



# RIVER CROSSINGS: SILVERTOWN TUNNEL

## SUPPORTING TECHNICAL DOCUMENTATION

### SILVERTOWN TUNNEL: INDEPENDENT PEER REVIEW GROUP - REPORT TO TFL RIVER CROSSINGS SPONSOR GROUP

Silvertown Tunnel Independent Peer  
Review Group (IPRG)

January 2014

This report sets out the independent expert scrutiny of the Silvertown Tunnel project and in particular the decision to progress with a Bored tunnel option in preference to an Immersed tube tunnel option.

This report is part of a wider suite of documents which outline our approach to traffic, environmental, optioneering and engineering disciplines, amongst others. We would like to know if you have any comments on our approach to this work. To give us your views, please respond to our consultation at [www.tfl.gov.uk/silvertown-tunnel](http://www.tfl.gov.uk/silvertown-tunnel)

Please note that consultation on the Silvertown Tunnel is running from October – December 2014.

**SILVERTOWN TUNNEL**

**INDEPENDENT PEER REVIEW GROUP**

**Report to TfL River Crossings Sponsor Group**

**Revision 1.0**

**January 2014**

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### APPENDICES

Appendix A	TfL, Transport Strategy & Planning, Silvertown Tunnel, Independent Peer Review Group, Terms of Reference, Rev 1.0 December 2013.
Appendix B	Information made available by TfL to the Peer Review Group
Appendix C	Credentials of the Review Team

# 1 Executive summary

## **Background**

- 1.1 The Silvertown Tunnel Independent Peer Review Group (PRG) has been formed to review the selection of the preferred option for the Silvertown crossing. The PRG members have a range of expertise in major tunnel works and a range of backgrounds including client, consultancy, contracting and safety regulation.
- 1.2 The review presented in this report was undertaken between 19<sup>th</sup> November and 11<sup>th</sup> December 2013.
- 1.3 Following TfL's identification of a tunnel at Silvertown as the preferred scheme the PRG has focussed in particular on the following considerations:-
  - Bored tunnel vs immersed tube tunnel,
  - "Long" tunnel vs "short" tunnel,
  - Cross passage spacing,
  - On site vs off site casting for immersed tunnel sections.
- 1.4 To facilitate the review the PRG has received a range of documents and briefings from representatives of the project team. The PRG has then met in closed session to develop and discuss its findings.

## ***Bored tunnel vs immersed tube tunnel***

- 1.5 The PRG has concluded that both the bored and immersed tunnel variants are technically feasible and use tried and tested technologies.
- 1.6 The estimated capital cost of the schemes is too similar to be a differentiating factor given the current level of design development. The decision to go into the Development Consent Order (DCO) process with a single option prior to procurement precludes market testing to establish precise costs of the options at this stage.
- 1.7 There are substantial differences between the two variants particularly in relation to the extent of any work in the river and the associated stakeholder implications. The need for major river works to construct an immersed tube tunnel inevitably implies disturbance of the river environment. It is therefore likely to meet resistance from groups such as the Port of London Authority and the Environment Agency, unless there is some compelling reason to favour the immersed tube solution. The likelihood of such objections, in conjunction with a number of other issues, means that confidence in the ability to deliver the immersed tunnel option at this location is significantly lower than for a bored tunnel.
- 1.8 The PRG has not identified any compelling reason to adopt the immersed tube tunnel and concludes that, on balance, the bored option offers lower consent risk and is therefore preferable.

## ***"Long" tunnel vs "short" tunnel***

- 1.9 The PRG considers that the adoption of the "long" tunnel option is reasonable given the likely planning and resultant schedule risks associated with the "short" option.
- 1.10 Notwithstanding this the long tunnel option necessarily increases the excavation of potentially contaminated ground and so further investigation to improve understanding of this risk would be beneficial.

### ***Cross passage spacing***

- 1.11 The PRG supports the use of a risk based approach to determine the cross passage spacings and anticipates that this may result in spacings of significantly more than 100m.
- 1.12 Although mined passages are feasible there are construction risks associated with cross passages, particularly when working under the river or in contaminated ground, and these risks should be considered as part of the overall assessment of the spacing.

### ***On site vs off site casting for immersed tunnel sections***

- 1.13 The PRG considers that the casting location for immersed tube tunnel elements does not need to be specified by the Client.
- 1.14 It is reasonable to consider the possibility of off site casting for planning purposes.

### ***Caveat***

- 1.15 The conclusions of the PRG are caveated by the fact there are some omissions and inconsistencies in the material presented for the review. Recommendations are made on actions to address these issues but it is not considered likely that resolution of these will significantly change the overall conclusions.
- 1.16 The review has identified (as reported in December 2013) that the decision on selection of a preferred option is the product of a semi-quantitative process. The decision to discount the immersed tunnel option (if that is the final option) will therefore be a qualitative one. The review has found this not to be an unreasonable approach.

## **2 Preamble: Review Requirements**

### ***Peer Review Group (PRG) role and function***

- 2.1 The Silvertown Tunnel Independent Peer Review Group was established to address a need identified by the TfL River Crossings Sponsor Group during a project gate review process.
- 2.2 A terms of reference document for the PRG was provided which identified the main function of the group as follows:

*“The PRG’s main purpose is to provide independent expert scrutiny of the Silvertown Tunnel project and in particular the decision to progress with a bored tunnel option in preference to an immersed tube tunnel option.”*

- 2.3 The terms of reference provided by TfL Planning are included in Appendix A.

