sediments and glacial deposits on the bed of the Firth.

There is also a possibility of encountering hard dolerite rock. Although there are no specific outcrops in the Firth on this corridor to indicate the presence of dolerite, the dolerite under the nearby Blackness castle indicates that outcrops are in the general vicinity. There is very little information available regarding the rockhead contours under the Forth so an indicative geotechnical cross section has been developed with a conjectured rockhead profile. This is shown in Figure 2.3.

There is a significant risk of encountering old mine workings in the area to the south of Wester Shore Wood where the ventilation station and construction compound are proposed.

Sandstone, shale and coal are generally suitable materials for mining, as this technique is suited to competent rock that can support itself until the excavation pass is complete and the lining is installed but is also not too hard so that it can be readily excavated by roadheader or similar means. Where harder rock is encountered, for example limestone or dolerite, drill and blast techniques may be required.

Limited geotechnical information available on the south side of the Forth suggests that the rockhead is shallow. The topography of the area reinforces this with steep cliff-like shorelines rising from the water. Mining generally requires a minimum of 5-10m of rock cover depending on the quality of the rock, amount of overburden and the size of the excavation, so with the possible exception of the portal where the tunnel approaches the surface, this cover should be readily achieved.

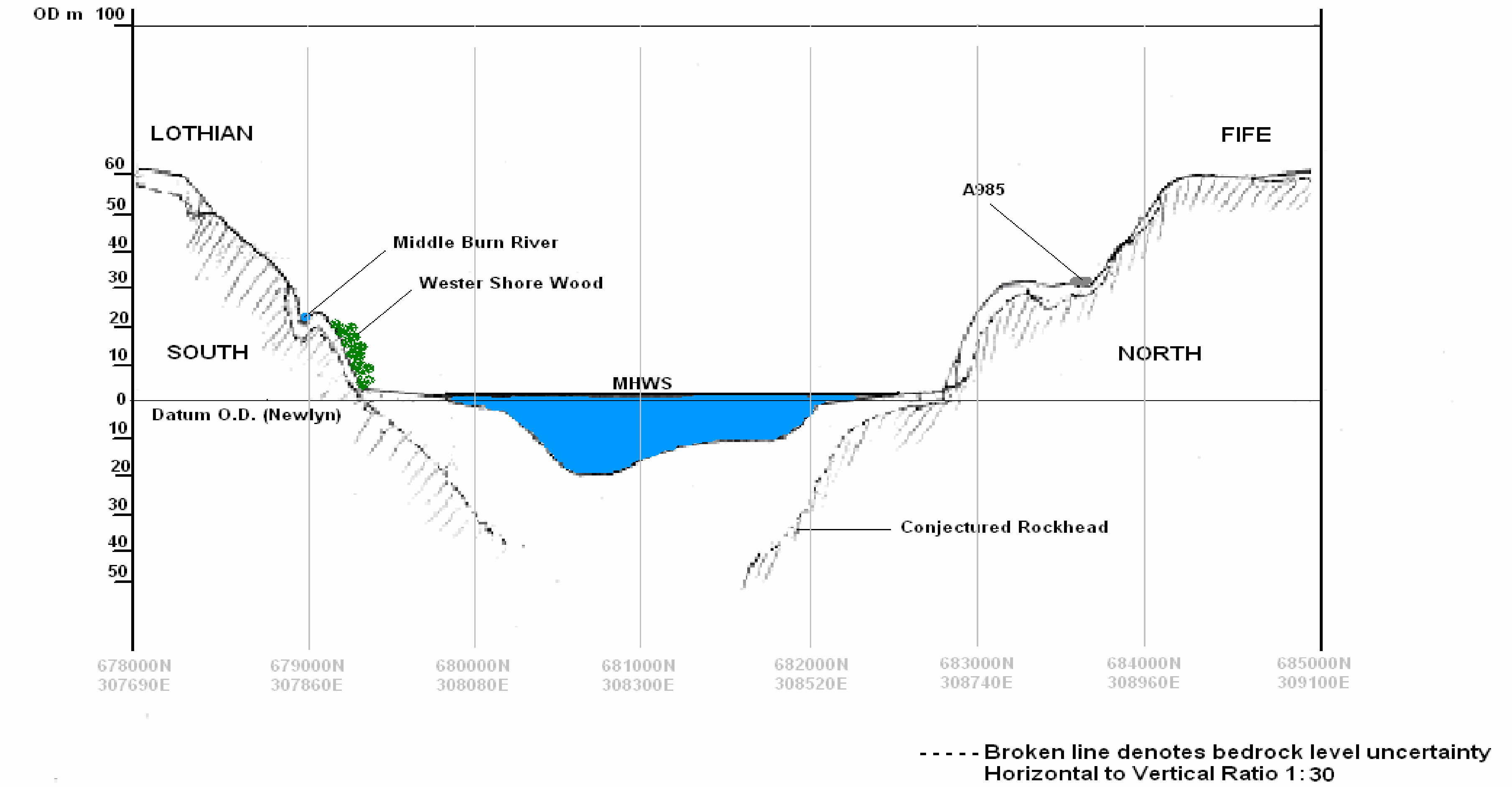


Figure 2.3 – Corridor C - Indicative Geological Cross Section

2.3 TUNNEL CONSTRUCTION ISSUES

There is little or no geotechnical information available along the route of the tunnel. Interpolation of limited existing geotechnical data has therefore been necessary. The risks associated with each tunnelling technique have been speculated based on both previous experience and suggested trends and observations in the available geotechnical data.

It is proposed that the approach tunnel on the southern shore is constructed using the SCL method. As described in Appendix B of Report 4, this is an open face method that relies on the mined strata being sufficiently stable in the short term to allow temporary support to be installed with only a limited amount of advance ground stabilisation. Typically, spiles (long steel or fibre glass dowels) are drilled into the face or crown to stabilise the ground and rock bolts installed radially to mobilise the strength of the ground in the short term. These ground support measures would be used in combination with sprayed concrete applied to exposed cut surfaces and in greater thickness radially to provide a temporary structural shell. The structure would then be completed by installing a waterproof membrane and an in situ structural concrete lining.

The use of the SCL method depends on the strata being sufficiently stable to allow a largely unsupported excavation. Threats to the stability of the excavation include significant and rapid changes in ground conditions and the presence of flowing water or water under pressure. It is suggested that faults may be present on the southern shore and doleritic intrusions are apparent in the general vicinity. The SCL method provides a flexible and cost effective way of managing the creation of the underground space and a better means of mining through dolerite than by the use of a Tunnel Boring Machine(TBM) where drill and blast excavation may be required.

Construction of the immersed tube section of the tunnel provides a number of challenges. A suitable casting basin has been identified adjacent to the Rosyth Dockyard in the former RD57 dry dock site. This site was initially constructed to refit the U.K.'s Trident nuclear submarines. The site has berthing facilities and a substantial adjacent landholding. It forms an ideal area for the cut and cover approach tunnel and ventilation station as significant dredging and excavation works would be required to accommodate the casting basin and a construction compound already established. Following completion of the units, the area would be redeveloped to form the approach tunnel, portal and ventilation station. An on-line casting basin such as this one has been regularly and successfully used in the construction of immersed tube tunnels to date. This area is designated as a protected area in the Admiralty Charts, with entry by unauthorised vessels prohibited. However, it is assumed that since the closure of the MoD naval base, this restriction is no longer applicable.

Immersed tube tunnel construction requires significant disturbance of the sediments along and adjacent to any alignment. This crossing would require the dredging of a channel approximately 13 metres deep by 40 metres wide at its deepest point in the bed of the Firth. The side slopes of the excavation would extend by approximately 40 metres on each side. This equates to approximately 2.25 million cubic metres of soil to be dredged and given that this material would be unsuitable for use as backfill to the units, it would need to be disposed most likely at sea. As the Forth has a long history of industrial and commercial operations upstream of the crossing there may be trapped pollutants within the existing upper sediments. There could be environmental implications downstream from the release of these pollutants and contaminated sediments. If the dredged spoil is disposed on land, the contaminated spoil would need to be treated prior to disposal.

There is only very limited geotechnical information available but interpolation of this data suggests that there is a possibility of encountering hard dolerite rock on the bed of the Firth. Although there are no specific outcrops in the Firth on this corridor to indicate its presence, the dolerite under the nearby Blackness Castle indicates that outcrops are in the general vicinity. A comprehensive site investigation is required so that the final alignment can avoid areas of hard rock as much as possible. Where this is not possible, the rock would need to be dredged by drill and blast techniques to create the required bed profile for the immersed tube. There is also a significant risk of encountering old mine workings in the area to the south of Wester Shore Wood where the ventilation station and construction compound is situated. Where mine workings affect the stability of the ground or present a risk to the infrastructure, they would need to be grouted prior to construction.

The tunnel alignment passes through an area near the southern shoreline that is designated as a “foul area” in the Admiralty Charts. Vessels are warned not to anchor or fish in this area owing to the existence of obstructions. Detailed investigations are required to investigate the extent and form of the obstructions and any remediation measures required.

At the southern landfall, there is extremely steep topography between the construction compound and the tidal area at Abercorn Point where the cut and cover works need to be carried out. Significant earthworks may be required to construct an access track down to the tidal zone. The access track needs to traverse a heavily wooded, sloped area containing the Midhope Burn valley at approximately the location of the existing Nethermill Bridge. It may be possible to carry out some of the excavation works in the tidal zone by dredging from the Firth side and the spoil transported away by barge rather than by land. Nevertheless, significant disruption is inevitable.

It should be noted that this construction site is immediately adjacent to the SPA, SSSI and RAMSAR designated shoreline of Wester Shore Wood. The access track and cut and cover works in the tidal zone are in Ancient Woodlands and Designated Landscape areas of Deer Park. The works would cause severe temporary disruption to the whole Abercorn Point area.

