



C300/410



Western Tunnels & Caverns Project Final Monitoring Report

Tottenham Court Road Station – Manual Monitoring

CRL Document No. **C300-BFK-C4-RGN-CRT00_ST005-53006**

Contract MDL reference: C14.022

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This document has been reviewed by the following individual for coordination, compliance, integration and acceptance and is acceptable for transmission to the above stakeholder for the above stated purpose.

Sign: _____ Name: _____ Role: _____ Date: _____
 Sign: _____ Name: _____ Role: _____ Date: _____

2b. Review by Stakeholder (if required):

Stakeholder Organisation	Job Title	Name	Signature	Date	Acceptance
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3. Acceptance by Crossrail:

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Reviewed/Accepted by: (signature)	Print Name	Position:	Date: 02/12/16	
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1. Purpose and Scope

The purpose of this report is to supplement the Grout Shaft final reports produced for the Tottenham Court Road area, as listed in Table 1. These reports provide a summary of the observed movements relative to the works at Tottenham Court Road Station in accordance with the requirements of the Instrumentation and Monitoring Specification KX10 C122-OVE-Z4-RSP-CR001-00007, Clauses KX10.2113 and KX10.2114. They include all manual survey data up to the termination of monitoring. However, there is additional instrumentation within the overall area of TCR station which is outside the extent of the compensation grouting arrays, as illustrated in Figure 1. This report presents the monitoring data from BRE and PLP not covered in the other reports.

KX10.2114

Close-Out Reports

Prior to the de-commissioning of any instrumentation, the *Contractor* shall produce a "close-out" report which summarises the data from the instrumentation the *Contractor* wishes to remove and relates it to the construction activities which produced any observed changes. The report shall demonstrate that the rate of change in the data has reached an acceptably small rate either in accordance with specified rates or, where no rate is specified, in relation to trigger values and an evaluation of any potential residual risks.

Report title:	Report Number:
Final and Close Out Monitoring Report:	C300-BFK-C4-RGN-CRT00_ST005-
Grouting Summary and I&M Final Report – TCR GS1	51225
Grouting Summary and I&M Final Report – TCR GS2	51226
Grouting Summary and I&M Final Report – TCR GS3	51227
Grouting Summary and I&M Final Report – TCR GS4	51228
Grouting Summary and I&M Final Report – TCR GS5	51229
Grouting Summary and I&M Final Report – TCR GS6	51230
Grouting Summary and I&M Final Report – TCR GS7	51231

Table 1 List of Final / Close Out Reports for TCR Station.

There are two areas not covered in the Grout Shaft Close Out reports as shown on Figure 1. These comprise:

1. Great Chapel Street (north of Hollen Street) and Oxford Street
2. East of Charing Cross Road

The first of these is primarily affected by works for the North Box of the Western Ticket Hall, including piling and diaphragm walling undertaken by C421 and excavation undertaken by BFK. Further works were undertaken subsequently by C422, although the scope of these is not known to BFK. The data has been adjusted to allow for movements prior to the start of BFK monitoring based on C421 final survey results (08 & 09/02/12), as supplied by CRL (see Appendix 2).

The second area is primarily affected by London Underground's TCR Station Upgrade (TCRSU) works and the only impact from C300 works is from the two TBM drives. A summary of the monitoring data is provided, with

the influence of the C300 works identified. The data has been adjusted to allow for movements prior to the start of BFK monitoring based on the contour given in Appendix 2. The contour is based on monitoring data from TCRSU provided by CRL and on the results of joint surveys undertaken by BFK and the TCRSU contractor in April and May 2013. The contour represents the best estimate of movements at 24/04/13 at the completion of BFK Grout Shaft 6 sinking and TaM drilling. A summary of the dates of TCRSU works (provided by C122) is given in Appendix 2

The rate of post-construction settlement is compared to the specified limit of 2mm/year and the slopes are compared to the slope trigger values given in the C122 I&M plan, of 1.0mm/m (1:1000) for Amber and 2.0mm/m (1:500) for Red.

The BRE data are presented in Section 2 and the PLP data in Section 3. Construction record plots are included from the adjacent grout shaft (Grout Shaft 1) for the west area which includes the activities which could produce movements in this area. For the east area the periods of the two TBM drives (westbound followed by eastbound) are indicated on the plots. The dates of construction for BFK works are given in Table 2 and the locations shown on the figures in Appendix 3.

West Area		
Western Ticket Hall South Box Excavation	17/04/2012	28/09/2012
Western Ticket Hall North Box Excavation	02/02/2014	20/04/2014
Eastbound running tunnel	25/07/2013	29/07/2013
East Area		
Westbound running tunnel	16/06/2013	21/06/2013
Eastbound running tunnel	08/09/2013	16/09/2013

Table 2 BFK Construction activity dates

The monitoring points from which data is presented are plotted in Appendix 3. A summary of the final settlements recorded on all BRE and PLP is also given on the figures in Appendix 3. It should be noted that the data from all instruments is available on the UCIMS platform.

