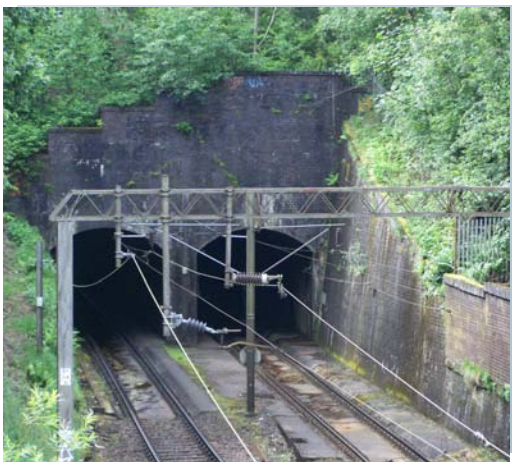
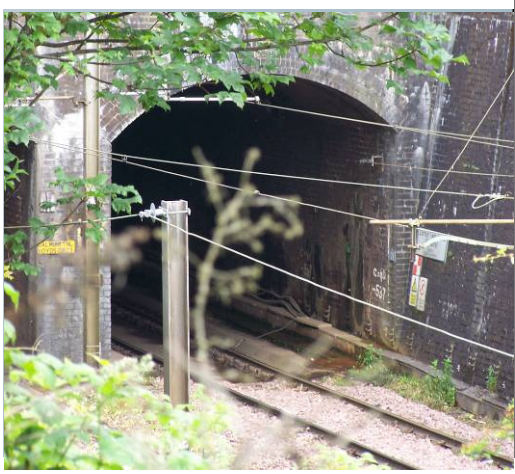
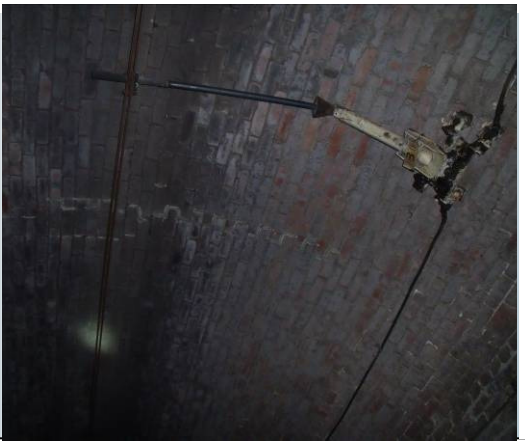
BCDP-S/082 2015/16 Tunnel Repairs – Design

YKR/ T268/023 Dalmuir Tunnel Assessment Report

September 2014







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This report has been prepared in accordance with procedure OP/P02 of Fairhurst's Quality and Environmental Management System

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Appendices

Tables

1.0 Introduction and Design Objective

1.1 Scope of Work and Tunnel Description

Dalmuir Tunnels (Structure Ref: T268/023) are located between Clydebank and Kilpatrick Station on the Yoker (YKR) line at National Grid Reference NS 489 708. The tunnels comprise of twin bore brick-lined tunnels 78m length under the Forth and Clyde Canal. The invert is a concrete slab and the lines are electrified. There is a history of flooding at this location leading to performance issues and the current drainage system comprises pipes in the four foot discharging to a sump and an associated pumping station. It is stated within the remit provided by Network Rail that there is a perception that there is insufficient capacity in the existing pipes.

The tunnels have been the subject of numerous examinations and studies, the most recent of which are:

- Structures Detailed Examination Report (October 2012);
- Bridge & Structure Examination Report, Rapid Response – Non Vehicle (September 2010).

Network Rail have included physical works within the tunnel in the capital expenditure for 2015-2016. The design remit is to develop a solution to improve the current drainage system and ensure the tunnels are effectively drained, and to repair any water damaged lining.

Fairhurst were commissioned by Amalgamated Construction Ltd (AMCO) to carry out an inspection of the tunnel in order to produce the Form 001. The findings of the inspection are contained within this assessment report, which will be included as an Appendix within the Form 001.