Construction of the ventilation station involves a separate underground adit tunnel branching from the mainline tunnel. Construction of intersections in mined tunnels is dependent on the geology. This is not anticipated to be problematic in this area, however the vent tunnel needs to cross under the Midhope Burn. Mining under a waterway presents significant challenges, particularly considering the limited cover available due to the low lying extent of the valley. A possible alternative is to construct a conventional shaft on the alignment of the mainline tunnel in the open field south of Abercorn Cottages, however this option means disruption to another worksite and the location of a permanent ventilation structure in a designated landscape area.

Marine cut and cover works or cofferdams are required in the tidal zones of the Forth to interface with the immersed tube tunnel. The cut and cover tunnel section is constructed in a dry excavation within the cofferdam with the immersed tube butted and sealed against the leading face of the cofferdam. This area is also used to construct a transition section to interface with the mined tunnel on the south bank. A roadheader can be received or launched from this area through the cliff face at Abercorn Point. This may involve mining under the water table for short length until the alignment rises sufficiently. Mining under the water table may be problematic, however it is anticipated that the rock would be competent enough at this depth to allow safe mining to proceed. Forepoling or pre-grouting could be used as potential ground treatment measures to compensate for the presence of groundwater if required.

Excavation and transport of significant amounts of spoil may impact on the area surrounding the portals and landfall worksites. It is expected that approximately 750,000 cubic metres of spoil will be generated on the south side of the crossing. This is equivalent to approximately 55,000 truck movements if all spoil is removed by road which is the most likely option. Some of the spoil excavated from the SCL tunnel on the southern side could be used as backfill for the immersed tube tunnel. This approach has been successfully used in previous projects.

The BP Kinneil to Dalmeny oil pipeline crosses the proposed alignment to the north of the M9. The tunnel is anticipated to be approximately 40m underground in competent rock at the crossover point and provided vibration and settlement are controlled, underground construction of the tunnel should not adversely affect the pipeline.

2.4 INCIDENT MANAGEMENT

The management of an incident in the tunnel is controlled by the Tunnel Control Centre (TCC). This is likely to be located within the toll plaza complex. The centre is responsible for monitoring the tunnel at all times, traffic management, traffic information communication and signal control. The automatic incident detection system, CCTV Alert, is used to feed information to the operator in the TCC identifying the nature, cause and severity of incidents that occur. CCTV Alert can automatically detect a vehicle stopping in the tunnel in the event of a breakdown or accident and it also detects fire. Typical response time should be approximately five minutes but will depend upon its location within a tunnel of this length.

It is noted that the ability to provide vehicular cross passages within the immersed tube tunnel would need to be confirmed by detailed analysis. An opening in the central walls large enough to allow vehicular movements may not be feasible for structural reasons.

2.4.1 Breakdowns

As per normal practice in tunnels of this length, recovery vehicles are located at each side of the tunnel adjacent to the portal and once the incident is detected by the TCC, a recovery vehicle is dispatched to the traffic incident. The driver of the broken down vehicle is instructed via radio or public announcement to remain in their vehicle pending recovery. Traffic in the tunnel should be able to negotiate the stranded vehicle without causing serious congestion behind. It is however noted that the reduced width of the cross section would require vehicles to pull onto the verge.

2.4.2 Traffic Accidents

A minor accident is managed in the same way as a breakdown, however in this instance two or more recovery vehicles may need to be dispatched to deal with the stricken vehicles. In the event of a serious accident where debris blocks the tunnel and traffic backs up behind the incident, a recovery vehicle from the opposite end of the tunnel can use the vehicle cross over outside the portal to enter the incident tunnel. The emergency services enter in a similar manner. Variable Message Signs (VMS) and lane closure indicators are activated by the TCC to warn tunnel users about an incident and if necessary, the incident tunnel is closed and alternative traffic management plans are implemented. These could include the introduction of a temporary contra-flow system in the non-incident tube or complete diversion elsewhere on the trunk road network in this instance.

2.4.3 Fire

Access for the emergency services is provided in number of ways depending on the circumstances. They can drive down the affected tube directly to the incident if there is no traffic blocking the route. Alternatively, if the route is blocked, the non-affected tunnel can be closed to traffic and the emergency services can use the crossovers at each portal to access the non-affected tunnel. If vehicular access is not possible or preferable, emergency access points are located in the ventilation shafts on each shoreline, which provide access on foot via stairs and lifts.

2.5 EVACUATION PROCEDURES

Evacuation of tunnel users in an emergency will be carried out via the pedestrian cross passages and the non-affected tube. Pedestrian cross passages are provided at 200 metre intervals. Emergency walkways are raised above the carriageway by only 75mm so that a wheelchair can easily negotiate the kerb and continue into the cross passage. Once through to the non-affected tube, the traffic may still be running unaffected by the incident in the other tube. Consequently full width offside walkways are provided so that people can safely continue along the non-affected tunnel away from the incident and prevent a back up of people through the cross passages. In the case of the immersed tube tunnel, it may be possible to provide an escape route via the central cell, so that users do not need to use the non-incident tube. However, this is accessed in the same way via fire proof doors in the central walls and the same procedure applies. Similarly, the cut and cover tunnel has doors through the central walls between the two traffic spaces.

Emergency exits will be located in the ventilation shafts on each shoreline. Stairs and lifts will be provided so that a suitable escape route is available for mobility impaired people.

Requirements for the ventilation system are such that ventilation will be provided in the cross passages and that positive pressure or other means of excluding smoke from the cross passages and non-affected tube will be provided. The ventilation system also must provide a means of extracting smoke in the event of a fire, so movement of smoke and fire gases in the tunnel near the incident should be minimised or eliminated by the ventilation system allowing clear unrestricted means of escape for users in the vicinity of the incident.

2.6 INTERVENTION PROCEDURES

Access for the emergency services will be provided in number of ways depending on the circumstances.

The first scenario is they can drive down the affected tube directly to the incident if there is no traffic blocking the route. Alternatively, if the traffic is stopped behind the incident and the route is blocked, the non-affected tube can be closed to traffic and the emergency services can use the crossovers at each portal to access the non-affected tube. From here the emergency vehicle can stop at the nearest pedestrian cross passage (at 200m intervals) to the incident and proceed on foot.

If vehicular access is not possible or preferable, emergency access points are located in the ventilation shafts on each shoreline, which provide access on foot via stairs and lifts. The emergency personnel can then continue on foot down the affected tunnel directly to the incident. Alternatively they can proceed down the non-affected tunnel and access the incident via the nearest pedestrian cross passage. Initially the traffic may still be running in the non-incident tube, so full width walkways are provided on both sides of the carriageway. They are raised above the carriageway by only 75mm so that a wheeled trolley bed can easily negotiate the kerb and continue into the cross passage.

2.7 HAZARDOUS GOODS IN TUNNELS

The passage of hazardous goods through the tunnel is subject to restrictions as outlined in the British Toll Tunnels Dangerous Traffic List of Restrictions booklet which is currently in its thirteenth edition. The basis for this list is the restructured 2005 European Agreement concerning the international Carriage of Dangerous Goods by Road, (ADR) as amended by the Report of the Committee of Experts meeting in December 2004.

The classes of dangerous goods according to the ADR are the following:

Class 1: Explosive substances and articles;

Class 2: Gases, compressed, liquefied or refrigerant;

Class 3: Flammable liquids;

Class 4.1: Flammable solids, self-reactive substances and solid desensitised explosives;

Class 4.2: Substances liable to spontaneous combustion;

Class 4.3: Substances which in contact with water emit flammable gases;

Class 5.1: Oxidising substances;

Class 5.2: Organic peroxides;

Class 6.1: Toxic substances;

Class 6.2: Infectious substances;

Class 7: Radioactive material;

Class 8: Corrosive substances;

Class 9: Miscellaneous dangerous substances and articles.

Larger loads and tankers carrying hazardous goods are generally prohibited from road tunnels but permitted access will depend on the substance being carried. Some will be allowed access under escort. To gain approval for carriage of hazardous good through the tunnel, the consignor of any goods, substances or articles on the list of restrictions must submit to the Tunnel Manager a written declaration as to the nature and quantity of such goods. Similarly for empty petrol or other tankers, a declaration is required as to the nature of the substance last carried if it has not been cleaned since that loaded journey. Permission may be granted for passage through the tunnel at a prescribed off peak time when the tunnel can be closed to the public following notification to the public of the temporary tunnel closure.

2.8 CONSTRUCTION PROGRAMME

An example construction programme for the immersed tube tunnel is shown in Figure 2.4. The programme does not include the planning and design stages.

A number of general assumptions were required to enable the construction programme to be drafted. These are listed below:

- The geotechnical conditions encountered are as currently envisaged based on the limited data currently available. Therefore a mined SCL tunnel has been assumed from the southern portal to the shoreline where a short cut and cover tunnel provides a transition to the immersed tube tunnel under the Forth;