### ***PRG scope and remit***

- 2.4 The terms of reference define the scope and remit as being:-

*“to review the selection of preferred tunnel option with respect to the following technical and engineering aspects*

- *Design – methodology and approach, and associated risks, opportunities and costs,*
- *Construction – methodologies, logistics, safety and associated risks, opportunities and costs,*
- *Sustainability and Environmental impacts of the proposals”.*

## ***PRG output***

- 2.5 The PRG was requested to provide a short report on its findings (this document) to the River Crossings Sponsor Group. This report was to cover the following areas:-
- *Critique of design and engineering approach,*
  - *Critique of construction feasibility, safety and logistics,*
  - *Critique of environmental impact assessment,*
  - *Critique of risks and opportunities,*
  - *Conclusions and recommendations on preferred option.*

## **3 Review Methodology**

### ***Peer Review Group membership***

- 3.1 The PRG was selected to include a range of engineering expertise relevant to the project. The group includes representation from consultancy, contracting, TfL's Rail and Underground engineering group and a tunnel safety specialist.
- 3.2 The group was intentionally selected to include representatives involved with current London Underground and Crossrail tunnelling works.

The members of the group were:-

Dr Keith Bowers (Chairman), Profession Head for Tunnel Engineering, London Underground. Crossrail Engineering Expert Panel member

Colin Eddie, Managing Director, Morgan Sindall Underground Professional Services. Formerly Crossrail Engineering Expert Panel member

Ian Gee, Director, Tunnelling & Underground Space, Atkins

Dr Donald Lamont, Independent Tunnel Safety Specialist (formerly Health and Safety Executive). Crossrail Engineering Expert Panel member.

- 3.3 In addition David Court of BAM Nuttall was unable to attend the meetings but provided further advice to the PRG.
- 3.4 Further details of the panel members are provided in Appendix C.
- 3.5 The panel were commissioned to provide professional opinion within their area of domain, within an undertaking provided by TfL that their respective companies would not be precluded from future involvement in the project, consequent on their participation in the review process.

### ***Peer review process***

- 3.6 The PRG received the documents listed in Appendix B and on the 19<sup>th</sup> November 2013 received an initial presentation from the project team on the development of the scheme to the present state.
- 3.7 The PRG held further discussions with representatives of the project team on 25th November and 9th December. In these discussions various questions were raised which resulted in the subsequent provision of additional documents.

- 3.8 The PRG has also met in private sessions on the 25th November, 9th December and 11th December to discuss the project and to prepare this report. This review was characterised by a period of intense activity within which a large quantity of information had to be appraised.
- 3.9 The primary output from the PRG is this report which represents the consensus view of the group. The following sections address the main subject areas considered in the review. This report assumes the reader is familiar with the scheme options and is therefore principally a commentary on the matters considered by the PRG to contribute to differentiation between the options.

## 4 The design approach

- 4.1 The design process, which has spanned several years, has considered a range of different design options for this Thames crossing. Earlier stages in this process have concluded that the preferred option should be a tunnel crossing at the Silvertown location. These decisions have not been reviewed by the PRG as they are not within the terms of reference.
- 4.2 A number of variants of this tunnel concept have been considered. These include both bored and immersed tube tunnels in a variety of configurations and with cut-and-cover approaches. These schemes use essentially the same horizontal alignment with a length of around a mile. All feature twin two lane highway bores plus means of emergency access from one bore (or cell) to the other.
- 4.3 This has culminated in the project team's identification of a preferred option – the 'Long Bored Tunnel' (referred to in this review as the 'bored tunnel' option) and a primary alternative option, the 'Long Immersed Tube Tunnel' (referred to in this review as the "immersed tube tunnel" option).
- 4.4 The bored tunnel option has been recommended by the project for taking forward toward a DCO application.
- 4.5 The recommended bored tunnel option comprises twin 11m internal diameter tunnels passing beneath the river Thames with a low point corresponding approximately with the low point of the river bed, with a minimum cover to extrados of 6.8m. The twin bored tunnels are connected to the portals by lengths of cut-and-cover approach tunnel.
- 4.6 Cross passages forming a link route between the independent tubes are proposed at a longitudinal spacing of 100m, consistent with the recommendation of Highways Agency BD78/99. These provide both an egress route for tunnel users and an intervention route for fire services during an emergency incident.
- 4.7 During the evolution of the preferred option, a risk-based analysis (in conjunction with CFD) of the requirements and performance of all safety systems which may be built into the tunnel, has indicated that the spacing (frequency) of cross passages can be significantly increased. The reduction in number of cross passages (and consequent reduction in the technically challenging inter-tube construction) would bring a scheme capital cost and (construction) risk reduction. It is understood that this will be pursued further during detailed design.
- 4.8 Having identified the bored tunnel and immersed tube tunnel alternatives, the project has identified a range of options within these two categories resulting in a total of eight permutations being summarised in the reports. These options are differentiated by the choice of bored or immersed tube construction, tunnel length ("short" or "long" alignment options) and by variations in the spacing of the cross passages. The immersed tube options are also separated into those with on site or off site casting.

## 5 The bored tunnel option

### ***Alignment and consequences for construction***

- 5.1 The proposed vertical and horizontal alignment of the bored tunnel appears to have been well considered and clearly balances the desire to maximise cover mid-River and maintain acceptable tunnel gradients (4%) for operational reasons. A minimum tunnel radius of 450m has been chosen which can easily be accommodated by use of currently available TBM and tunnel lining technologies.