2.0 Summary of Work Undertaken to Date

2.1 Structures Detailed Examination Reports

Previous tunnel inspections and examination studies concluded that the general condition of the tunnel is fair to good (see Appendices 1 & 2 of this report). However, a number of specific enhancement / repair works have been identified to alleviate flooding within the tunnels. Network Rail have included physical works within the tunnel in the capital expenditure for 2015-2016, and the following design elements are indicated in the Technical Workscope in order to develop a solution to improve the current drainage system and ensure the tunnels are effectively drained:

- devegetation works at portals/sidewalls
- refurbishment of existing portal drainage
- enhancement of overall drainage system up to the pumping station
- general lining repairs/ grout injection throughout the tunnels

3.0 Visual Assessment

In order to develop the Form 001 (Approval in Principle) for the works, a visual inspection was carried out during a night shift in the early hours of 3rd June 2014. The inspection was carried out by Fairhurst engineers during an overnight possession. Access was from track level only, and the inspection utilised hand held LED lighting.

A further inspection of the tunnels was carried out during the day on 13th June 2014. The inspection was carried out by Fairhurst drainage engineers from outside the Network Rail boundary to allow an assessment of the surrounding drainage conditions.

The findings of the visual assessment are displayed on updated extracts from the Amey 2012 Detailed Examination report (Appendices 1 and 2), and summarised within the Tunnel Inspection Notes (Appendices 3 and 4). Photographs of typical defects are presented in Appendix 5.

3.1 Visual Assessment of Lined Tunnel

As noted in section 1.1 above, Dalmuir Tunnel comprises twin bore brick-lined tunnels 78m length under the Forth and Clyde Canal. The following text describes significant features noted within each section of the tunnel and associated portals, and photographs of typical defects are shown in Appendix 5 (Photographs 1.1 to 1.18).

3.1.1 Findings - Up Bore lining

The walls, haunches and crown of the Up bore are brick lined throughout the whole length of the tunnel. The Form 001 inspection confirms the findings of the October 2012 Tunnel Examination Report with regard to the condition of the lining in the Up bore, namely that *"the tunnel is in good condition. The brick arch is generally good, although brickwork throughout the crown has been cut out,* (see Photograph 1.4) *presumably to house OHLE supports (longstanding). There are several longstanding fractures on the sidewalls which remain stable".* Damp areas and areas of calcite staining are noted (Photographs 1.3 and 1.5), but the tunnel is generally dry with the exception of the core hole discussed in section 3.3.1 (Photograph 1.8). It appears that water ingress has been an ongoing issue at this location (SM3 +16m, up wall), and the brick lining in the surrounding area is likely to have undergone a substantial amount of cyclical wetting/drying. It was not possible to ascertain the condition of the brickwork during an initial survey in this area. To comment on the consequences of continual wetting, intrusive investigation is required.

In addition to the longstanding circumferential cracks which are in accordance with the 2012 report (see Photographs 1.6 and 1.7) other defects noted were small areas of open joints within the brick work at the crown.

General observations noted in the Up bore tunnel lining are presented in Table 1.

Table 1: Structural Observations – Up Bore Lining

Chainage	Location	Observations
SM0 and SM1	Up Wall	Localised wet areas
SM1 and SM2	Crown and Down Wall	Open joints and circumferential crack
SM1 and SM2	Up wall	Localised wet areas

Chainage	Location	Observations
SM2 and SM3	Up Wall	Localised wet areas
SM3 to end	Down wall	Localised wet areas
SM3 to end	Up Wall	Significant wet area located within final approximately 5m
SM3 to end	Down Wall and Haunch	Circumferential cracks

3.1.2 Findings - Down Bore lining

The walls, haunches and crown of the Down bore are brick lined throughout the whole length of the tunnel. The Form 001 inspection confirms the findings of the October 2012 Tunnel Examination Report with regard to the condition of the lining in the Down bore, namely that *"the tunnel is in good condition. The brick arch is generally good, although there is a section of removed brick for OHLE. The fractures noted in the report remain stable".*

Localised damp areas and areas of calcite staining are noted (Photograph 1.14), but the tunnel is generally dry. In addition to the open joints within the brickwork and longstanding circumferential and longitudinal cracks which are in accordance with the 2012 report, several additional cracks were noted (see Photographs 1.12, 1.13, 1.15 and 1.16).