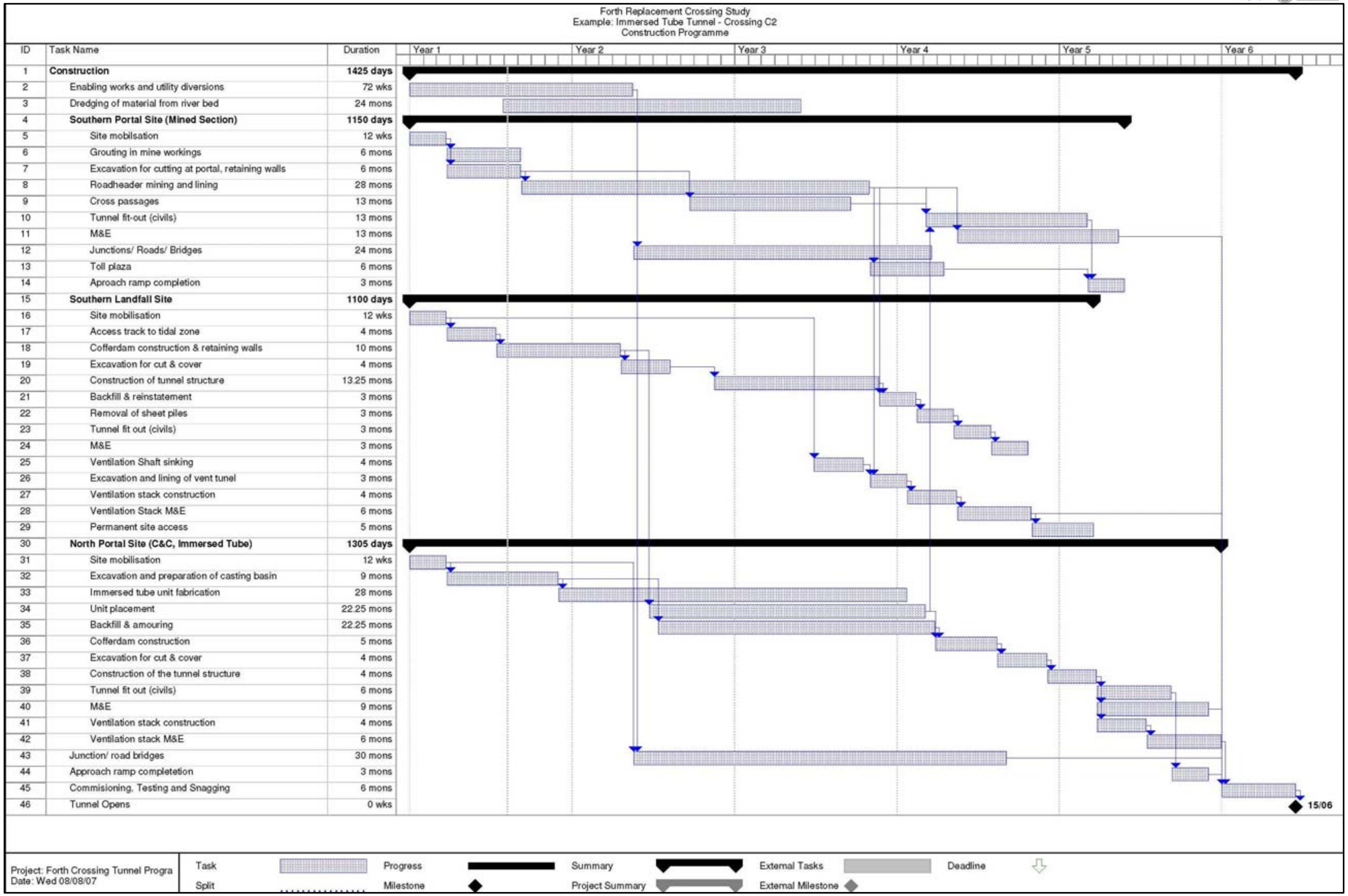


Figure 2.4 – An Example of a Possible Construction Programme for an Immersed Tube Tunnel

- Extraction of spoil from the SCL southern approach tunnel via the southern portal. All spoil disposed off site to within an approximate 20 mile radius of the site by road; and

- The programme assumes that construction commences from the three work sites simultaneously.

Excavation and preparation of the casting basin for the immersed tube units commences in parallel with dredging of the channel. Dredging of the river bed to form the required channel for the immersed tube units is a critical activity, however it is anticipated that there will be seasonal delays resulting from environmental or ecological mitigation, and also some minor delays for navigation reasons. These delays can be built into the programme as the placement of the units can proceed from the southern side before the channel is fully dredged to the north. In any case, preparation of the casting basin and fabrication of the units means there is a considerable lead-in time before placement of the units begins.

It is anticipated that fabrication of the immersed units will continue in parallel with the placement and backfilling of the previously constructed units. Only after completion of the immersed units can the cut and cover works and approach ramp on the northern side commence.

At the same time, construction activities commence at the southern ventilation shaft work site. Early work involves providing access to the tidal zone where some marine works are required in preparation for the interface with the immersed tube tunnel. The cut and cover works can progress in parallel. The ventilation shaft and adit tunnel commence later in the programme, as the vent tunnel cannot be excavated until completion of the mainline twin tunnels.

During this time, excavation of the cuttings at the southern portal and grouting of old mine workings commence to enable the tunnelling operations to get underway without delay. Underground tunnelling begins from the southern portal where roadheaders are launched down the two approach tunnels simultaneously towards the southern shoreline. An average advance rate of 3.5 metres per day has been assumed giving a total drive time of 28 months. Construction of the cross passages can commence in the SCL tunnels while excavation of the mainline is still underway.

Fit out of the civil works in the tunnel commences after completion of the cross passages in the SCL tunnel and placement of the immersed units. Installation of the M&E components can be carried out simultaneously behind the civils fit-out.

Commissioning and testing follows substantial completion of construction and is the last item before hand-over and opening to traffic.

2.9 NETWORK LINKAGES

2.9.1 Northern Side of the Firth of Forth

The tunnel would emerge at a position approximately 100 metres north of the existing RD57 site and approximately 3.3 kilometres west of the existing roundabout which forms the junction of the B980/A823/A823(M). The alignment of the road would bear in a north westerly direction to a point at which it would cross the A985. The road, from this point heads north east at a gradient of between 2 and 3 per cent. The existing railway line is in cutting at this location so would be bridged prior to the new junction. The existing roundabout would be amended to a new grade separated junction with the A823(M). It is likely that lane provision on the A823(M), will be increased to the west of Junction 2 of the M90 (Masterton junction).

Additionally, depending on the results of detailed traffic analysis, it is likely that the capacity of certain movements to/from the A823(M) and the M90 at Masterson will require improvement.

The new junction of the tunnel alignment and the A823(M) near Pitreavie can also be amended to provide connection to the proposed Rosyth Bypass if required.

2.9.2 Southern Side of the Firth of Forth

Due to the topography and gradient restrictions within the tunnel, it is necessary to extend the tunnel such that the exit will be located south of the M9, approximately 1 kilometre west of the B9080 at Winchburgh. A major new motorway junction would be required at this location to ensure free flowing traffic from the M9 gains access to the tunnel alignment. It is anticipated that the major movement would be between the tunnel and M9 Edinburgh, therefore the junction design will be required to reflect this major traffic flow.

The toll plaza and tunnel approach will be in cutting that gradually increases in depth to 20 metres at the tunnel entrance. The road gradient on approach to the tunnel will be one to two per cent.

It is acknowledged that there is the potential for a new motorway junction at Winchburgh to facilitate development in the area. Initial examination confirms that this can be accommodated within the new junction arrangement. This would also provide access from the tunnel alignment to the local road network.

To facilitate easy diversion from the existing Forth Road Bridge it is anticipated improvement works may be required at the existing Junction 1a on the M9 to enable movements to/from the M9 Spur towards the tunnel to be undertaken. Similarly, consideration will be required to remodel the junction of the new M9 Spur and the A90 at Dalmeny (currently under construction) to enable access to/from A90 Edinburgh.

3 Environment

3.1 INTRODUCTION

The following sections describe the likely environmental effects of the immersed tube option Tunnel C2 in relation to the nine environmental sub-objectives identified in the STAG methodology. The significance of environmental impacts have been assessed on a seven point scale from Major positive to Major negative and it should be noted that where impacts are referred to as "significant" this indicates that the level of impact is either Major or Moderate.

3.2 NOISE AND VIBRATION

3.2.1 Introduction

STAG recommends that the noise appraisal follows the approach set out in WebTAG Unit 3.3.2(1)[1]. The STAG appraisal considers operational noise only, and is based on changes in traffic flows. The appraisal aims to estimate the change in the population annoyed by noise for a do-minimum strategy compared with the proposed option. The approach is to estimate the total number of people exposed to different noise levels and, using the annoyance response relationship data provided in WebTAG, calculate the change in the number of people likely to be 'annoyed'.

As a further requirement of WebTAG, introduced in February 2006, an assessment of the noise impacts in monetary terms has also been undertaken. This approach relates the predicted noise change due to the scheme to a monetary valuation (based on 2002 property prices). A method for assessing vibration is not included within either WebTAG or STAG.

3.2.2 Key Issues

A number of properties and communities lie adjacent to the routes of the road network tie-ins associated with the Tunnel C2 alignment. These include residential and other sensitive properties. However, it is noted that a number of properties located close to the northern and southern bridgeheads of the existing Forth Road Bridge will already experience significant impacts from noise generated by north and south-bound traffic on the bridge.

The majority of new road network connections proposed south of the Firth of Forth are located away from communities; however, there are individual properties close to the proposed roads that may be affected by traffic generated noise. On the southern shore the road network tie-ins run primarily through agricultural land to the south of the M9 to the east of Craigton.

On the northern shore in Fife, the road network connections could impact on a number of communities and in particular the network connection for Option Tunnel C2 runs from close to the shoreline to the west of Rosyth Dockyard across field past Pattiesmuir to join the A823(M) to the south of Rosyth. Closure of the existing Forth

[1] WebTag 'Transport Analysis Guidance' Website: http://www.webtag.org.uk/ . Department for Transport. Update February 2007.

Road Bridge may also have the potential to affect a greater number of receptors in sub-urban and urban districts of Edinburgh and Dunfermline.

3.2.3 Appraisal Outcome

Construction noise varies considerably during any building project. Properties within 50 to 100m of such works can be disturbed. The character of construction noise varies during the project depending on the activities being undertaken. For changes to existing road infrastructure and construction of new over ground roads, initial phases can involve road breaking, earth moving followed by planing. These activities can produce high levels of noise and vibration but would be of limited duration.

Rolling and compaction can also be noisy but finishing phases of paving and signage erection tend to be low noise operations. Predicted construction noise is likely to exceed 75 $DB_{LAeq,12hr}$. Major negative short term impacts are therefore predicted to occur at locations in close proximity to construction works.

Traffic modelling (based on the Tunnel C1 alignment at this stage) indicates that once operational, this option would experience a significant increase in road traffic and consequently traffic related noise. Increases and decreases in traffic flows are predicted to occur across a large area and consequently a large number of receptors are likely to be affected, both positively where traffic flows are predicted to be reduced, and negatively where traffic flows are predicted to increase.