### ***Bored tunnelling methodology***

- 5.2 The preferred construction methodology is use of an earth pressure balance (EPB) tunnel boring machine (TBM). Given the high proportion of cohesive materials along the drive this would be a logical choice. The proposed drive site at Silvertown is considered to be sufficiently large to safely and efficiently construct the tunnels using EPB technology. Although it is anticipated a *particular* method ultimately will not be mandated by TfL, it is questionable whether the proposed drive site would be sufficient to accommodate the separation facilities should a Contractor choose a Slurry TBM alternative.
- 5.3 The bored tunnels will be driven from a drive shaft forming part of the subsequent approach structures at Silvertown on the north side of the Thames.
- 5.4 It is clear that considerable consideration has been given to the construction methodology of both the bored tunnel and immersed tube tunnel solutions. A review of the feasibility, cost and programme for both of the principal options has been undertaken.
- 5.5 Low cover is a consideration for this tunnel (although there are a number of other tunnels under the river with less cover which were successfully constructed without the benefit of modern tunnelling technology). If the cover is predominantly London Clay as indicated by the available ground investigation data from previous projects, no major issues are expected. Potential geotechnical risks would include loss of clay cover associated with scour features and other natural geological structures. If the TBM is required to operate in full EPB Mode for the entire length of the drive and the lining is a modern, gasketed, pre-cast, concrete design, such hazards are considered to be manageable.
- 5.6 The reviewers' view is that the above conditions are an achievable scenario and that the present ground investigation data indicates arguably more geologically favourable conditions than the current Crossrail river crossing works. However, there would be an increase in construction risk if the tunnel passed into less competent ground (such as a scour feature). Therefore greater certainty would be achieved if more ground investigation can be obtained at the earliest opportunity. Better ground knowledge is likely to reduce risk and therefore cost in the main contract.
- 5.7 It is judged unlikely that further ground investigation would expose a problem which would lead to a fundamental change of design solution. It is likely that ground conditions identified as a local hazard could be dealt with through some form of ground treatment. If this were to occur it would probably involve cross passage construction being enabled by ground treatment from the first bore. It is unlikely that such enabling works would be needed for the TBM drives.
- 5.8 Of potentially greater concern is the possibility of the TBM encountering artificial obstructions. This would have the potential to delay the TBM while the obstruction was removed by an intervention through the cutterhead. It is recommended that a more exhaustive investigation be undertaken as this type of hazard probably represents a greater risk than variations in natural ground.
- 5.9 The proposed drive sequence has been reviewed and is judged optimal. It is agreed that the use of a single TBM launched at Silvertown and rotated at Greenwich is feasible and would be

expected to offer best value for money. This solution will also be expected to result in an optimum overall construction duration.

- 5.10 The review was not able to conclude whether adequate consideration had been given to the availability of sufficient power to support the (major) TBM demand for tunnel driving (see programme comment also below).
- 5.11 The proposed logistical support also appears to have been well considered with spoil and segment movements being favoured by barge. Use of conveyors within the tunnel is supported and the reviewers would agree that the use of rubber tyred vehicles for materials handling in the tunnel is an effective solution. The PRG are aware that Wallasea Island will have adequate capacity to receive the spoil for this scheme and this is considered to be a logical choice.

### ***Cross Passage Construction***

- 5.12 Construction of the Cross Passages clearly constitutes one of the most challenging features of the bored tunnel scheme. If sumps are mined from cross passages rather than being placed in the main bore invert they will also require careful attention, although they will have the benefit of greater cover. Cross passage construction may be a particularly significant issue under the river and in any areas of contaminated ground.
- 5.13 It is clear that effective thinking has been applied to the construction methodology and the reviewers agree with the proposed methodology and associated potential ground treatment schemes which include:
- jet grouting in gravels,
  - permeation grouting to stabilise overlying gravels where the tunnel is below but with low cover to gravels,
  - vacuum dewatering in the Lambeth Group.
- 5.14 Based on past experiences these measures are considered feasible and are expected to be sufficient. It is noted that the first bore provides good access to treat under river cross passage areas prior to completion of the second bore. It is envisaged that cross passage construction will commence from the first bore once the TBM has travelled a minimum of 500m past the first cross passage. The reviewers agree that this represents a good solution.

### ***Cost and programme***

- 5.15 In the limited period available for the review it has not been possible to undertake a thorough review of the cost model however the reviewers have no specific reason to doubt it. The schedule of cost components has been reviewed and these are considered to be realistic.
- 5.16 The construction programme is considered to be realistic (perhaps bordering on conservative).
- 5.17 The reviewers note that the TBM will require a significant electricity supply which may itself have a significant lead time.
- 5.18 It is clear that the cost is significantly linked to schedule and so likely to be conservative.
- 5.19 It may be helpful to compare the suggested 52 week programme with other recent TBM drives under the river such as the DLR crossing at Woolwich. Note that given a similar mechanised tunnelling system the rate of progress would be expected to be relatively insensitive to the diameter of the bore.
- 5.20 There is a concern that the QRA approach needs further work. During the review and discussions with the team some potential for double counting of risks has been identified and this needs to be resolved. It is acknowledged that the project team understand this issue and is working to address it.

## 6 The immersed tube tunnel option

### *Alignment and consequences for construction*

- 6.1 The horizontal alignment proposed for the immersed tube tunnel is similar to that for the bored tunnel. The vertical alignment is somewhat shallower.
- 6.2 Typically immersed tube tunnels achieve benefits by reducing the crossing length when compared to a bored option as a consequence of their reduced depth. In the case of Silvertown this does not occur (at least with the long options which are favoured for planning reasons) because surface constraints dictate the position of the portals. Thus a common benefit of an immersed tube is not achieved here.