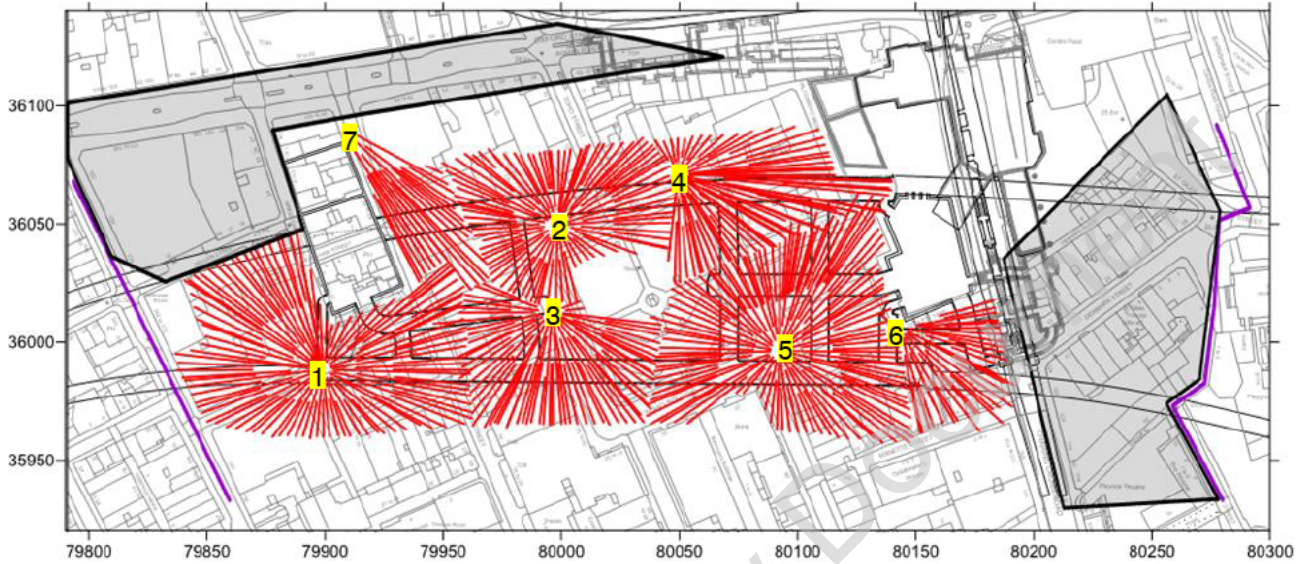


Figure 1 Extent of West and East areas not covered by Grout Shaft reports

Learning Legacy

2. Summary of the observed settlements: BRE

2.1. Hollen Street North

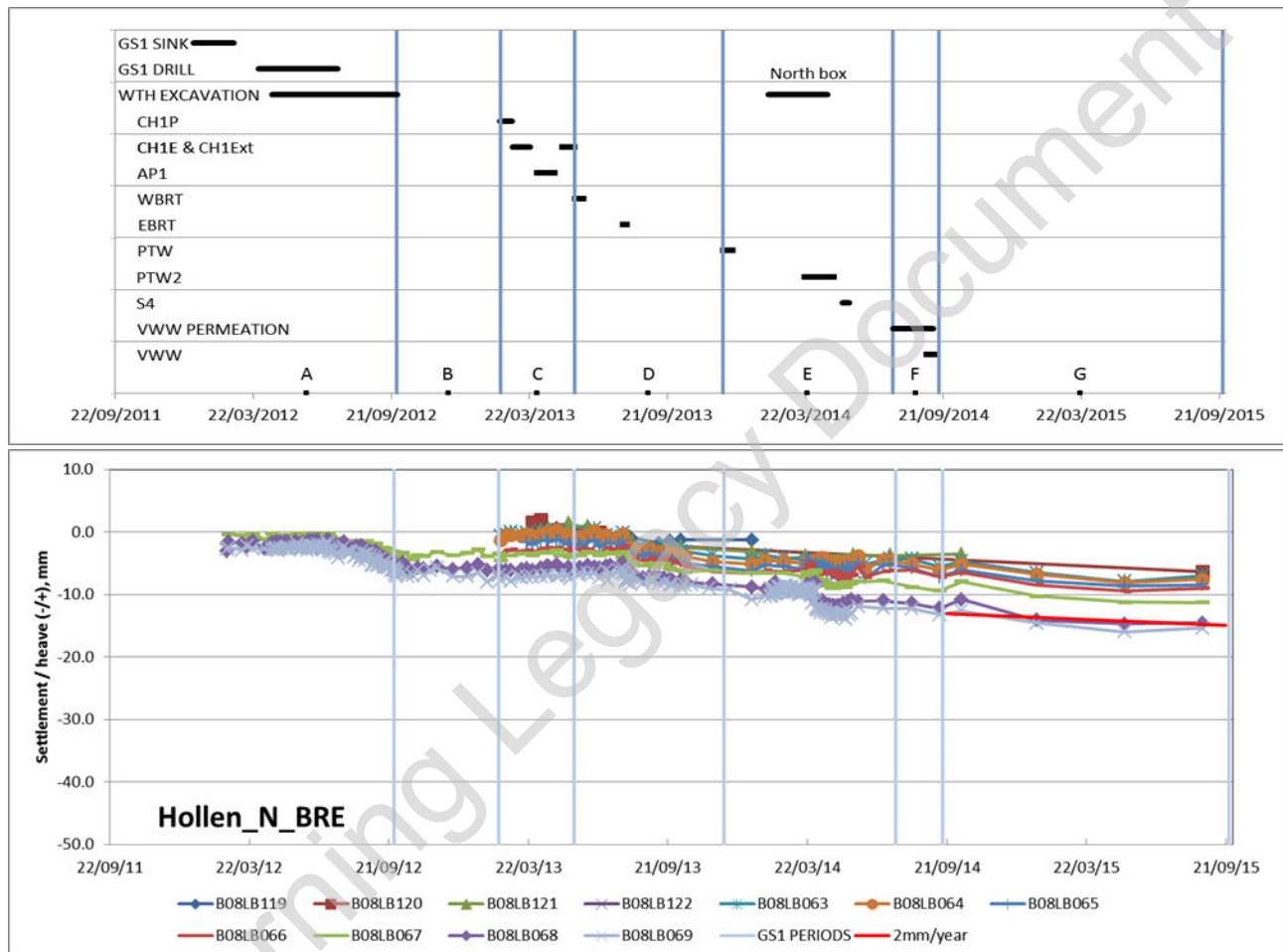


Figure 2: Data time-plot: comparison against 2mm/year settlement rate (long-term)

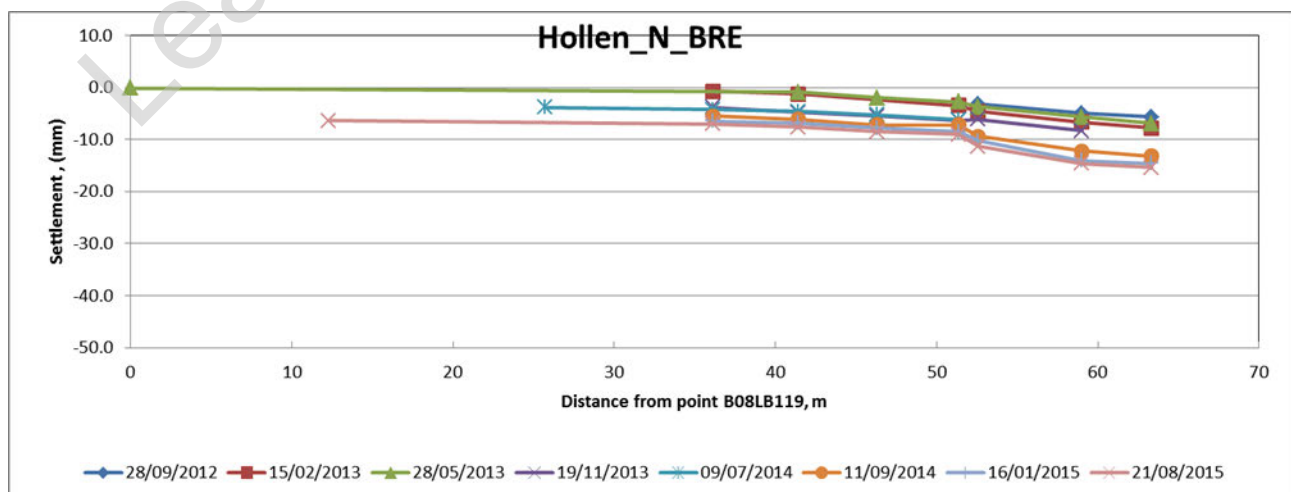


Figure 3: Profile plot: Hollen Street North façade



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The points on the north façade of Hollen Street settled up to 12mm at the end of C300 Works. Settlement of ~3mm was recorded due to C421 works prior to BFK monitoring. No change is evident in the settlement during TaM drilling. Small effects associated with the WTH south box, the EB TBM and the WTH north box are visible from the settlement time-plot. It is noted that most of the BRE were installed after the South Box was excavated due to an ongoing re-development of 16-18 Hollen Street. Minor adjustments of up to 4mm were applied to points (B08LB064 to 066) at distances in excess of 40m on the profile plot, based on the observed distribution of movement. There is a potential impact from C422 works following completion of the C300 works.