3.2.4 Summary

The traffic predictions indicate that operation of the route corridor C (Tunnel C2) option has the potential to cause significant changes in road traffic noise, not only on local routes, but also much further a field. From the traffic predictions, a number of existing roads in West Lothian, Falkirk, City of Edinburgh and Fife have been identified that will experience a change in traffic flow of:

- Less than -20%; and
- Greater than +25%.

In some areas reductions in traffic flows are predicted resulting in reduced noise levels, although overall, the Tunnel C2 option, in common with all other options, is considered to have significant negative impacts. Operational noise impacts would be experienced across a wide area. The magnitude of the impact is dependent on the proximity of the receptor to the source of noise, i.e. the closer the receptor to the source of noise, the greater the impact magnitude. Table 3.1 below summarises this assessment for Tunnel C2.

Table 3.1 - Summary of Assessment

Proposal	Overall Temporary Effects	Overall Permanent Effects
Tunnel C2	Minor to Major Negative	Minor to Major Negative

3.3 GLOBAL AND LOCAL AIR QUALITY

3.3.1 Introduction

The global and local air quality assessment consists of two parts, a strategic level assessment and a local level assessment. The strategic level assessment considers emissions of pollutants over the whole study area and the local level assessment considers the impact of the scheme on concentrations of pollutants at a local level.

The strategic level assessment, presented below, considers emissions of carbon dioxide, a greenhouse gas, which may impact on a global scale.

3.3.2 Strategic Level Assessment

Total annual emissions of nitrogen dioxide (NO_2) (as total nitrogen oxides (NO_X)), fine particulate matter (PM_{10}) and carbon dioxide (CO_2) have been calculated for two scenarios, based on traffic data for Tunnel C1 (which is a very similar alignment to Tunnel C2) comprising a do-minimum scenario and do-something scenarios for the corridor, all for 2017.

Due to the wide area that could be affected by changes in traffic flow, and therefore changes in emissions, all road links within an area of 1200 km^2, centred on the existing crossing, were assessed.

The results are presented in Table 3.2 below. The percentage impact for each pollutant when compared to the do-minimum is shown in brackets minus represents a reduction against the do-minimum.

Table 3.2: Annual Emissions of NO_2, PM_{10} and CO_2, 2017

Pollutant	Do-Minimum	Tunnel C2 (Emissions)	Percentage Change from Do Minimum
NO_2 (as NO_X) (T/yr)	2,945	2,881	(-2.1%)
PM_{10} (kg/yr)	80,634	80,287	(-0.4%)
CO_2 (kT/yr)	1,043	1,026	(-1.6%)

3.3.3 Summary

The Strategic level assessment for air quality predicts a slight reduction in total annual emission for all three pollutants equivalent to a minor beneficial (or positive) impact for this alignment; however, it should be noted that these results show a very minor improvement in air quality and are therefore not considered to be significant and, in addition, they have not been informed by a local level assessment. Also note that these calculations are based strictly on a replacement crossing strategy and if the existing Forth Road Bridge is retained in any capacity for motor traffic these reductions may not occur.

3.4 WATER QUALITY, DRAINAGE, FLOOD DEFENCE

3.4.1 Introduction

For the purpose of this study, the water environment includes water quality, drainage and flooding. A baseline desk study has been undertaken and surface waterbodies located within a 500 metre wide corridor around the proposed alignment of Tunnel C2 have been identified. Where such information has been available, the desk study has incorporated the following:

- identification of the locations and characteristics of principal water bodies in the area;
- details of river classifications from Scottish Environment Protection Agency (SEPA) for relevant waterbodies. Classifications reflect the status of the watercourse in terms of chemical and biological properties, aesthetic quality and toxicity assessment; and
- details of the reporting categories assigned to the surface waterbodies within each corridor, as determined by the Characterisation and Impact Analysis undertaken by SEPA required by Article 5 of the Water Framework Directive (WFD);

It should be noted that no water quality monitoring was undertaken as part of this assessment.

3.4.2 Appraisal Outcomes

This section considers the potential effects of the construction and operation of a replacement Forth crossing. It should be noted that all impacts have been assessed taking into account the mitigation described in Appendix A.

Construction and operation activities may impact on the water environment. Construction activities would include:

- site clearance and demolition activities;
- earthworks, including the construction of embankments and cuttings;
- road upgrades including widening, re-profiling and junction alterations;
- construction of new roads linking the crossing to the existing network;
- construction of the toll plaza (if required) and associated facilities;
- excavation in intertidal areas and on the bed of the Firth;
- prefabrication of tunnel sections;
- installation of tunnel sections.

Potential impacts associated with the proposed tunnel are set out below. Temporary and permanent impacts include:

- potential mobilisation of pollutants or sediments by surface runoff during construction, particularly where works take place within the vicinity of surface waters;
- surface runoff that could form a pathway allowing contaminants to enter nearby watercourses, where construction activities take place on or close to areas of contaminated ground;
- re-alignment or culverting of watercourses leading to reductions in water quality;
- culvert construction that could damage the banks or beds of the watercourses and have secondary indirect impacts on riparian or aquatic ecosystems;
- dredging of the bed of the Firth and excavations within the intertidal area would have a significant negative impact on the hydrology of the Firth of Forth as a result of displaced sediments and increased turbidity;
- contaminated surface runoff containing fuels, oils, lubricants, salt or grit could enter carriageway drainage systems and then be discharged to watercourses;
- increase in the volume of surface runoff due to the introduction of impermeable surfaces;
- poorly designed or blocked culverts could lead to localised flooding; and
- culverted watercourses could experience a reduction in water quality meaning those watercourses identified as being at risk of not achieving the objectives of the Water Framework Directive (WFD) may not achieve "good status" by 2015[2].

The surface waters potentially affected by Tunnel C2 are detailed within Appendix A.

The most significant negative effects of the proposed immersed tube tunnel relate to the displacement of sediments from the bed of the Firth of Forth and the resultant increase in turbidity and consequent reduction in water quality. In addition, construction work within the RD57 site at Rosyth Docks, where the northern portal will be formed, may cause the release of low level radioactive waste known to be deposited there.

Significant negative effects associated with the culverting or re-aligning of surface waters could prevent waterbodies achieving the objectives of WFD. As well as potential damage to the banks and/or bed of affected watercourses during the construction of culverts, in the long term there would be reductions in water quality and secondary indirect impacts on the riparian or aquatic ecosystems. Compensatory mitigation, such as ecological improvements of other sections of the affected surface water could offset negative impacts.

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[2] See article 4(1) of "Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy" which requires that member states protect, enhance and restore all bodies of surface water with the aim of achieving good surface water status by 2015. This is translated into Scots law by the Water Environment and Water Services (Scotland Act) 2003 (the WEWS Act 2003).

All other temporary and permanent impacts, in particular those related to the potential contamination of surface runoff, handling site drainage and potential for flooding could be adequately mitigated through the adoption of the mitigation outlined in Appendix A.

As a result of the significant negative effects on water quality within the Firth of Forth the overall temporary effects have been assessed as Major negative although once construction has been completed disturbance of sediments, etc., should cease and the impact will reduce to minor negative.

3.4.3 Summary

In terms of surface water quality, construction of the immersed tube Tunnel C2 would have a significant negative impact on the Firth of Forth. Dredging, drilling and blasting will displace large volumes of sediment from the bed of the Firth of Forth and cause increased turbidity. In addition, construction works around the northern portal may release low level radioactivity from RD57 into the water environment. The permanent effects of Tunnel C2 immersed tube tunnel have been assessed as Major negative for water quality.

However, the overall temporary and permanent effects of Tunnel C2 on land, where the alignment crosses water courses, etc., should be effectively mitigated by adherence to legislation and the adoption of best practice such as Sustainable Urban Drainage Systems (SUDS) and SEPA Pollution Prevention Guideline (PPGs).

Effects resulting from culverting or re-alignment of watercourses would require compensatory mitigation to offset potential negative impacts on water quality. However, it is noted that under the WFD surface waters take the overall quality of the poorest stretch within them, meaning that affected watercourses may not achieve the Directive’s targets by 2015. Table 3.3 below summarises the findings of the assessment regarding water environment issues.

Table 3.3 Summary of Assessment

Option	Overall Temporary Effects	Overall Permanent Effects
Corridor C - Tunnel	Major Negative	Minor Negative

Further details regarding the assessment of Water Quality, Drainage and Flood Defence are provided in Appendix A.

3.5 GEOLOGY

3.5.1 Introduction

Baseline geological and groundwater information was obtained by means of a desk study review of currently available information. No fieldwork was carried out to confirm the findings of the desk study. An appraisal of contaminated land issues is included in the Agriculture and Soils section below.

The local geology and groundwater regime was determined from geological and hydrogeological maps published by the British Geological Survey (BGS), borehole records held by the BGS, previously published reports, and relevant Geological Memoirs. Information on the presence of any SSSIs of geological interest was obtained from SNH, while Fife Council and the Edinburgh Geology Society were consulted on the presence of any Regionally Important Geological Sites (RIGS) on either side of the Firth of Forth.

Potential impacts relating to geology include damage to areas designated for their geological interest, effects on active or potential mineral extraction activities, including sterilisation of reserves, and loss of deposits of limited extent or of ecological or other value, e.g. significant areas of peat. Impacts on groundwater quality or flow regime which affect the resource potential, for human use, ecology or river baseflows would be of concern.

Key Issues for Geology are discussed in Appendix A.

3.5.2 Appraisal Outcomes

The potential impact on the local geology and groundwater regime has been considered for this crossing option. No designated or non-designated sites of geological interest are predicted to be affected by this option and the types of bedrock and superficial strata affected by the option are widespread in the area. No specific geological deposits with ecological or other value, e.g. significant peat deposits, are identified in the vicinity of the option. However, Tunnel C2 is likely to sterilise more oil shale reserves than other options considered, but it is unlikely that oil shale working will become economically viable in the future.