### *ITT Methodology*

- 6.3 The proposed methodology is based upon that adopted for many previous successful projects in continental Europe. Technology such as thermal control during casting should provide a watertight construction (with no external waterproofing deemed necessary).
- 6.4 The dredging proposals have been developed in conjunction with an experienced marine contractor. It is noted that the seasonal constraints have been respected. The reviewers see no reason to doubt these aspects.
- 6.5 Clearly the location of the casting yard is a key consideration and impacts on the timing of the release of the Safeguarded Boundary. Both on-site and off-site casting are clearly feasible. Programme benefits associated with off-site casting are however compelling.
- 6.6 It is noted that driven high modulus piles are proposed for the construction of the temporary cofferdams in the river. The length of these piles is considerable and the reviewers consider the proposal to install these using silent piling techniques as possibly optimistic and worthy of further investigation. Percussive driving of such large piles would almost certainly be problematic and quite possibly unacceptable to the local community.
- 6.7 The temporary cofferdams will also have a significant adverse impact on river flows. Experience from the Tideway project suggests that significant river modelling would be expected to be required to satisfy the Environment Agency, Port of London Authority and other stakeholders.
- 6.8 The programme has been reviewed and the PRG agrees that the constraints, as currently understood, have been respected in the construction methodology and programme.
- 6.9 The informal comments made by the Port of London Authority highlight the significant issues related to river working. Whilst none of these are deemed as "show-stoppers" from a technical viewpoint it is clear that a number of challenging agreements with stakeholders will need to be made.

### *Cost & programme*

- 6.10 In the limited period available for the review it has not been possible to undertake a thorough review of the cost model. The schedule of cost components has however been reviewed and these appear to be realistic.
- 6.11 The construction programme is considered to be realistic. Opportunities clearly exist to shorten the overall duration for off-site casting. It should be noted that the 48 month programme may be effectively extended if there is a requirement for work to start in a particular season.
- 6.12 There is a concern that the QRA approach needs further work. During the review and discussions with the team some potential for double counting of risks has been identified and

this needs to be resolved. It is acknowledged that the project team has identified this issue and is working to address it.

## **7 Sustainability and environmental impact**

### ***Sustainability***

7.1 It is understood that a high level sustainability appraisal has been undertaken for the River Crossing programme including the Silvertown crossing but that no specific separate study had been conducted to differentiate between the bored and immersed options. Nonetheless the team have undertaken a significant amount of relevant work and have agreed to prepare a note to explain what has been done to date and what assumptions have made for the following areas:

- whole-life costing, including maintenance efficiency,
- minimising carbon footprint,
- maintenance liabilities beyond the 30 year concession period.

### ***Environmental Impact***

7.2 Both bored and immersed tunnels will involve extensive excavations in Greenwich and Silvertown through old industrial sites. Thus there is a risk of ground contamination affecting deep ground works. The issues involved are likely to include contaminated spoil removal, contaminated ground water migration and contamination ingress from adjacent sites (i.e from land outside the immediate footprint of the scheme). In consequence the evaluation of the risk must consider a greater area than the site footprint itself and should include anywhere that contamination may come from or go to as a result of the works.

7.3 These issues are likely to affect all the construction options (bored, immersed, long option, short option etc). Consideration should be given to whether the extent of this effect varies significantly between options.

7.4 The review team understand a privately financed procurement model is preferred for the project.

7.5 The reviewers are concerned that the contamination risk, particularly associated with the old gas works in Greenwich, could affect private funding of the scheme. It is possible that the funding organisations considering financing the works may consider the contamination an undesirable risk and price it accordingly (or decline to price it). It is suggested that consideration be given to the possibility of early investigation of this risk and also the possibility of some form of enabling works to reduce risk in the main contract.

7.6 Construction noise may also be a source of differentiation between options. Both construction options will involve significant elements of above ground works, however, the reviewers note in particular the extent of the piling close to the river bank for the immersed option. It appears from the drawings that these are proposed to be installed using low noise piling processes. However, given the size of the piles in question, the reviewers are uncertain of the feasibility of this. If a low noise process proved inadequate the reviewers are concerned that significant amounts of percussive piling might be required which could cause significant noise issues.

7.7 The PRG has not seen evidence of significant consultation with the Environment Agency. It is likely that the Environment Agency will have views in particular on work close to the river and also in contaminated ground. It would seem essential to seek an initial dialogue.

## **Whole Life Cost considerations**

- 7.8 Whole life cost is a possible source of differentiation between the options. Under the proposed procurement approach the first thirty years maintenance cost will be picked up by the DBFM entity. However, TfL has an interest because it will decide which form of tunnel solution will be used and it will inherit any residual issues at the end of the concession.
- 7.9 Maintenance costs beyond 30 years will be a TfL liability.
- 7.10 The business case information provided to the PRG does not differentiate the maintenance costs between construction types.
- 7.11 It is the view of the PRG that maintenance costs are a second order consideration in differentiating between the construction options. Therefore the absence of a construction method specific whole life cost assessment is not a major concern.

## **8 Health and safety considerations**

### **Construction Health and Safety**

- 8.1 In the materials reviewed the scheme options (and particularly the long bored and long immersed tube tunnel options) are differentiated mainly on the tunnel works themselves. Limited information is provided on construction health and safety. The PRG has not seen a comparison of risks between the options considered.
- 8.2 In accordance with the CDM regulations construction health and safety should be a design consideration even at feasibility stage.
- 8.3 From the information received the PRG considers that there are differences in the construction health and safety risks associated with the main options because they include different construction processes.
- 8.4 For the immersed tube tunnel scheme activities to consider would include:
- Casting operation - large scale reinforced concrete work, possibly some opportunity to mitigate risk through factory type conditions and production line working
  - Floating and towing – work over water, not mainstream UK construction risks but these operations are not anticipated to introduce unusually high construction health and safety risks.
  - Dredging and immersion – this will include an element of diving work which is an inherently high consequence operation from a health and safety viewpoint. Note that the diving will be in tidal water, poor visibility and in close proximity to machinery and structures.
  - On land works - will probably be broadly similar to the bored option (ie same order of magnitude of risk)
- 8.5 For the bored tunnel scheme activities to consider would include:
- Soft ground tunnelling using a tunnel boring machine - main risks associated with machinery and working underground including underground transport.
  - Cross passages – break outs

- 8.6** These issues have not been addressed to any great extent in the material received. The reviewers consider that a formal comparison of the construction health and safety implications should be undertaken.