General observations noted in the Down bore tunnel lining are presented in Table 1.

Table 2: Structural Observations – Down Bore Lining

Chainage	Location	Observations
SM0 and SM1	Crown	Open joints and circumferential crack
SM0 and SM1	Down haunch	Localised wet areas
SM1 and SM2	Down wall	Localised wet areas
SM1 and SM2	Crown, Down haunch and Up wall	Open joints and longitudinal and circumferential cracks
SM2 and SM3	Down wall	Localised wet areas
SM3 to end	Down wall	Localised wet areas
SM3 to end	Down Haunch and Up Wall	Longitudinal and circumferential cracks

3.2 Visual Assessment of Portals and Walls

In accordance with the technical work scope, which refers to a requirement for devegetation around the tunnel portals and walls, a visual assessment was made from track level. During the additional off track visit, additional photographs of the portals and associated walls were taken.

3.2.1 Findings – Up Bore Portals and Walls

The up portals and associated walls are formed entirely of brick. Vegetation and staining/seepage noted along the lowest height, most easterly end of the Clydebank wingwall

(see Photograph 1.1). Although not visible during the inspection, the 2012 Structures Detailed Examination Report identifies "*a separation joint between wall and arch, extending 1m from the top of the wall, open 5mm-10mm"*. The Clydebank side portal is in good condition with minor areas of calcite staining noted (see Photograph 1.2).

The 2012 Structures Detailed Examination Report identifies *"two step fractures through upside haunch voussoir and spandrel, open 5mm, approx 2m and 1m in length"* located within the Dalmuir headwall (see Photograph 1.9). It was not possible to inspect these in any detail from track level.

The entire Dalmuir wingwall is almost entirely obscured by moss and other vegetation. There are ten downpipes located on the wingwall (Photograph 1.10) - the open ditch at the base of the wall within the cess collects the water flow from the pipes. A gutter and downpipe arrangement located at Ch.3+16m within the tunnel also outfalls to the open ditch – see section 3.3.1 for further information. Orange deposits are being excreted through the downpipes into the open ditch.

General observations noted in the Up bore portals and walls are presented in Table 3.

Table 3: Structural Observations – Up Bore Portals and Walls

Portal	Location	Observations
Clydebank	Parapet, Headwall and Face ring voussoir	No notable features
Clydebank	Wingwall	Unable to fully inspect due to vegetation
Dalmuir	Parapet and Wingwall	No notable features
Dalmuir	Parapet and Face ring voussoir	No notable features
Dalmuir	Headwall	Step fractures
Dalmuir	Wingwall	Unable to fully inspect due to vegetation

3.2.2 Findings – Down Bore Portals and Walls

The down portals and associated walls are also formed entirely of brick. The Clydebank wingwall is in good condition. There are minor calcite deposits on the head wall (Photograph 1.11) and the 2012 Structures Detailed Examination Report notes *"diagonal bed joint fracture through eleven stone courses open 3mm max".*

The Dalmuir wingwall appears to be in good condition and with the exception of minor vegetation coverage there are no noteable features (Photograph 1.18). Four steel rods are present within the voussoir of the Dalmuir portal and the 2012 Structures Detailed Examination Report notes *"longstanding hairline step fracture from voussiors through headwall for 4m"* and *"3m long vertical fracture to central pier, open 2mm".* These were noted but were not examined in detail and can be seen in Photograph 1.17. Calcite deposits are also noted generally on the portal walls.

General observations noted in the Down bore portals and walls are presented in Table 4.