The overall long term behaviour gives a settlement rate of 2mm/year. By inspection of the profile plot, no slope triggers have been exceeded. The residual risk associated with long-term settlements is considered to be negligible.

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2.2. Great Chapel Street – West (north)

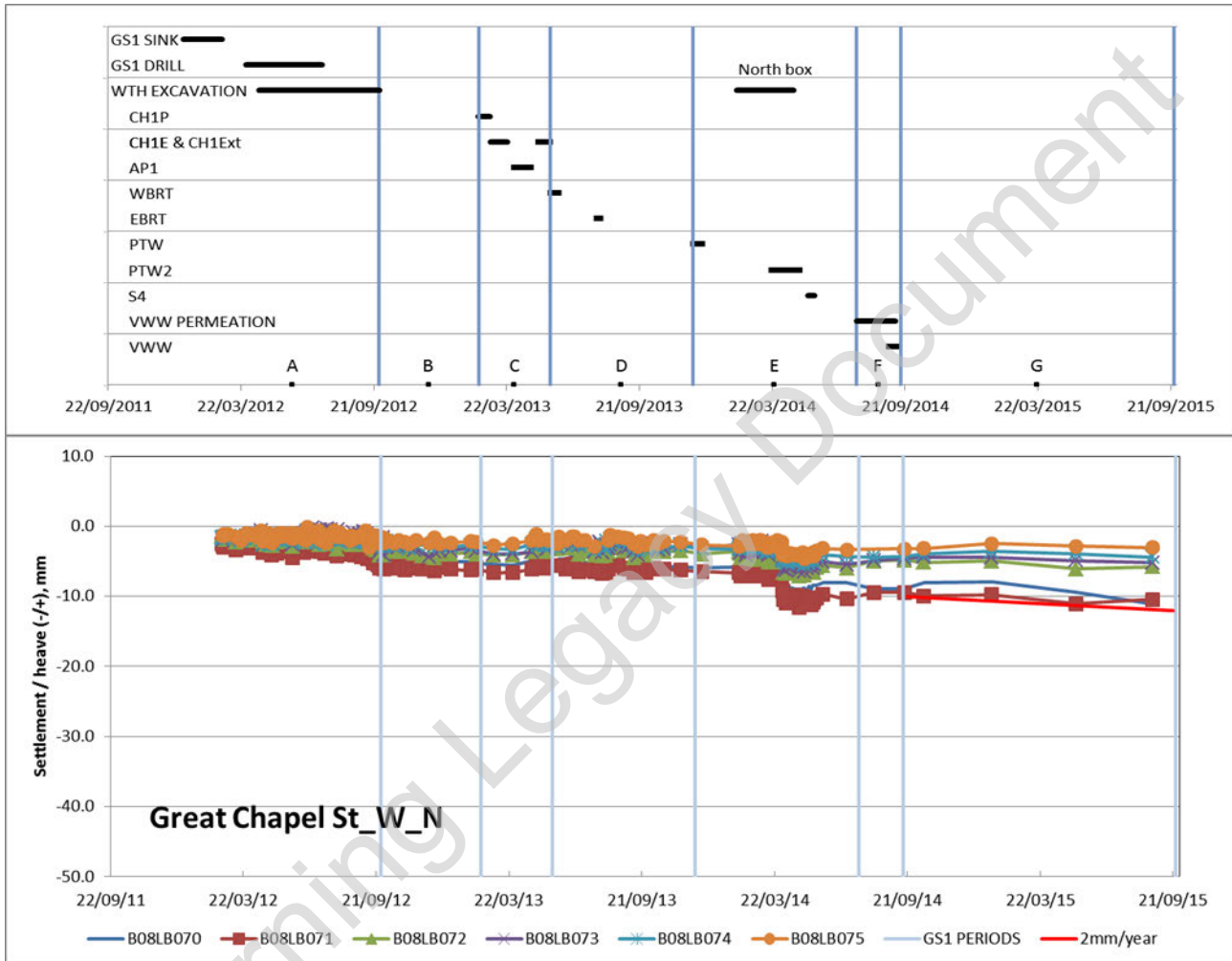


Figure 4: Data time-plot - comparison against 2mm/year settlement rate (long-term)