### ***Safety in Operation***

- 8.7 The preferred option for costing purposes is currently presented as being the bored tunnel with 100m cross passage spacings. There is some inconsistency amongst the earlier reports as to the desired spacing.
- 8.8 The project recognises scope to optimise spacing through a quantified risk analysis. This would also take account of other factors including fire suppression systems and other incident management facilities that could be used in the tunnel. The result may be a significant increase in the spacing. The PRG endorses this approach and notes that the decision on cross passage spacing needs to be cogniscent of construction risk issues such as the mining under the river or in contaminated ground. It should also consider likely behaviour in the tunnel including factors such as whether road users will be willing to evacuate towards a fire if that is the direction of the nearest passage.
- 8.9 It would be beneficial to establish the tunnel safety group at the earliest opportunity and seek its input to decisions affecting safety in operation. Advice from existing highway tunnel operators, for example through the Road Tunnel Operator Association may also be beneficial.
- 8.10 The detail of this issue is expected to be resolved through subsequent design development of the bored tunnel case.

## **9 General observations**

### ***Conduct of project team***

- 9.1 The reviewers found the documents provided by the team to be generally of a high technical quality. Similarly the project team showed a good command of the subject matter and provided helpful responses to queries. In several cases the team prepared supplementary papers following meetings which greatly assisted the review. Additionally the team's summary report of December 2013 has been of considerable value in clarifying a complex picture and history of decision-making.

### ***Robustness of project decision making process***

- 9.2 It is apparent that the project development has been over a prolonged period of time and has included a number of discrete studies. This seems to have contributed to some inconsistencies in the documents particularly where baseline assumptions have changed over time. A number of key decisions appear to have been made (or confirmed) relatively recently yet appear pre-judged in earlier reports. For example:
- The July 2013 tunnel report pre-supposes the bored option is selected yet various documents justifying this decision are dated later,
  - The business case document was compiled at a time when the bored option was considered to have 15% lower cost yet the current costing indicates the two options to be very similar in cost.
- 9.3 In consequence, caution must be exercised in drawing conclusions from a variety of sources compiled at different times and with different assumptions.
- 9.4 The PRG recommends that the project compiles a single decision tree to map the decision making. This should both trace the decisions made to date and plan the anticipated future

design decisions. This will assist planning and also aid presentation of the case for the DCO process, public enquiry etc.

- 9.5 The PRG notes that in the final summary (as reported in December 2013) the decision is the product of a semi quantitative process. Some but not all areas are quantified. Perhaps most notably environmental impact is not expressed in monetary terms. Hence part of the decision to discount the immersed option (if that is the final decision) will be qualitative. The reviewers consider that this is not an unreasonable approach but the client should be aware of this compromise.
- 9.6 The reviewers also noted that the client decision to enter into the DCO process prior to procuring the main works means that the true cost of the main options cannot be market tested.

### ***Balance in the treatment of different disciplines***

- 9.7 The reviewers considered that the work to develop the design of the tunnel structures (both bored and ITT) and associated tunnels systems appeared thorough and well documented. The extent of this work is generally appropriate to the current stage in the project life cycle.
- 9.8 It was noted that some other aspects of the work did not appear to have been developed to the same level. In particular only limited information was presented on the likely environmental impacts of the work in the vicinity of the river, the likely remediation of contaminated land and on sustainability. Additionally there was no formal study of construction safety for each option. All of these factors have potential to influence the choice of a preferred option.

### ***Construction cost and programme***

- 9.9 The reviewers were given visibility of the schedule of costs which was beneficial in understanding the project.
- 9.10 In general the reviewers judge that the durations assumed tend to be robust (and appropriate to the requirements of the EIA, necessitated by future statutory processes) and so when optimism bias is added the projected result would be expected to be close to a maximum cost. This is particularly the case for the bored option where the times allowed appear generous based on a brief comparison with other recent river crossings.
- 9.11 In version 5 of the December 2013 addendum (the latest available cost summary) the difference between the main options (B and E) is 2% cost which is far smaller than the uncertainty on the costs. Estimate uncertainty is likely to be at least 15% if not significantly higher.
- 9.12 Taken at face value this suggests that the decision should be based on factors other than cost. However, note that this depends on a relatively crude costing of the immersed tube tunnel.
- 9.13 The data reviewed did not include a whole life cost model although it was noted that the business case model includes figures which indicate whole life cost has been considered. It was not apparent whether whole life costs for the different construction options had been evaluated but the reviewers consider it unlikely that there would be major differences. Further advice on this could be sought from other highway tunnel operators.
- 9.14 In the data originally presented to the review an element of double counting of risk was identified. Following discussion this was acknowledged by the team and is being corrected.
- 9.15 The reviewers note that the quantified risks in the papers presented are of fairly similar values for the bored and immersed tube tunnel options, whereas the risk profile for the two different options was expected to be very different. On inspection it is apparent that there are a number of significant risk factors which are not included in these costs. These generally relate to consents and environmental issues which would be expected to impact more adversely the risk for the immersed tube tunnel option.

- 9.16 Additionally it was noted that the risk values for the bored tunnel are based on relatively detailed design whereas elements of the immersed tube tunnel option with off site casting the risk was based on a “broad brush” estimate.
- 9.17 For these reasons the PRG considers the current quantified risk values should be treated with caution in any decision making process. The PRG suspects that more comprehensive analysis would probably show relatively higher risk for the immersed tube tunnel option.
- 9.18 PRG view is that the nature of the risks and uncertainties associated with the ITT means that certainty of outcome (in terms of delivery to programme and cost) is likely to be significantly higher with the bored option.