Table 4: Structural Observations – Down Bore Portals and Walls

Portal	Location	Observations
Clydebank	Headwall	Fracture
Clydebank	Parapet, Face ring voussoir and Wingwall	No notable features
Dalmuir	Parapet and Wingwall	No notable features
Dalmuir	Face ring voussoir	Steel rods
Dalmuir	Headwall	Step and vertical fractures

3.3 Drainage

Although no topographical survey information has been provided, the Dalmuir tunnels appear to be located at a low point on the Dalmuir-Clydebank section of railway with the Up bore located at a lower level than the Down bore.

No record drawings or survey information has been provided for the surface water drainage serving the Dalmuir tunnels and it is recommended that a drainage survey (including confirmation of all pipe sizes, pipe material, pipe invert levels, chamber invert level, chamber cover levels and a CCTV survey to confirm the network condition) is carried out.

An initial drainage investigation was carried out by AMCO engineers during a night shift in the early hours of 10th August 2014. This initial investigation provided limited information on the sizes, condition and levels of the existing drainage infrastructure, but was inconclusive in terms of providing sufficient information to fully assess the capacity of the existing drainage infrastructure. The spot level information received for the tunnel drainage carrier pipes suggest that there is a low point in the drainage system within an area which should have a continuous fall.

The following description is provided based on the internal tunnel inspection carried out on 3rd June 2014, the external inspection of 13th June 2014 and the initial drainage investigation by AMCO of 10th August 2014. The assumed tunnel/track drainage infrastructure is shown on drawings 103589/YKR/T268/023/2001 and 103589/YKR/T268/023/2002.

All track drainage from the south and from the tunnels is collected to the north side of the tunnels and discharged to the Dalmuir Pumping Station located 75m to the north of the tunnels. Assessment of the Dalmuir Pumping Station is not included as part of these works.

3.3.1 Findings – Up Bore Drainage

Track Drainage

The Up bore is drained via a 150mm diameter carrier pipe installed within a concrete surround and located in the cess on the north side of the tunnel. Access to the carrier pipe can be made via the cess at the Clydebank end of the tunnel (see Photograph 2.1). The carrier pipe was found to be damaged in several locations and access points along the carrier pipe were found to either have concrete slab covers missing or broken (see Photographs 2.2 to 2.7).

There are multiple positive drainage connections from the concrete tunnel invert to the carrier pipe. It is assumed that the carrier pipe collecting tunnel drainage connects to the track drainage discharging to the Dalmuir pumping station to the north west. Information received from AMCO's initial drainage investigation on 10th August 2014 suggests that there is a low point in the carrier pipe run within the Up bore. If this is correct, then the carrier pipe will be unable to drain fully by gravity and silt/sediment will accumulate in the low point. All levels and pipe routes of the drainage system serving the tunnel must be confirmed to inform the detailed design of any remedial works.

The drainage connections from the concrete invert slab were also found to be partially blocked with silt and standing water and silt deposits were found in the tunnel invert during the inspections of 3rd June and 10th August 2014. Standing water was also observed during the inspection of 13th June 2014 (see Photograph 2.8).

Tunnel Structure

Localised areas of dampness and staining were observed during the inspection of 3rd June 2014. Remedial works associated with repairs to the brick lining are identified in section 4.1.

Water ingress through a corehole on the side wall of the UP bore at Ch.3+16m was previously identified during the inspection of 7th October 2012 and a gutter and downpipe arrangement subsequently installed. This arrangement was collecting water ingress through the corehole during the inspection of 3rd June 2014 (see Photograph 2.9), but during the inspection of 13th June 2014, a jet of water was observed to be spouting over the gutter and onto the track (see Photograph 2.10).

Clydebank Portal

The condition of the Clydebank portal of the Up bore is also described in section 3.2.1.

The portal wingwall was found to be in good condition with staining observed at the east end.

Dalmuir Portal

The condition of the Dalmuir portal of the Up bore is also described in section 3.2.1.