Shallow groundwater in the vicinity of the option is not considered to have significant resource potential or to sustain sites of ecological interest or surface water baseflows. Deeper groundwater in the bedrock strata is not predicted to be significantly affected by this option, although tunnelling, especially if mine stabilisation is required, may create very localised changes in the groundwater regime. The tunnel options within Corridor C have the greatest potential for such a change of the various options considered, being in an area of more extensive mine workings.

3.5.3 Summary

The appraisal has shown that no significant impacts on the local geology and groundwater regime are predicted and, therefore, these aspects are not an important consideration in option selection.

3.6 BIODIVERSITY

3.6.1 Introduction

The following section discusses the over-riding biodiversity issues associated with the proposal to construct an immersed tube tunnel across the Firth of Forth between Abercorn Point and Rosyth Dockyard, followed by a discussion of potential impacts and broad mitigation measures. Appendix A presents an assessment of impacts after consideration of mitigation. The key issues are set out in a hierarchical order, dealing with protected sites in the first instance, followed by protected species. In both cases, the hierarchy is descending order from European (international) importance to UK (national) to local/regional designations.

The baseline data has been collated from many sources and aims to present an overview of the main issues to inform the decision making process for route selection.

3.6.2 Key Issues

The international importance of the Forth's intertidal and coastal habitat to birds affords one of the highest levels of designation possible in the UK, under the Birds Directive (Council Directive 79/409/EEC) of two Special Protection Areas (SPAs); the Firth of Forth SPA and the Forth Islands SPA (see 49550/T/01). It should be noted that these designations may be geographically extended to include the open water habitat of the Firth of Forth within the timescale of the project.

A third international site, the River Teith, is designated under the Habitats Directive (Council Directive 92/43/EEC) as a Special Area of Conservation (SAC), which also requires consideration as it may be vulnerable to indirect impacts. Furthermore, the Firth of Forth is designated as a Ramsar site under the Ramsar convention, and together these designated sites contribute to the European network of protected sites known as Natura 2000 sites which are protected by the Conservation (Natural Habitats, &c.) Regulations 1994 as amended.

These sites are afforded additional protection through designation as Sites of Special Scientific Interest under the Wildlife and Countryside Act (1981) as amended.

If the preferred route has potential for a significant effect on the integrity of any of these European sites, an Appropriate Assessment would be required, being a detailed analysis all potential impacts and how they would be mitigated to avoid adverse impact on the integrity of the Natura 2000 site(s). If residual impact cannot be avoided, the lack of an alternative plan has to be demonstrated. If there is no alternative to the development there must be imperative reasons of over riding public interest (IROPI) (which may be of a social or economic nature) for the plan/project to proceed and compensatory measures would be required to ensure that the overall coherence of the Natura 2000 resource is protected. These measures may require inclusion of other areas outwith the Natura site that are to be included within the designation or habitat creation. In time these can be included within the Natura site.

Any assessment of impact on Natura 2000 sites has to consider effects outwith the Natura 2000 sites boundaries, as the qualifying species also depend upon related habitats and/or the broader landscape for their survival, as well as the habitats contained within the designated area. This is most relevant to the open water of the Forth which provides fundamental habitat for birds in both SPAs.

In addition to the Natura 2000 sites there is a Site of Special Scientific Interest in the study area which is protected by the Wildlife and Countryside Act 1981, as amended.

Table 3.4 summarises the international and national designations. Please note that in the following text, the international sites are referred to only by their Natura 2000 designation, as this is the over-riding legislation.

Table 3.4 Internationally and Nationally Protected Sites

Site	International Designations	National Designation
Firth of Forth	Special Protection Area (SPA) and Ramsar site	Site of Special Scientific Interest
Forth Islands	SPA	Site of Special Scientific Interest
River Teith	Special Area for Conservation (SAC)	Site of Special Scientific Interest
St Margaret's Marsh		Site of Special Scientific Interest

Details of designated sites are included in Appendix A.

The protection of species mirrors the hierarchy of importance that applies to protected sites. Species protected by the Conservation (Natural Habitats, &c.) Regulations 1994, as amended have the highest level of protection and are referred to as European Protected Species (EPS).

The Wildlife and Countryside Act (1981), as amended, protects species important in a UK context under Schedule 5 of the Act. Badgers are afforded protection from harm and persecution under The Protection of Badgers Act (1992).

At this level of assessment, there is a lack of comprehensive information available for species to provide a 'level playing field' for route selection. Data searches were carried out to assess if there were any pertinent documented protected species issues that should be considered, and these are discussed within the corridor proposals.

All species of British bats are European Protected Species. The frequent shelterbelts and parcels of ancient woodland in the vicinity of Corridor C offers potential roost habitat for bats, particularly when coupled with open water.

Water voles are on Schedule 5 of the Wildlife and Countryside Act (1981) as amended and may be present in one or all of the zones of impact. There are no records of water voles within data searches carried out or in the National Water Vole Survey within Corridor C.

The potential impacts on international and national sites are the primary biodiversity considerations informing route selection and the consideration of European Protected

Species is also of importance. However, general diversity has to be considered under the Nature Conservation (Scotland) Act 2004 which places a duty on every public body and office holder to further the conservation of biodiversity.

This duty is fulfilled in this report as:

- Undesignated local sites with notable biodiversity, listed in local plans;
- Ancient woodland listed on the Ancient Woodland inventory, and;
- Habitats in the route corridor.

3.6.3 Appraisal Outcomes

For the purpose of this route appraisal, the zone of influence for potential terrestrial and intertidal impacts is defined as 500 metres to either side of the likely route, including 500 metres from the edge of the cut and fill for the tunnel exits. In the terrestrial corridor, impacts will decrease with increasing distance; however, wetland habitats are likely to be more vulnerable to impact as they may be impacted indirectly due to alterations to hydrological conditions as a result of development. The zone of influence for the Firth of Forth is more difficult to define at this stage, so the study considers the broader context of the mid-Firth of Forth for the estuarine environment.

During this study access to land was not possible to facilitate detailed surveys. However, a walkover survey was carried out from roads and paths to update the Phase 1 Assessment and an otter survey of the shore lines was undertaken together with some sampling of watercourses for otter signs when possible from land with public access.

3.6.4 Potential Impacts: Tunnel C2

International and National Issues

The proposed alignment for Tunnel C avoids, though is adjacent to, the intertidal areas of the firth designated as the Firth of Forth SPA. However, when considering the potential impacts on an SPA the important factor is whether there will be adverse impacts on the *qualifying features* of the SPA, whether they are actually present within the boundaries of the SPA or not. WeBS low tide data for the winter of 03/04 indicates that redshank, curlew and wigeon all occur in significant numbers in this corridor (above one per cent of SPA designated threshold level).

In the case of the Firth of Forth SPA these qualifying features comprise over-wintering birds which use most of the intertidal areas within the firth, including the mudflats around Abercorn Point that are not currently designated as part of the SPA. Therefore, with the construction method and alignment proposed for Tunnel C2 there is still a significant risk that qualifying features of the SPA will be adversely affected through disturbance and loss of feeding habitat during the construction period.

The construction method will also mean that a considerably amount of barge movements will be required in open water areas of the firth which may also impact on qualifying features of both SPAs in their feeding and loafing areas. In addition, increased activity within intertidal and open water adjacent to the SPA may disturb birds within the SPA itself.

With regard to the consequence of dredging the channel that will take the immersed tube below the low water mark there are likely to impacts on water quality and consequently on related ecology within the Firth during the construction period. The characterisation of the Firth of Forth undertaken by SEPA as part of the implementation of the Water Framework Directive identifies the Firth as being in Category 1a – at risk of not achieving “good” status - the target of the Directive. SEPA recognises the water quality in the Firth of Forth is historically poor citing historic discharges and the Firth’s inherently turbid nature.

However, the displacement of sediments associated with Tunnel C would exacerbate existing water quality problems and could have significant indirect impacts on ecology and the wildlife that inhabits the Firth of Forth. Impacts resulting from increased suspended sediment in the Firth include:

- A reduction in the depth of light penetration into the water. This effectively decreases rates of photosynthetic activity and thus primary productivity in submerged plants such as eelgrass (*Zostera* spp.), which is a basic food source for aquatic animals. A reduction in the food source at the primary level may then have a knock-on effect upon higher trophic levels, including birds;
- High turbidity levels can adversely affect invertebrate populations, interfere with the behaviour, migration, feeding and growth of salmonids and other fish species. It can also cause damage to fish gills by abrasion (hyperplasia), and clogging. This is significant in relation to potential impacts on Atlantic salmon which are a qualifying feature of the River Teith SAC. Note that such effects would not be spatially limited to the construction zone; and
- Cetaceans, protected by the Habitat Regulations, the Wildlife and Countryside Act (1981) as amended by the Nature Conservation (Scotland) Act 2004 do use the Firth. An immersed tube tunnel could have an impact on these species reducing the availability of food to them as well as disturbance during construction.

The proposed location for the shaft and site entrance for the southern shore is generally screened from the Firth of Forth SPA by linear belts of woodland but the scale and duration of the works may still lead to disturbance issues. Indirect effects relating to the works on the northern shore and in open water areas may also have potential for impact. However, the birds of the SPA may become habituated to the general construction activities, and mitigation measures may be possible to limit specific disturbance events by seasonal timing of certain construction activities and having an enforced buffer zone and screening structures for the SPA on either shore.

<u>European Protected Species</u>

Otters are present on the Grand Union Canal, which lies within 200 metres to the south of the Tunnel C2 toll plaza area (if required) and proposed road infrastructure. The railway line sits between the canal and the proposed new toll plaza (if required) and roads, but there are many ponds present to the south of Hopetoun Estate that may be used for feeding, particularly in spring when amphibians are spawning. It is likely that otters would move along ditches and small burns to access these ponds.