### **Consents risks**

- 9.19 The reviewers note that a major difference between the bored and immersed tube options is in the extent of disturbance to the river itself. Although not permanent this will persist over some time and could significantly impact the river use, river environment and the flood defences. This means a number of agencies including the Port of London Authority and the Environment Agency will be significant stakeholders. These agencies might be expected to resist a scheme involving works in the river unless they see a compelling reason not to adopt the bored solution which will have much less impact on the river.
- 9.20 The reviewers note that the relevant statutory consultees, while expressing preferences, have not judged the immersed tube tunnel option to be out of the question. Therefore, in the view of the PRG, those consultees’ *preferences* should not disproportionately affect option selection for a publically funded project.
- 9.21 The reviewers also note the legal advice that the “DCO may authorise the compulsory acquisition of land only where the land is "required for the development" and there is a "compelling case in the public interest". The reviewers are concerned that there appears to be a significant consents risk if TfL were to progress the immersed tube tunnel scheme to DCO based on the information presently available. It appears possible that adversely affected parties might raise a sustainable objection to the DCO land take for the immersed tube tunnel (permanent works). The argument would be that there was no compelling case in the public interest not to progress the bored tunnel option with its potentially reduced (surface) land take.
- 9.22 A separate consents risk would arise in the event that the scheme was promoted using one of the short tunnel options. This would necessarily involve a pre-DCO planning application to make changes to the masterplan for the Greenwich peninsular. It is clear that the London Borough of Greenwich would probably resist this change, and so the application might be rejected. This is represented in the final Summary and Comparison of Tunnel Options document as a risk incurring a two year delay (a cost of around £50m), however, in reality such a result would render this option impossible to complete.

## **10 Opportunities**

- 10.1 Two principal opportunities were noted during the review.
- 10.2 In the bored tunnel option there is a significant amount of unused space under the carriageway. This presents an opportunity either for TfL to make use of the space for some part of the tunnel systems or ventilation. Alternatively, or possibly in conjunction with TfL use, there is opportunity to lease the space for other service providers as a river crossing for cables or other infrastructure. It is acknowledged that the project team is aware of this potential and it is recommended that this opportunity is investigated further.
- 10.3 The reviewers also consider that there may be a significant opportunity associated with improving knowledge of contamination on the sites in advance of the main works procurement (in particular on the Greenwich side). The site is known to have been associated with an old and large gas works and therefore has a high risk of contamination (with relatively shallow remediation, when compared to the depths of proposed cut-and-cover construction). It is

possible that those offering finance to the future DBFM entity will view the contamination risks as being commercially undesirable. This could manifest in significant, and arguably, unnecessarily high cost-risk premium to TfL. There may be opportunity to investigate and treat contamination through some form of dedicated enabling works and thus reduce the overall cost to TfL.

## 11 Conclusions

- 11.1 The PRG has concluded that both the bored and immersed tube tunnel variants are technically feasible and use tried and tested technologies.
- 11.2 The estimated capital cost of the schemes is too similar to be a differentiating factor given the current level of design development. The decision to go into the DCO process with a single option prior to procurement precludes market testing the cost of the options.
- 11.3 In contrast the risks associated with the two tunnel options for this location are sufficiently different to provide a means of differentiation. In particular the consent risk associated with the immersed tube option is judged significantly greater. This review has not identified any compelling reason to adopt the immersed tube tunnel and so concludes that the bored tunnel option is lower risk and therefore preferable.
- 11.4 The major risks associated with the immersed tube tunnel are associated with disturbance to the river operations and environment and the likelihood of strong stakeholder objections to the river works. This significantly reduces confidence in obtaining consents for this option which in turn reduces confidence in the ability to deliver the tunnel to time and budget when compared to the bored tunnel. These risks cannot be fully quantified at this time but, after due consideration, the PRG considers that the partly qualitative comparison is reasonable.
- 11.5 The PRG considers that the adoption of the “long” tunnel option is reasonable given the likely planning and resultant schedule risks associated with the “short” option. This view is independent of whether the tunnel is bored or immersed tube.
- 11.6 In the event that a bored tunnel option was to be selected, the PRG supports the use of a risk-based approach to determine the cross passage spacings and anticipates that this may result in spacings of significantly more than 100m and therefore a reduced need for cross passage construction under the river or in contaminated land.
- 11.7 In the event that an immersed tube tunnel was to be selected the PRG considers that the casting location does not need to be specified by the client at this stage. Furthermore, an approach considering the possibility of off site casting would be reasonable.
- 11.8 The conclusions of the PRG are caveated by the fact there are some omissions and inconsistencies in the material presented for the review. Recommendations are made on actions to address these issues but it is not considered likely that resolution of these will influence the overall conclusions.

## 12 Recommendations

- 12.1 The reviewers recommend that the project consider the following additional actions.

### ***Project process***

- 12.2 Prepare a decision tree showing how the various issues considered are linked and lead to the conclusion on the preferred method. This decision tree should reference all the supporting evidence.

### ***Stakeholders***

- 12.3 Consult with the Environment Agency in a similar way to the earlier consultations with the Port of London Authority and the London Borough of Greenwich in order to get an initial

understanding of the Agency's likely position in relation to work affecting the river and also contaminated land.

### ***Construction health and safety***

- 12.4 Formally assess and document differences in construction health and safety risk between the construction options considered.

### ***Ground investigation***

- 12.5 Consider early ground investigation to reduce risk associated with scour features, man-made obstructions or similar issues under the river.
- 12.6 Consider further investigation of contamination issues. Review whether the extent to which different options would be affected is significantly different.
- 12.7 Review the developing strategy of contaminated land risk transfer to the main DBFM contractor, and consider opportunities that may exist to address this risk differently, and achieve overall cost savings to TfL.

### ***Piling near the river associated with immersed tube construction***

- 12.8 Review the feasibility of silent piling techniques for structures near the river bank. Review the implications for disturbance if silent techniques are not achievable.