The portal wingwall was found to be heavily vegetated and obscured by moss (see Photograph 2.11). Ten horizontal drainage pipes through the wingwall were observed each with downpipes discharging to an open channel in the cess along the bottom of the wingwall (see Photograph 2.12). This open channel appears to discharge to the end of the 150mm carrier pipe through the tunnel which

The wingwall drainage pipes were generally found to be in good condition but orange silt deposits were observed in the outlets from the downpipes thus affecting the wingwall drainage capacity (see Photograph 2.14).

Two inspection chambers were also observed in the cutting above the wingwalls, but these were not inspected or opened during the inspections (see Photographs 2.15 and 2.16).

3.3.2 Findings – Down Bore Drainage

Track Drainage

The Down bore is drained via a 150mm diameter carrier pipe installed within a concrete surround and located in the cess on the north side of the tunnel. The condition of the carrier pipe has not been confirmed, but there was no evidence of damage to the concrete surround

evident. Access to the carrier pipe can be made via the cess at the Clydebank end of the tunnel (see Photograph 2.17).

Information received from AMCO's initial drainage investigation on 10th August 2014 suggests that there is also a low point in the carrier pipe run within the Down bore. If this is correct, then the carrier pipe will be unable to drain fully by gravity and silt/sediment will accumulate at the low point. All levels and pipe routes of the drainage system serving the tunnel must be confirmed to inform the detailed design of any remedial works.

There are positive drainage connections at approximately every 3m along the length of the tunnel (see Photograph 2.18). No standing water found in the tunnel invert during the inspection of 3rd June 2015.

The track drainage from the south of the tunnels appears to be collected via cess drainage and is conveyed through the tunnels via a separate 300mm diameter carrier pipe also located in the cess on the north side of the Down bore. This carrier is set at a higher level than the tunnel invert and tunnel drainage carrier pipe as the pipe joints can be seen above the top of concrete haunch (Photograph 2.19).

Tunnel Structure

Localised areas of dampness and staining were observed during the inspection of 3rd June 2014. Remedial works associated with repairs to the brick lining are identified in section 4.1.

A series of weep holes were observed at the bottom of the tunnel walls along the south side of the Down bore (Photograph 2.20). Seepage through the holes was observed and it is recommended that the weep holes are inspected regularly and cleaned as part of a regular maintenance regime for the tunnel drainage.

Clydebank Portal

The condition of the Clydebank portal and wingwall of the Down bore is described in section 3.2.2.

No positive drainage features are visible.

Dalmuir Portal

The condition of the Dalmuir portal and wingwall of the Down bore is also described in section 3.2.2.

No positive drainage features are visible.

4.0 Structural Work

4.1 Tunnel Lining, Portal and Sidewall Repairs

4.1.1 Design Approach

Given the type of defects noted in the tunnel, it is considered that the majority of the repairs will comprise only superficial pointing of areas which display open joints, and pointing of specific fractures/open joints and date tabbing. It is considered appropriate that the repairs be carried out in line with accepted Network Rail standards as detailed in the Technical User Manual for the Application of Standard Tunnel Repairs (NR/CIV/SD/TUM/520, Rev A02, dated June 2009).

Sporadic areas of minor water ingress were noted, and it is possible that after detailed inspection, and intrusive investigation there may be the requirement to spot replace bricks in the event that they are considered to be unfit for purpose. Additionally, in one particular area which has been subjected to a period of continual wetting, it is considered that grout injection is an appropriate solution. Both repairs can be carried out in line with the accepted Network Rail standards noted above.