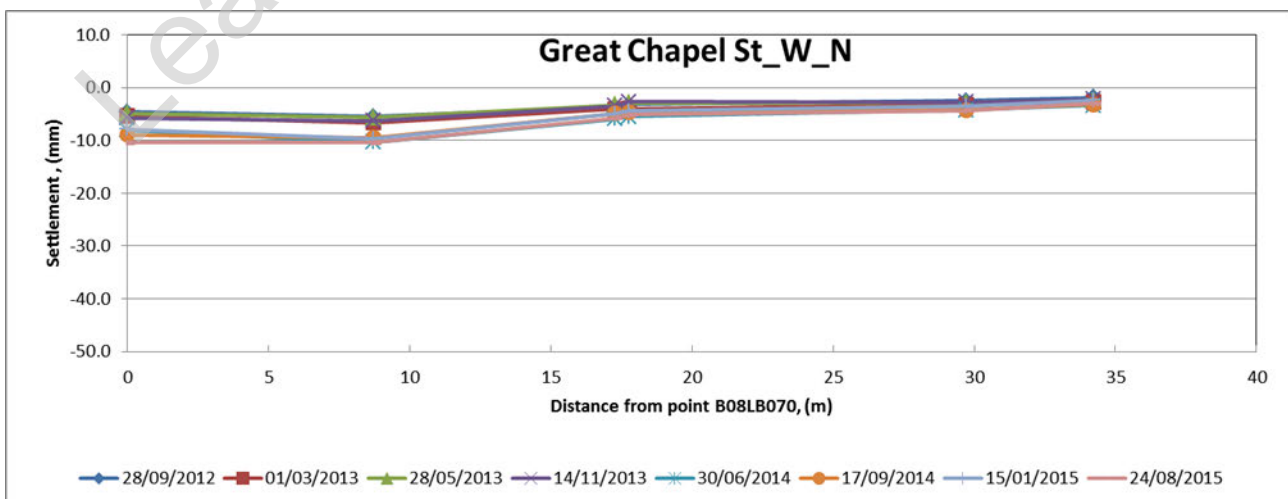


Figure 5: Profile plot: Great Chapel Street North façade



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The points on the west façade of Great Chapel Street settled up to 11mm due to the C300 works. Small effects (~5mm) associated with the WTH South Box and the WTH North Box are visible from the settlement time-plot.

The overall long term behaviour gives a settlement rate of 2mm/year. By inspection of the profile plot, no slope triggers have been exceeded. The residual risk associated with long-term settlements is considered to be negligible.

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2.3. Oxford Street South (west)