### ***Maintenance***

- 12.9 Consult with the Road Tunnel Operator's Forum on experiences of maintenance issues and costs for the tunnel types being considered.

## **Appendix A      Peer Review Group Terms of Reference**



## Transport Strategy and Planning

Silvertown Tunnel  
Independent Peer Review Group

Terms of Reference

Status:	First Issue
Version:	1.0
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# 1 Introduction & Purpose

This document sets out proposed Terms of Reference for the Silvertown Tunnel Independent Peer Review Group (IPRG). The setting up of a IPRG was identified by the River Crossings Sponsor Group as part of an agree 'Plan of Action' to respond to concerns raised by IIPAG during the Gate B review process and reported at Surface Board (24<sup>th</sup> September 2013).

One of IIPAG's principle concerns related to the lack of independent, expert scrutiny regarding the selection of a preferred tunnel option. Specifically IIPAG recommended that the decision to proceed with a bored tunnel in preference to an immersed tube tunnel should be scrutinised including all relevant information and material regarding costs, risks and constraints. IIPAG also suggested that expert tunnelling input be sought from London Underground and Crossrail where similar expert review groups have been set up.

## 2 Silvertown Tunnel Peer Review Group

### 2.1 Role and function

The PRG's main purpose is to provide independent expert scrutiny of the Silvertown Tunnel project and in particular the decision to progress with a bored tunnel option in preference to an immersed tube tunnel option.

The specific roles and functions of the IPRG are as follows:

- Provide independent, expert advice to assist the project
- Review relevant project documentation and material pertaining to tunnel options
- Seek a consensus view on recommendations and findings
- Report recommendations and findings to the Project Sponsors

(NB: No decision has yet been made about the future role of the PRG beyond the initial review of preferred tunnel option. The future need and role of such a group will be considered further by the River Crossing Sponsor Group once the initial review has been concluded.)

### 2.2 Scope & remit

The current scope and remit of the IPRG is to review the selection of preferred tunnel option with respect to the following technical and engineering aspects:

- Design – methodology and approach, and associated risks, opportunities and costs
- Construction – methodologies, logistics, safety and associated risks, opportunities and costs
- Sustainability and Environmental impacts of the proposals

In addition, in light of land-use and other physical constraints on alignment a key assumption of the review is that the proposed locations of the tunnel portals are fixed. Hence the review will focus on establishing the best tunnel solution to link these 'fixed' portal locations.

The PRG will have access to all previous technical studies, surveys and engineering reports and will have the support and assistance of the project team. A list of reference documents relevant to this review can be found at Appendix A.

## 2.3 Membership and Chair

The membership of the IPRG has been selected to provide independent and expert knowledge of tunnel design and construction, and environmental impact assessment. The IPRG will be supported by technical advisors with specific knowledge of the project. The proposed IPRG membership and technical advisors is set out below:-

Name	Current role and organisation	Area of expertise
<b>IPRG Members:</b>		
Keith Bowers	Principal Tunnel Engineer , London Underground & Member of Crossrail Engineering Expert Panel	Tunnel design, construction and operation
David Court	Tunnelling Consultant, BAM Nuttall	Tunnel construction
Colin Eddie	Engineering Director, Morgan Sindall	Tunnel construction
Ian Gee	Principal Tunnel Engineer, Atkins	Tunnel design
Donald Lamont	Independent Hyperbaric and Tunnel Safety Consultant & Member of Crossrail Engineering Expert Panel	Tunnel construction safety
<b>Technical Advisors:</b>		
Jonathan Baber	Project Director, Mott MacDonald	Tunnel designer
David Sharrocks	Associate, London Bridge Associates	Construction advisor
Neil Kedar	Head of Consents and Environmental Assessment, TfL Planning	Environmental impact assessment & Consents

It is proposed that Keith Bowers will act as chair subject to consensus agreement of the group. Secretariat support for IPRG will be provided by the TfL project team. The chair will be responsible for guiding the work of the group and ensuring that all relevant matters are properly considered and that all recommendations and findings have the consensus support of the group.

### 2.3.1 Project and Secretariat

Project and secretariat support will be provided by TfL.

## 2.4 Frequency of meetings

It is initially envisaged that the PRG will need to meet on two occasions to undertake the review of preferred tunnel options as follows:

- Familiarisation and fact finding session – this is the opportunity for members to familiarise themselves with the project and all previous work relevant to the selection of tunnel options. The project team will be available to answer questions and provide background information. The meeting will then include a closed session for the panel to agree how they should approach the task.
- Review of tunnel options session – the group will discuss the pros and cons of the possible tunnel options (cut & cover combined with either bored or immersed tube) in respect of design and construction feasibility, safety and environment, risks &

opportunities. The main aim of this session will be to arrive at a consensus view on the preferred tunnel option to be progressed through Gate B.

The above sessions are likely to be 2-3 hours in duration and timetabled during November 2013. The need for additional sessions or meetings is at the discretion of the chair but must take account of the overall timescales referred to below.

## ***2.5 Required output & timescales***

The PRG will be required to present its findings and recommendations on the preferred tunnel option in a short report to the River Crossings Sponsor Group. The exact format of this report is not defined but should cover the following areas:-

- Critique of design and engineering approach
- Critique of construction feasibility, safety and logistics
- Critique of environmental impact assessment
- Critique of risks and opportunities
- Conclusions and recommendations on preferred option

The anticipated deadline for completion of the PRG report will be mid-December 2013, and the report should be submitted in electronic format to Michele Dix and Richard de Cani as lead sponsors.