4.1.2 Outline Methodology

The repairs are considered to be minor, standard repairs, the specification for which is presented on Network Rail Drawing NR/CIV/SD/520A Tunnel Lining Maintenance Repair – Standard Drawings: Specification for the Works. Reference may also be made to the accompanying drawings:

- NR/CIV/SD/525A Tunnel lining cross pinning and grouting
- NR/CIV/SD/526A Stitching of Cracks between brick spandrel/voussoir and tunnel lining
- NR/CIV/SD/527A Stitching of Cracks
- NR/CIV/SD/528A Stitching of Transverse Cracks in Brickwork
- NR/CIV/SD/529A Spot Replacement of Bricks

5.0 De-vegetation Work

5.1 De-vegetation of Portal Structure and Headwall

5.1.1 Design Approach

De-vegetation of all four portal structures and portal headwalls are required to allow detailed inspection and also to reduce the risk of future degradation from root jacking. Localised areas of up upper slope located behind the up bore, up side wingwalls is also required. All vegetation must be removed, with stems and trunks cut as close to the structure as possible, and then treated with herbicide to prevent re-growth.

5.1.2 Outline Methodology

The de-vegetation will require work at height and in close proximity to OHLE. Appropriate safety measures must be taken in accordance with working at height regulations (i.e. industrial rope access), and isolations and blockages must be in place whilst work is undertaken.

Reference should be made to the Design Assessment Forms (Designer's Risk Assessments) which will be produced with the Form 001.

6.0 Drainage Enhancement/Repair

6.1.1 Design Approach

The review of the Bridge & Structure Examination Report, Rapid Response – Non Vehicle report dated 23rd September 2010 and visual inspection of the tunnels on 3rd and 13th June 2014 suggests that the capacity and condition of the carrier drain and associated number and

condition of drainage connections through the Up bore is insufficient to cope the require design event in accordance with Network Rail standards.

No record drawings or information has been provided to confirm the existing drainage infrastructure.

A hydraulic model of the drainage system will be constructed to confirm the capacity of the existing network and to determine the scope of any remedial/enhancement works which may be required to increase the capacity of the drainage system.

6.1.2 Outline Methodology

To enable a hydraulic model of the drainage system to be constructed, a full drainage survey is required.

The drainage survey should confirm all pipe sizes, pipe materials, pipe invert levels, chamber invert levels and chamber cover levels to confirm the drainage network serving the tunnels. A CCTV survey should also be carried out to confirm the network condition.

Following completion of the network modelling exercise, the scope of any remedial/enhancement works will be identified and submitted as part of the Form 003 approval process.

It is envisaged that the works may involve the replacement of the existing carrier pipe encased in concrete through the Up and Down bores and the installation of additional connection pipes.

7.0 Design Summary

7.1 Structural Work

Based on the observations made during the inspection, it is considered that the areas earmarked for lining repair work can be remediated through standard brickwork repairs, localised areas of grouting, and stitching of cracks. Investigation in the form of coreholes may be required at detailed design stage to determine the condition and thickness of the brick lining in the areas where grout injection is considered to be necessary.

The Form 001 Approval in Principle will therefore be presented for these repairs with the relevant Network Rail Standard Details. Designer's Risk Assessments (Design Assessment Forms) will be produced.

The exact locations where general lining repairs are required will be confirmed at detailed design (Form 003 stage), however the locations at which the remedial solutions are likely to be employed within the Up bore are presented in Appendix 3 and summarised as follows:

Table 5: Up Bore Portal, Sidewall and Lining Repair Works Required

Portal	Location	Work required
Clydebank	Wingwall	Undertake devegetation of wall and upper slope and re-inspect. Re-point and date tab separation joint.
Clydebank	Headwall/Portal	Undertake devegetation of upper slope and re-inspect.

Portal	Location	Work required
Dalmuir	Wingwall	Undertake devegetation of wall and upper slope and re-inspect.
Dalmuir	Headwall/Portal	Undertake devegetation of upper slope and re-inspect. Re-point and date tab step fractures.
Chainage	**Location**	**Work Required**
SM0 and SM1	Up Wall	Localised wet areas – general lining repairs/grout injection.
SM1 and SM2	Crown	Re-point open joints in crown.
SM1 and SM2	Down Wall	Point repair and date tab circumferential crack.
SM1 and SM2	Up wall	Localised wet areas – general lining repairs/grout injection possible.
SM2 and SM3	Up Wall	Localised wet areas – general lining repairs/grout injection possible.
SM3 to end	Down wall	Localised wet areas – general lining repairs/grout injection possible.
SM3 to end	Up Wall	Grout injection at end of tunnel at significant wet area. Coring required to determine lining thickness.
SM3 to end	Down Wall and Haunch	Point repair and date tab circumferential cracks.