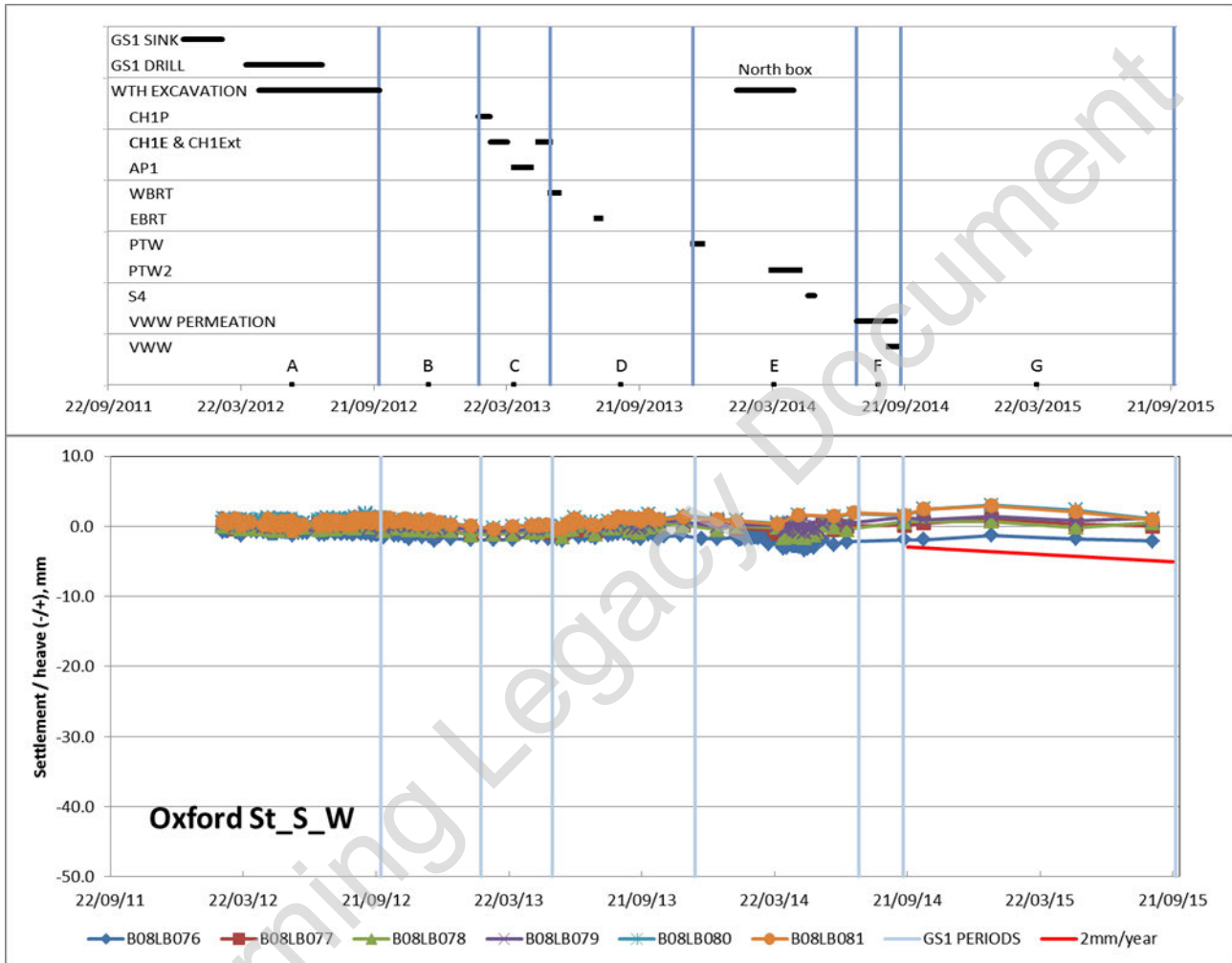


Figure 6: Data time-plot - comparison against 2mm/year settlement rate (long-term)

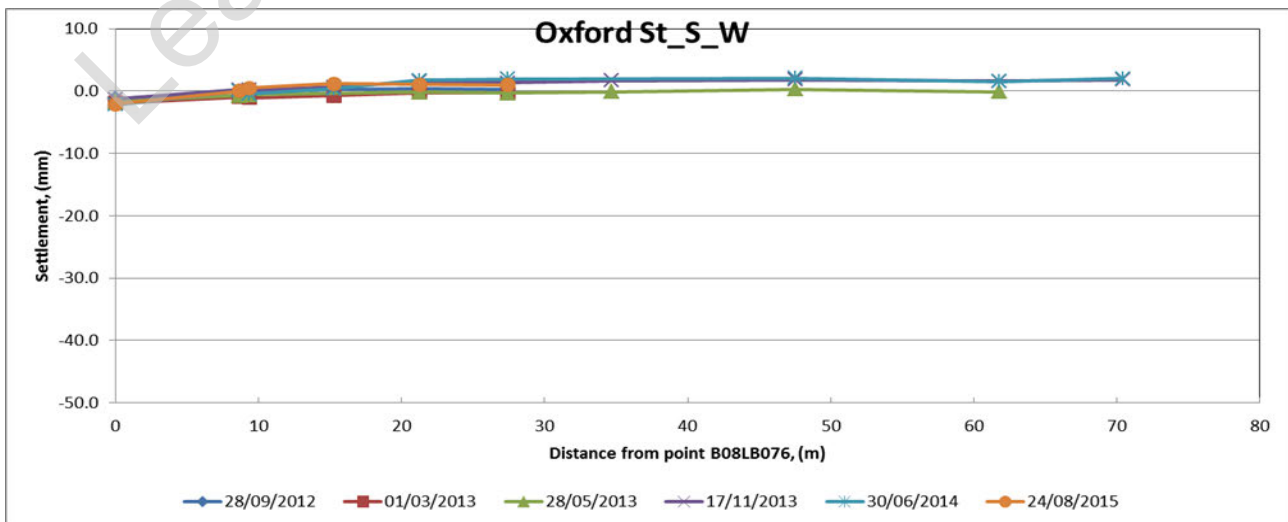


Figure 7: Profile plot: Oxford Street South façade (west)



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The points on the south façade of Oxford Street west of Great Chapel Street show negligible movement throughout construction and subsequently in the settlement time-plot.

The overall long term behaviour gives a settlement rate of less than 2mm/year. By inspection of the profile plot, no slope triggers have been exceeded. The residual risk associated with long-term settlements is considered to be negligible.

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2.4. Oxford Street South (east)