Sensitive design of all water course crossings would avoid fragmentation of habitat and otter fencing may be appropriate to reduce/avoid road mortalities.

In addition, Atlantic salmon, various species of lamprey and cetaceans may be affected by construction activities within the Firth either through direct impacts or indirectly due to increased disturbance or release of sediments.

Local Sites

Thirteen areas of woodland listed on the Ancient Woodland Inventory occur within the corridor, however, of these, three woodlands would be subject to any direct impacts:

- Wester Shore Wood is adjacent to the proposed construction area and access to the foreshore is proposed in the vicinity of the point where the Midhope Burn enters the firth.
- Swine Burn Wood AWI and unnamed AWI pockets, which are immediately adjacent to proposal new spur road from the M9. Both sites are on established of plantation origin, and;
- Unnamed woodland which is immediately south of the M9. A long established woodland of plantation origin. The northern part of the wood would be lost to the proposal junction alignment

3.6.5 Summary

Construction of Tunnel C2 has the potential for adverse direct and indirect impacts on qualifying features of the Firth of Forth Special Protection Area (SPA) and may potentially also affect qualifying features of the Forth Islands SPA and the River Teith SAC. Impacts associated with portals, construction sites and open water activities could cause disturbance to the SPA and possibly affect the estuarine environment.

The proposed immersed tube method is likely to cause considerable disruption to the natural sedimentation processes by dredging and blasting. This has potential implications for open water birds and shore birds of the Firth of Forth SPA, the breeding terns of the Forth Islands SPA and migrating salmon and lamprey associated with the River Teith Special Area of Conservation (SAC).

Additionally, cetaceans and other protected species (such as basking sharks and seals) may be disturbed and there may be far reaching impacts from disturbed sediments smothering eelgrass beds, which are an important habitat feature of the Firth of Forth. It is worth noting that a number of these species are specifically protected by the Nature Conservation (Scotland) Act 2004, particularly from “reckless” harm. Therefore, as with the SPAs and migrating salmon and lampreys, mitigation comprising seasonal constraints may be imposed during construction works, including blasting and movement of sediments in order to avoid such harm occurring.

The requirement to avoid disturbing wintering birds associated with the Firth of Forth SPA, whilst at other times of the year avoiding disturbance to breeding and feeding terns associated with the Forth Islands SPA, may require onerous seasonal constraints that could significantly affect the construction programme for the bridge.

In addition, the potential impacts on and interaction with the common tern colony of the Leith Docks SPA may also need to be considered.

The scale and duration of the construction work that is likely to impact on Natura 2000 sites, i.e. the SPAs and SAC, and aquatic European Protected Species, gives limited scope for seasonal timing of construction operations. This difficulty, as discussed above, is further compounded by the opposing seasonal interests of all of the sites and species. This option would require an Appropriate Assessment[3] with regard to these Natura 2000 sites.

In addition, this option may impact on protected species such as badger, bat and otter. Non-designated sites will also be affected by all options, in most cases this will lead to a loss of ancient woodland.

3.7 LANDSCAPE

3.7.1 Introduction

The following section considers the potential impacts of Tunnel C2 and its associated infrastructure on the landscape resource of the study area. The study area comprises some very diverse landscape types largely resulting from the unique geological processes which underpin the landscape and the resulting agricultural and mineral wealth which first attracted settlement to the area.

The current landscape of the area centred on the Firth of Forth reflects this combination of human and geological influences and forms a distinctive character marked by volcanic outcrops, intricate shorelines and wide sweeping views across the Forth. Hills to the north and south of the Firth form a backdrop for views within the area, as well as providing long distance elevated views across the Firth. The rail and road bridges in particular are a strong focus for views within the study area and are an important, iconic landmark for Edinburgh, the Lothians and Fife as well as Scotland as a whole.

3.7.2 Landscape Designations

The landscape designations identified in the Dunfermline and West Fife, Rural West Edinburgh and Edinburgh City local plans are illustrated in drawing number 49550/T/EC2/04 and include:

- Gardens and Designed Landscapes (GDL);
- Area of Great Landscape Value (AGLV);
- Area of Outstanding Landscape Quality (AOLQ);
- Greenbelt; and

[3] Where a project/plan is likely to have a significant effect on Natura 2000 sites (eg SPA/SAC) in Great Britain, Regulation 48 of the Habitats Regulations requires that an Appropriate Assessment (AA) be undertaken prior to the giving of any consent or permission. The AA assesses the implications of the project/plan for the site, in view of that site's particular designated features and conservation objectives. Note the need for AA's extends to projects/plans outwith the boundary of the site in order to determine their implications for the interest(s) protected within the site.

- Tree Preservation Orders (TPO).

3.7.3 Landscape Character

Scottish Natural Heritage, in conjunction with partner Councils, has undertaken detailed review and classification of the various landscape areas and types of landscape in Scotland. The north section of the study area is covered by Fife Landscape Character Assessment, dated 1999 (Review Number 113) and the southern section by the Lothians Landscape Character Assessment, dated 1998 (Review Number 91).

3.7.4 Appraisal Outcome

The potential impact on landscape character has been considered for each crossing option. The extent to which this option would affect the existing landscape character varies substantially depending on the individual components of the scheme option and the capacity of the existing landscape to absorb these components. It should be noted that the character of the Firth of Forth and the coastal fringe landscapes is very dependant on atmospheric and weather conditions with the haar and low cloud substantially changing the experience and character of the landscape.

The main sources of landscape impact associated with this crossing option would be as a result of the new road construction connecting the crossings with the existing road network, road upgrades including widening, re-profiling and junction alterations, tunnel and portals, the bridge structure and toll plazas (if required).

Mitigation measures associated with the reduction of potential adverse impacts on landscape character would involve detailed consideration of the vertical and horizontal alignment of the new roads, junction arrangements and tunnel portals during development of the scheme design and would include the following mitigation measures and objectives:

- Achievement of best fit with the contours;
- Retention and best use of existing vegetation;
- Protection for nearby properties through the use of existing features;
- Avoidance where possible of the loss or damage to landscape features such as specimen trees, hedges, water features; and
- Avoidance where possible of the loss or damage to sites of ecological or archaeological interest.

The key principles of the landscape mitigation measures would include:

- Any new planting should use native species to increase the biodiversity and nature conservation value of the area; and
- Landscape planting, earthworks (mounding and earth shaping) and other mitigation measures where appropriate to minimise the visual impact of the scheme and enhance the existing local landscape character and structure.

3.7.5 Summary

Table 3.5 below summarises the potential impacts on landscape.

Overall, this option is considered to have significant permanent impacts on the landscape resource of the study area.

Table 3.5: Summary of Assessment

Option	Overall Temporary Effects	Overall Permanent Effects
Tunnel C2	Moderate to Major Adverse	Moderate Adverse

3.8 VISUAL AMENITY

3.8.1 Introduction

The following section considers the potential impacts of the Tunnel C2 crossing option and its associated infrastructure on the visual amenity of the study area.

Landscape and visual impacts are closely related issues with considerable overlap between the two assessments. Visual amenity is defined as the pleasantness of the view or outlook of an identified receptor or group of receptors. The visual impact assessment determines the degree of anticipated change to visual amenity, considering buildings, areas of public open space, roads and footpaths that would occur as a result of the proposed scheme. The buildings, open spaces, roads and footpaths that would yield views of the crossing options are collectively referred to as ‘receptors’.

3.8.2 Appraisal Outcome

To the north of the Forth the majority of receptors are located in the urban areas of Inverkeithing, Rosyth and south-eastern parts of Dunfermline as well as a number of scattered receptors across the more open countryside. To the south of the Forth receptors are generally more dispersed with various scattered receptors across the rolling countryside with groups of receptors generally limited to the urban area of South Queensferry.

Visual impacts would result from various elements of the proposed crossing options but most notably from the new infrastructure, the bridge structure and the tunnel portals. The mitigation commitments outlined in the landscape character assessment have been considered during the visual assessment process and are reflected in the appraisal of overall permanent effects.

Drawings 49550/T/EC2/07 and 49550/T/EC2/08 identify the key visual receptors associated with Tunnel C2. Major Adverse impacts would be associated with residential properties which have immediate views of the development or where the focus to their view would substantially change. Visual impacts would be less where receptors are less sensitive to change such as commercial buildings or where the changed view is peripheral and more distant.

3.8.3 Summary

Table 3.6 below summarises the potential temporary and permanent impacts of Tunnel C2 is considered to have on visual amenity.

During the construction period, the majority of receptor groups which directly overlook the development corridor or with immediate views towards it would experience significant and adverse visual impacts as a result of the visually intrusive construction activity associated with the construction of the development. In the long term, significant and adverse visual impacts would be limited to more sensitive receptor groups (expectation and importance of the changed landscape to the receptor) and those with an immediate orientation towards the development.

The majority of visual impacts would result from the new infrastructure associated with the crossing option, to a lesser extent the tunnel portals and most extensively from the new road infrastructure required. This would result in various receptors experiencing impacts ranging from Major Adverse through to Minor Adverse or Neutral depending on their proximity to the development and their angle of view.

Table 3.6: Summary of Assessment

Option	Overall Temporary Effects	Overall Permanent Effects
Corridor C - Tunnel	Minor Adverse – Major Adverse	Minor Adverse – Major Adverse

3.9 AGRICULTURE AND SOILS

3.9.1 Introduction

This assessment considers the effect the option would have on agricultural land and soils. It also includes potential occurrences of contaminated land, on or close to the crossing option. Baseline information was obtained by means of a desk study review of designated areas, land classification maps and aerial photography. No fieldwork was carried out to confirm the findings of the desk study.

Details regarding the key issues in relation to Agriculture and Soils are provided in Appendix A.

3.9.2 Appraisal Outcomes

Permanent Impact on Agricultural Land Quality

The Tunnel C2 option would result in the loss of agricultural land which is mostly classified as prime quality agricultural land. Therefore, the permanent effect for this option is assessed as moderate negative.