### 3 Document history

<b>Edition</b>	<b>Date</b>	<b>Changes</b>	<b>Status</b>	<b>Author</b>
0.1	14/10/13	Initial draft	Draft	J Saldanha
0.2	18/10/13	Incorporating K. Bowers comments	“	“
0.3	08/11/13	Updated membership	“	“
1.0	Dec 2013	D Sharrocks replaced F Ellis	First Issue	“

### Authorised for Use:

**Approved by:** Matthew Yates \_\_\_\_\_ **Date:** \_\_\_\_\_

**Authorised by:** Michele Dix \_\_\_\_\_ **Date:** \_\_\_\_\_

**Document owner:** Jason Saldanha \_\_\_\_\_ **Date:** \_\_\_\_\_

# Appendix A

## Main reference documents:

1. Silvertown Tunnel Project Feasibility Report v.1 – TfL August 2013
2. Tunnel Engineering Report - Mott Macdonald June 2012
3. Alignment Development Report - Mott Macdonald Jan 2011
4. East London River Crossings: Assessment of Options Report – TfL December 2012
5. Sustainability Appraisal – Mott MacDonald January 2011
6. Tunnel Engineering Report - Mott Macdonald July 2013

## **Appendix B      Information received for review**

### **Silvertown Tunnel**

#### **Independent Peer Review Group**

#### **List of Reference documents**

##### **Reports**

1. Silvertown Tunnel Option Alignment Development- Mott MacDonald (MMD) Jan 2011
2. Silvertown Crossing - Tunnel Engineering – MMD Jun 2012
3. East London River Crossings: Assessment of Options – TfL Dec 2012
4. Silvertown Tunnel – Further development of Tunnel Engineering – MMD Jul 2013
5. Silvertown Tunnel Project Feasibility Report – TfL Aug 2013
6. Silvertown Tunnel – Outline Business Case – TfL Aug 2013
7. Silvertown Tunnel Option - Tunnel Engineering Addendum A – MMD Oct 2013
8. Silvertown Tunnel Development Impacts Study – Atkins Nov 2013
9. Silvertown Tunnel Options Study (Environmental Impact) – Hyder Nov 2013
10. Summary & Comparison of Tunnel Options – TfL Dec 2013

##### **Memos**

1. Cover to tunnel and risk of breach beneath River Thames – MMD Sep 2013
2. Ground risks and unexploded ordnance – MMD Nov 2013
3. Emergency response times – MMD Nov 2013
4. M&E Equipment space-proofing in the tunnel – MMD Nov 2013
5. Tunnel Options Assessment for Gate B review – TfL Nov 2013
6. Advice note – implications of promoting a DCO which would authorise construction of either a bored tunnel or an immersed tube tunnel at Silvertown. Pinsent Masons, Planning & Environment, 12 December 2013

##### **Presentations**

1. Silvertown Tunnel – IPRG Familiarisation Session – TfL 19 Nov 2013

## **Appendix C      Credentials of the Review Team**

**Keith Bowers** BSc, MSc, PhD, CEng, FICE, MIMMM, FGS

Keith Bowers is London Underground's Profession Head for Tunnel Engineering. He has engineering accountability for the railway's existing tube tunnels and shafts, new underground construction projects including major station upgrades and line extensions and ownership of technical standards. He also serves as Tunnel Asset Engineer for new works for London Overground and is a member of the Crossrail project's Engineering Expert Panel. Keith's past experience includes a mixture of research, consultancy and project delivery in the field of transport infrastructure. He has worked on tunnel design and construction, tunnel boring machine management and the operation and maintenance of road and rail tunnels.

**David Court** C.Eng. FICE

David Court was Tunnelling Manager for BAM Nuttall Ltd until his retirement in 2010. Since retirement he has been retained by BAM Nuttall as Tunnelling Consultant and Bid Manager and subsequently Project Director for the successful BAM / Ferrovial / Kier Joint Venture bid for the £500m Crossrail Western Tunnels contract. David has 46 Years of Heavy Civil Engineering with over 30 years international experience in Tunnelling including Hydropower, Metro, Railway and Water and Sewage tunnels. He has held a range of senior positions including Construction Manager and then Project Manager on the Medway Immersed Tube Tunnel from 1992 – 1996. David is a former Chairman of the British Tunnelling Society, a member of the Industry Advisory Panel for the Crossrail Tunnelling Academy, a member of Tunnel Skills and a member of the BSI committee for Safety in Tunnelling.

**Colin M Eddie** FEng, CEng, BSc, FICE

Colin Eddie has 34 years of experience in the design and construction of tunnels in the UK. He is Engineering Director of Morgan Sindall's Tunnelling Unit and Managing Director of their in-house tunnelling consultancy business (Underground Professional Services Ltd). He has led the D&C process on a number of high profile projects including; HS1 North Downs Tunnel, Heathrow T5, Lee Tunnel and Crossrail C510 (primary linings). He is a former member of the Crossrail Expert Panel and PRG for the Thames Tideway Project.

**Ian Gee** BEng(Hons), CEng, MICE, MStructE

Ian Gee is a chartered civil and structural engineer with twenty four years experience as a designer in civil engineering consultancy, specialising in the design of tunnels, ground engineering and earth retaining structures. He has worked on the planning and engineering design of a range of national and international transportation projects comprising tunnelling. He has worked on the development of projects promoted through TWA, hybrid Bill and DCO statutory processes, and has been expert witness (tunnelling and related matters) for TfL at Public Inquiry.

**Donald Lamont** BSc, MEng, PhD, CEng, FICE, FCIHT, FCIWEM

Donald Lamont had 13 years with consulting engineers mainly on site supervision on roads, bridges, pipelines and small tunnels before joining HSE. In HSE he worked for over two decades as head of tunnel and ground engineering. Donald has extensive experience of health and safety issues relating to tunnelling and tunnel operation as well as experience of drafting legislation, standards, research and guidance on health and safety in tunnels. He now runs his own consultancy. He is a member of the Crossrail Engineering Panel.