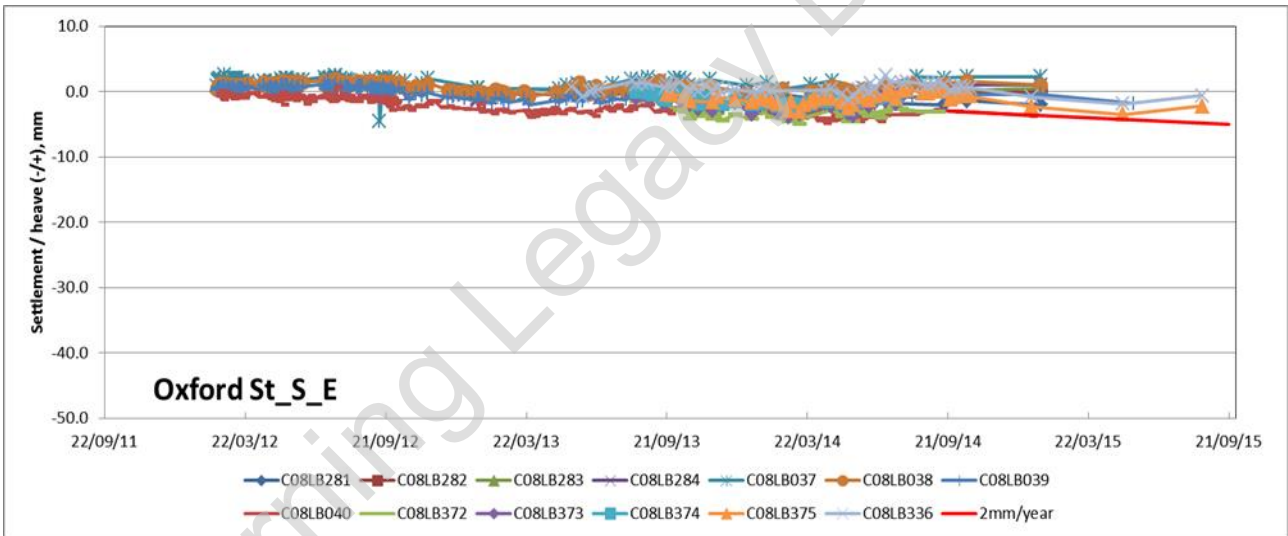
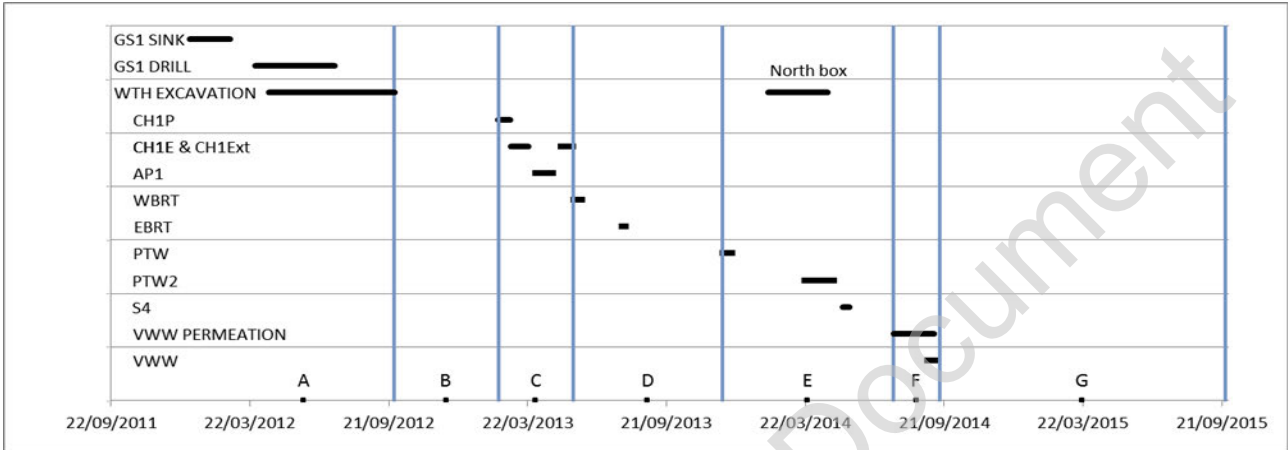


Figure 8: Data time-plot - comparison against 2mm/year settlement rate (long-term)