Permanent Impact on Severance or Loss of Agricultural Land

This option will have a significant impact on the loss and severance of large areas of agricultural land due to the construction of road infrastructure and the toll plaza (if required). In order to assess the impact individually for the corridor it is necessary to know how much of the land will be viable post construction due to severance. However, due to time and access constraints consultation with Scottish Executive Environment and Rural Affairs Department (SEERAD) and individual farmers was not possible and is therefore, not included in this assessment. With the information available the impact for the corridor is assessed as moderate to major negative due to the large area of land potentially affected which exceeds the threshold for significant impact as defined in STAG.

Permanent Impact on Designated Areas

Tunnel C2 does not affect any fields that are protected under a national or local designation.

3.9.3 Permanent Impact relating to Construction Sites

The shaft construction sites would most likely result in the permanent functional loss of the entire field due to the size of the permanent structures together with their required access routes. This together with the loss of prime quality agricultural land means a moderate negative impact has been assigned.

3.9.4 Permanent Impact on Soils

A significant negative impact is considered for the tunnel option as it would potentially disturb large quantities of soil, particularly during cut and cover activities. In addition, there would be considerable quantities of spoil to be disposed of. Some of this could be disposed of to landfill or disposed of to designated marine areas outwith the firth. Alternatively, as most of this material will comprise marine sediments and boulder clay some of this material could be used for various other construction or restoration projects, such as land reclamation, within and outwith Scotland. Overall, the impact is assessed as being moderate negative.

3.9.5 Permanent Impact relating to Contaminated Land

The appraisal of contaminated land issues is mainly based on evidence from current and historical Ordinance Survey maps at this stage. The actual presence of contaminated land will be investigated by preliminary ground investigations proposed for the crossing options and ultimately by a detailed investigation on the route of the selected option.

The appraisal indicates that there is some potential for occurrence of contaminated land on routes. However, it is known that low level radioactive waste was deposited within the RD57 area at Rosyth Docks, which is where the northern portal of Tunnel C2 will be located. This may have significant consequences in terms of the need to remediate this land as to the potential effects of the release of radioactive material to the environment. A major negative impact is therefore assigned to this issue.

3.9.6 Summary

Table 3.7 below summarises the findings of this sections. The appraisal has shown that there are potentially significant negative impacts (i.e. moderate or major negative impacts) on agriculture and soils for this option. In addition, there may be significant contamination issues associated with this option specifically associated with low level radioactive waste within the vicinity of the northern portal site.

Table 3.7: Summary on Agriculture and Soils

Option	Overall Temporary Effects	Overall Permanent Effects
Corridor C - Tunnel	Major Negative	Moderate to Major Negative

3.10 CULTURAL HERITAGE

3.10.1 Introduction

This section discusses the archaeological and cultural heritage issues associated with the Tunnel C2 crossing proposal, followed by a discussion of potential impacts and broad mitigation measures.

Baseline data was collected for an irregularly shaped study area, designed to cover the various options and the surrounding area, from the following sources:

- City of Edinburgh Sites and Monuments Records held on the Canmore[4] database;
- Fife Sites and Monuments Records held on the Canmore database;
- West of Scotland Archaeology Service for West Lothian;
- The Statutory List of Buildings of Special Architectural or Historic Interest;
- The National Monuments Record of Scotland; and
- The Inventory of Gardens and Designed Landscapes in Scotland;

3.10.2 Local Plans.

The data from these was plotted onto base mapping. Sites located within approximately 500m of the proposed route alignment are discussed and an initial assessment of archaeological potential has been made.

3.10.3 Generic Impacts

Assessment of impacts on Cultural Heritage receptors has been made based on the data available from Historic Scotland, the Historic Environment Records and the National Monument Record for Scotland. A walkover survey was not undertaken at this stage.

[4] Canmore – The Royal commission for the Ancient and Historic Monuments of Scotland (RCAHMS) database of archaeological sites, monuments, buildings and maritime sites in Scotland.

Impacts on the archaeological and heritage sites have been made based upon the information available to date. Once an option has been chosen and more detailed plans developed it is likely that the impact assessment will change. Full details regarding the impacts discussed, in brief, below can be found in the Cultural Heritage Worksheets and AST submitted as part of this report.

3.10.4 Tunnel C2

The Corridor C Tunnel would create both direct physical impacts and indirect visual impacts upon archaeological sites, the built heritage and historic landscapes. Both direct and visual impacts would also be caused by the linkages to the current road network. There would be adverse impacts upon four sites of national importance, four sites of regional importance and five sites of local importance. These impacts are both direct and visual. The magnitude of the impact from this option is considered to be Moderate Adverse.

3.10.5 Summary

The table below summarises the likely permanent impacts upon the cultural heritage resource by the proposed crossing options.

Table 3.8: Summary of Impacts on Cultural Heritage

Option	Permanent Impact	Sites of National Importance	Sites of Regional Importance	Sites of Local Importance
Tunnel C2	Moderate Negative	4	4	5

3.11 STAG PART 2 - ENVIRONMENTAL SUMMARY

The findings from the environmental appraisal are summarised in Table 3.9 below.

Table 3.9: - Permanent Environmental Impacts

Topic	Tunnel C
Noise and Vibration	Moderate negative*
Global and Local Air Quality**	Minor positive
Water Quality	Major negative
Geology	Neutral
Biodiversity	Major negative
Landscape	Moderate to Major negative
Visual Amenity	Moderate negative*
Agriculture and Soils	Major to Moderate negative
Cultural Heritage	Moderate Negative

** NB: For Visual Amenity and Noise & Vibration some properties for each option will suffer Major Negative impacts whilst other will be subject to Minor Negative or Neutral impact, depending on their proximity, and in the case of visual amenity views, of the proposed development and therefore, the median level of impact has been used in this summary.*

*** NB: for Global and Local Air Quality, the assessment is based on global air quality i.e. CO_2 emissions only.*

4 Costs to Government

4.1 INTRODUCTION

This section presents an assessment of the Cost to Government of the assessed scenario. It discusses how the cost estimates were calculated. These costs are presented in current prices.

It then calculates the net cost of the proposal in 2002 prices and values so that they can be compared with the TEE benefits presented in section 5.7 of Report 4.

Finally, a summary is presented, which compares the benefits which can be expressed in money-terms with the costs.

4.2 SCENARIO COSTINGS

This section presents the costings calculated. The costs are divided into the following categories:

- the cost of constructing the crossing;
- the ongoing costs of operating and maintaining the crossing;
- the cost of constructing the network linkages;
- the additional annual maintenance burden of the network linkages;
- other costs.

4.3 COST OF CONSTRUCTING THE CROSSINGS

Tunnel Cost Estimates

Cost rates for each component of the tunnel construction were taken from industry standards such as Spons and from project experience elsewhere to enable an overall cost estimate to be established. A unit cost per metre length of tunnel for the SCL and cut and cover tunnelling techniques was derived from the detailed costing estimate undertaken for the bored tunnel in Corridor C. These were then adjusted for this route to account for the particulars of this alignment, for example the cut and cover tunnels on this option involve marine works and hence the costs allow for this extra work and the complexity involved. Other costs such as site mobilisation and the tunnel control centre were assumed to be the same for all the tunnel options.

Costs for the immersed tube section have been derived by using overall project costs for other major comparable projects in the UK and abroad. These all-in costs have been collated and a unit cost per length of immersed tube tunnel has been extrapolated. This unit rate was cross checked by breaking the construction process into a number of components for which costs were calculated individually from industry standards in a similar fashion to the bored tunnel and collated to form an all-in cost.

Table 4.1: Corridor C – Immersed Tube Tunnel Construction Costs (£000's Q4 2006 prices)

Cost Item	Cost, £000's
Immersed Tube	310,961
SCL	115,814
Cut & Cover	55,847
Vent Shaft	17,180
Ground Treatment	49,748
M&E	102,037
Overheads	147,886
Total	**799,112**

The following assumptions were made when estimating the tunnel construction costs:

- All costs based on 2006 Q4;
- Site investigations of the proposed crossing have yet to be carried out, however the limited geotechnical information available indicates that doleritic intrusions are present in the area and for the purposes of building up a robust cost estimate, it has been assumed that some dolerite will be encountered in the channel and that marine drill and blast techniques to remove the dolerite will be unavoidable.
- A desktop study of the area shows that there is a significant chance of encountering old mine workings on the southern banks of the Forth. Based on the information available it has been assumed that ground treatment will be required for old mines in the vicinity of Wester Shore Wood.

The following exclusions were made:

- the costs do not include for land costs;
- the costs do not include for statutory undertaker costs;
- the costs do not include for ground investigation;
- design and supervision fees are excluded;
- non-recoverable VAT;
- demolition; and
- Optimism Bias Uplift.

4.4 COSTS OF OPERATING AND MAINTAINING THE CROSSING

Tunnel Cost Estimates

Cost estimates of the annual operation and maintenance costs have been carried out by reviewing reported costs for the existing Forth crossing, as well as a review of power supply requirements for tunnel services such as lighting and ventilation from other similar tunnelling projects in the UK and abroad. Table 4.2 presents these costings on a per annum basis, averaged over 60 years.

Table 4.2: Annual Tunnel Operation and Maintenance Costs (£000's Q4 2006 prices)

Category	Corridor C Immersed Tunnel
Operation	4,539
Maintenance	4,554
Total	**9,093**

4.5 COSTS OF CONSTRUCTING THE NETWORK LINKAGES

The alignment was broken down into its respective sections to the north and south of the Firth of Forth. Within each section the length of individual road types was completed based on the proposed carriageway cross-section. All cross-sections have been based on official guidance.

A per metre cost for each cross-section was initially based on SPONS Q4 2006 unit estimate rates for highways works. After consultation with a senior quantity surveyor the rates were checked and amended in accordance with recent construction projects and guidance. The per metre costs included all highways construction elements including drainage, earthworks, pavements, fencing and barriers, accommodation works and signage and road markings. For each section all structures including underbridges, overbridges and viaducts were identified and costs produced on a per item and metre basis. The toll plaza cost was developed as an item cost based on existing the Forth Bridge Toll layout and recent construction projects.