The locations at which the remedial solutions are likely to be employed within the Down bore are presented in Appendix 4 and summarised as follows:

Table 6: Down Bore Portal, Sidewall and Lining Repair Works Required

Portal	Location	Work Required
Clydebank	Wingwall	None.
Clydebank	Headwall/Portal	Undertake devegetation of upper slope and re-inspect. Re-point and date tab fracture.
Dalmuir	Wingwall	Undertake devegetation of wall and upper slope and re-inspect.
Dalmuir	Headwall/Portal	Undertake devegetation of upper slope and re-inspect. Re-point and date tab step and vertical fractures.
Chainage	**Location**	**Work Required**
SM0 and SM1	Crown	Re-point open joints in crown and point repair and date tab circumferential crack.
SM0 and SM1	Down haunch	Localised wet areas – general lining repairs/grout injection possible.

SM1 and SM2	Down wall	Localised wet areas – general lining repairs/grout injection possible.
SM1 and SM2	Crown	Re-point open joints and repair and date tab longitudinal crack.
SM1 and SM2	Up wall	Repair and date tab circumferential crack.
SM1 and SM2	Down haunch	Re-point open joints.
SM2 and SM3	Down wall	Localised wet areas – general lining repairs/grout injection possible.
SM3 to end	Down wall	Localised wet areas – general lining repairs/grout injection possible
SM3 to end	Down Haunch	Repair and date tab longitudinal crack.
SM3 to end	Up Wall	Repair and date tab circumferential cracks

7.2 Drainage Enhancement/ Repair

Based on the observations made during the inspections, it is envisaged that the drainage enhancement works will involve the replacement of the existing carrier pipes encased in concrete through the Up and Down bores and the installation of additional connection pipes.

Further investigation work is required to confirm the connectivity of all track, tunnel and cutting drainage to the Dalmuir Pumping Station. Pipe sizes, pipe material, pipe invert levels, chamber invert levels, chamber cover levels should be confirmed as part of the investigation and it is recommended that a CCTV survey is also carried out to confirm the condition of the existing drainage infrastructure.

8.0 Site Inspection and Monitoring

8.1 Site Inspection

It is recommended that the works be set out in conjunction with the Designers to confirm that any design assumption with regard to the position and nature of the works is as per the conditions encountered on site. If conditions are uncovered that are not in line with the anticipated conditions then the Designer should be contacted immediately for further instruction.

8.2 Infrastructure

Services information will be procured from Network Rail/ AMCO and will be presented with the Form 001. The works should proceed in a manner which does not affect any drainage or OHLE infrastructure.

9.0 Further Considerations

9.1 Constraints to Inspection

The inspection of the tunnel was undertaken from track level only. No intrusive work was undertaken at the time of inspection which would confirm or otherwise that water ingress has caused significant degradation of the brickwork namely at the up bore up wall at SM3 + 16m.

Track drainage chamber covers were lifted by AMCO during the initial drainage investigation on 10th August 2014 to determine chamber depths and dimensions, but no survey work was undertaken to determine the connectivity or condition of the drainage infrastructure. Spot levels were only taken during the AMCO survey and these were not tied back in to any bench mark (either temporary or permanent).

9.2 Request for Further Information

A drainage survey including confirmation of all pipe sizes, pipe material, pipe invert levels, chamber invert levels, chamber cover levels and a CCTV survey to confirm the network condition and connectivity is required to enable a detailed assessment of the existing drainage infrastructure and drainage remedial/enhancement works to be identified.

Information regarding the exact details of the brick lining – i.e. no. of brick courses is required to inform the detailed design of grout injection. If there are no existing detailed records of the lining, coring of the walls will be required.