Table 4.3 presents the costs for each scenario.

Table 4.3: Costs of constructing the network linkages (£millions Q4 2006 prices)

Scenario	Cost
Corridor C Immersed Tube Tunnel	449

4.6 COST OF MAINTAINING THE NETWORK LINKAGES

The additional road length will impose an ongoing burden on the road maintenance budget. It is therefore necessary to calculate the annual cost of maintaining the network linkages. This was done by calculating the additional road length, and applying standard rates per kilometre built. These rates vary by type of road.

Table 4.4 presents the annual additional maintenance requirement of the network linkages.

Table 4.4: Annual cost of maintaining the network linkages (£millions Q4 2006 prices)

Scenario	Cost
Corridor C Immersed Tube Tunnel	0.3

4.7 OTHER COSTS

Preparation and supervision costs were calculated by applying a standard percentage to the costs of construction. The cost of purchasing the land was also calculated. These costs are presented in Table 4.5.

Table 4.5: Other costs (£millions Q4 2006 prices)

Scenario	Preparation	Supervision	Land
Corridor C Immersed Tunnel	37.4	15.6	27.7

4.8 PRESENT VALUE OF COST TO GOVERNMENT

This section presents calculations of costs so that they can be compared with the transport benefits presented in the Transport Economic Efficiency section (Section 5.7 of Report 4). The costs that STAG requires to be assessed are:

- public sector investment costs;
- public sector operating and maintenance costs;
- grant/subsidy payments;
- changes in revenue; and
- changes in indirect taxation.

The costs are therefore presented in 2002 prices, with values discounted to 2002 values. They are assessed over a period of 60 years from the opening of the crossing. Optimism bias has been applied, as described in Section 4.2.1 of Report 4. Table 4.6 presents the results for each scenario. Costs are indicated by negative values. Positive values are gains to government.

Table 4.6: Cost to Public Sector (£millions, 2002 values and prices)

Category	Corridor C Immersed Tunnel
Public sector investment costs	-1.72
Public sector operating and maintenance costs	-0.15
Grant/subsidy payments	0
Revenues	0.28
Taxation impacts	-0.33

The public sector investment costs are the capital costs that are spent to construct the crossings and associated network connections.

The public sector operating and maintenance costs are the ongoing burden imposed on the public purse by the crossing and associated network linkages.

Grant/subsidy payments are sometimes required in transport schemes in order to fund a service provided by a private company (e.g. First ScotRail, bus operators etc) that does not cover its own costs. That is not the case in this scheme, so all values are zero.

Public sector revenues are affected by the change in the amount of toll revenue collected. This scenario increases the amount of toll revenue collected by the government.

Indirect taxation revenues will change when a scheme shifts expenditure to or from fuel, which is heavily taxed, and to or from public transport fares, which are not taxed. This must be reflected in the assessment. This scenario increases the indirect tax revenues collected by the government.

4.9 MONETISED SUMMARY

This section presents the benefits from the TEE section of the analysis and compares them with the Cost to Government shown above. This allows a judgement to be made as to the value for money of the scheme. However, it should be emphasised that not all transport benefits are able to be monetised, and that there may be other benefits to society, not transport related, that could result from the implementation of the scheme.

Table 4.7: Monetised Summary of Costs and Benefits (£m, 2002 values and prices)

Category	Corridor C Immersed Tunnel
Present Value of Benefits (PVB)	4.65
Present Value of Costs (PVC)	-1.91
Net Present Value (NPV)	2.74
Benefit to Cost Ratio (BCR)	2.44

The Net Present Value (NPV) is calculated as the Present Value of Benefits (PVB) minus the Present Value of Costs (PVC). It therefore calculates the net benefit to society. The Benefit to Cost Ratio is the Present Value of Benefits divided by the Present Value of Costs multiplied by minus one. This therefore presents the amount of benefit society gets from each pound spent on the project.

4.10 RISKS AND UNCERTAINTY

Overview of Tunnel Key Risks

There is little or no geotechnical information available along the route of the tunnel. Interpolation of limited existing geotechnical data has therefore been necessary. The risks associated with each tunnelling technique have been speculated based on both previous experience and suggested trends and observations in the geotechnical data.

It is proposed that the approach tunnel on the southern shore is constructed using the Sprayed Concrete Lining (SCL) method. This is an open face method that relies on the mined strata being sufficiently stable in the short term to allow temporary support to be installed with only a limited amount of advance ground stabilisation. Typically, spiles (long steel or fibre glass dowels) are drilled into the face or crown to stabilise the ground and rock bolts installed radially to mobilise the strength of the ground in the short term. These ground support measures would be used in combination with sprayed concrete applied to exposed cut surfaces and in greater thickness radially to provide a temporary structural shell. The structure would then be completed by installing a waterproof membrane and an in situ structural concrete lining.

The use of the SCL method depends on the strata being sufficiently stable to allow a largely unsupported excavation. Threats to the stability of the excavation include significant and rapid changes in ground conditions and the presence of flowing water or water under pressure. It is suggested that faults may be present on the southern shore and doleritic intrusions are observed throughout the area. The SCL method provides a flexible and cost effective way of managing the creation of the underground space and a better means of mining through dolerite than by the use of a TBM where drill and blast excavation may be required. The presence of water may affect the depth to which the SCL tunnel can be taken close to the shore.

This particular scenario incorporates an immersed tube tunnel beneath the deep water channel. Should dolerite be found in the dredged excavation it is likely that marine drill and blast or intervention from the surface would need to be employed.

Mine workings are likely to be in close proximity to the southern approach tunnel and the ventilation adit tunnel. The workings will need to be stabilised in a zone around the tunnels before construction in these areas.

The means and methods described and the risks raised in this section have been promoted based on our current high level understanding of the geotechnical conditions. These views may change based on a better understanding of the strata and hence the risks involved in construction. The primary source of risk contingency at this stage is the lack of geotechnical information. Secondary to this, is the difficulty of access to the southern tidal zone, and the high amount of environmental disruption that construction will cause to the area.

4.11 OPTIMISM BIAS

STAG highlights a systematic tendency for project appraisers to be overly optimistic. As a result, STAG requires appraisers to make explicit adjustments for this bias. The standard optimism bias for fixed links i.e. bridges and tunnels, is 66 per cent. However this may be reduced by:

- full identification of stakeholder requirements (including consultation);
- accurate costings; and
- project risk and management.

It is considered that, due to the limited baseline information available, the tunnel proposal should be assessed with the recommended 66 per cent optimism bias.

4.12 TRANSPORT ECONOMIC EFFICENY

Table 4.8 below shows a comparison of the cost of construction of the C2 tunnel option compared with the previously appraised crossing options.

Table 4.8: Costs of Constructing the Replacement Crossing (£millions, 2006 prices) Including Optimism Bias

Corridor Crossing Type	C (ITT) Tunnel	C Tunnel	D Tunnel	D Cable-Stayed Bridge	D Suspension Bridge	E Tunnel
Crossing Construction	1,327	1,527	1,418	789	974	1,738
Network Connections Construction	449	425	447	464	464	355
Other Costs	350	374	349	219	250	365
Total	**2,126**	**2,326**	**2,214**	**1,472**	**1,689**	**2,458**

Table 4.9 below shows a summary and comparison of the costs/benefits of the crossing options developed as part of the STAG 2 appraisal process and previously reported in Report 4 against the C2 Tunnel design.

Table 4.9: Monetised Summary of Costs and Benefits (£millions, 2002 values and prices)

Corridor Crossing Type	C ITT Tunnel	C Tunnel	D Tunnel	D Cable-Stayed Bridge	D Suspension Bridge	E Tunnel
Present Value of Benefits (PVB)	4,655.6	4,655.6	5,303.1	6,026.1	6,026.1	6,317.1
Present Value of Costs (PVC)	-1911.4	-2087.4	-1967.7	-1,397.3	-1,574.9	-2,172.2
Net Present Value (NPV)	2744.2	2568.2	3,335.3	4,628.8	4,451.1	4,144.9
Benefit to Cost Ratio (BCR)*	**2.44**	**2.23**	**2.70**	**4.31**	**3.83**	**2.91**

* ratio, not monetary value

Comparing the BCR values above, demonstrates that the C2 Tunnel option is only marginally better performing than the Corridor C bored tunnel option.

5 Summary and Conclusions

5.1 SUMMARY

The objective of this report has been to provide a detailed assessment of the proposal to construct an immersed tube tunnel in Corridor C. The report has followed a similar format to that taken in the main appraisal report (FRCS –Report 4) for consistency. In appraising the immersed tube option the report has used the Scottish Transport Appraisal Guidance (STAG).

C2 Tunnel Construction

The proposed immersed tube tunnel in Corridor C would be 6.15 kilometres long, of which approximately 2.2 - 2.3 kilometres would be constructed as an immersed tube with approach sections being constructed as a combination of cut and cover and SCL sections. It would take 5.5 years to construct and would cost an estimated £2.1 billion, including network connections and Optimism Bias at Quarter 4 2006 prices.

Environment

The Environmental Appraisal findings show that environmental impacts of Tunnel C2 may have Major to Moderate adverse impacts.

This is because the C2 Tunnel option is proposed as an immersed tube that would disturb sediments and may impact on the Firth of Forth SPA and Forth Islands SPA, which are protected at the European level, as well as other European protected species such as cetaceans.

Transport Economic Efficiency

The C2 Tunnel option produces monetised benefits which are greater than the costs. The C2 Tunnel produces the third highest NPV and BCR of the four possible tunnel options appraised and is only marginally better performing than the bored tunnel in Tunnel C.

5.2 CONCLUSIONS

Although the proposed C2 immersed tube tunnel is slightly better performing overall than the Corridor C bored tunnel in economic terms, this option has a much larger environmental impact due to the nature of the proposed construction methodology.