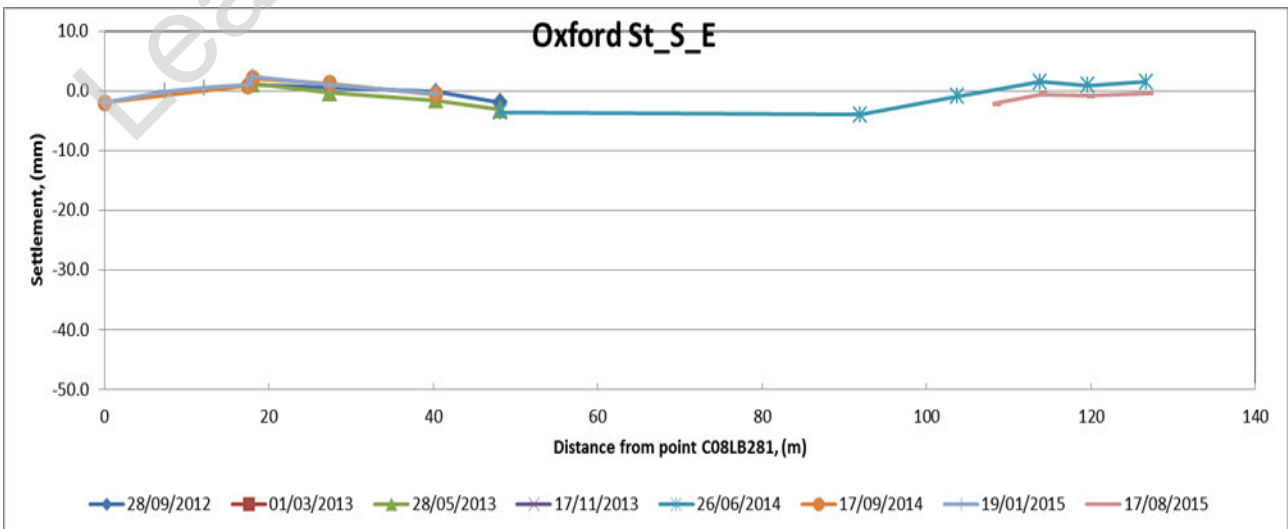


Figure 9: Profile Plot: Oxford Street South façade (east)

The points on the south façade of Oxford Street east of Great Chapel Street show negligible movement throughout construction and subsequently in the settlement time-plot.

The overall long term behaviour gives a settlement rate of less than 2mm/year. By inspection of the profile plot, no slope triggers have been exceeded. The residual risk associated with long-term settlements is considered to be negligible.

2.5. Charing Cross Road East

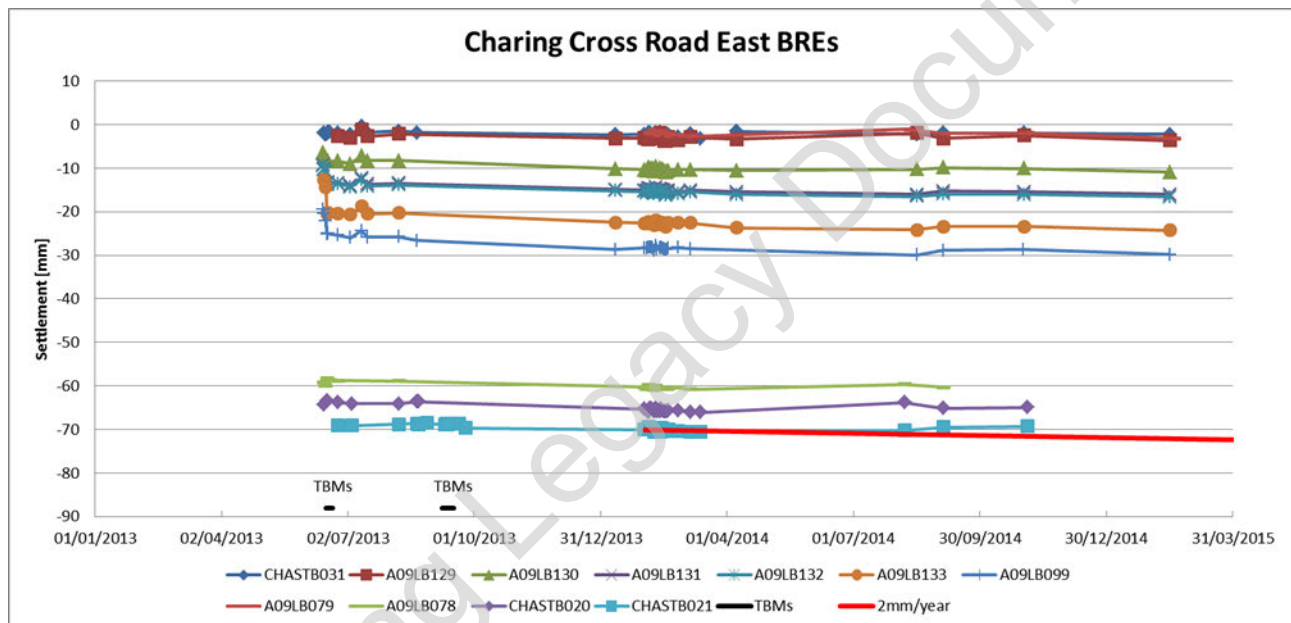


Figure 10: Data time-plot - comparison against 2mm/year settlement rate (long-term)

The points on the façade on east side of Charing Cross Road had settlement of up to 70mm prior to C300 works, attributable to TCRSU works. A small increase in settlement (~6mm) is evident from the first (WB) TBM, and the overall maximum increase in settlement over the whole C300 monitoring period is 10mm. However, no increase in settlement was noted on the points with the greatest settlement from TCRSU works. Hence the impact of C300 works is negligible compared to that from the TCRSU works.

The overall long term rate of settlement is less than 2mm/year. The residual risk associated with long-term settlements is considered to be negligible.

2.6. Flitcroft Street North

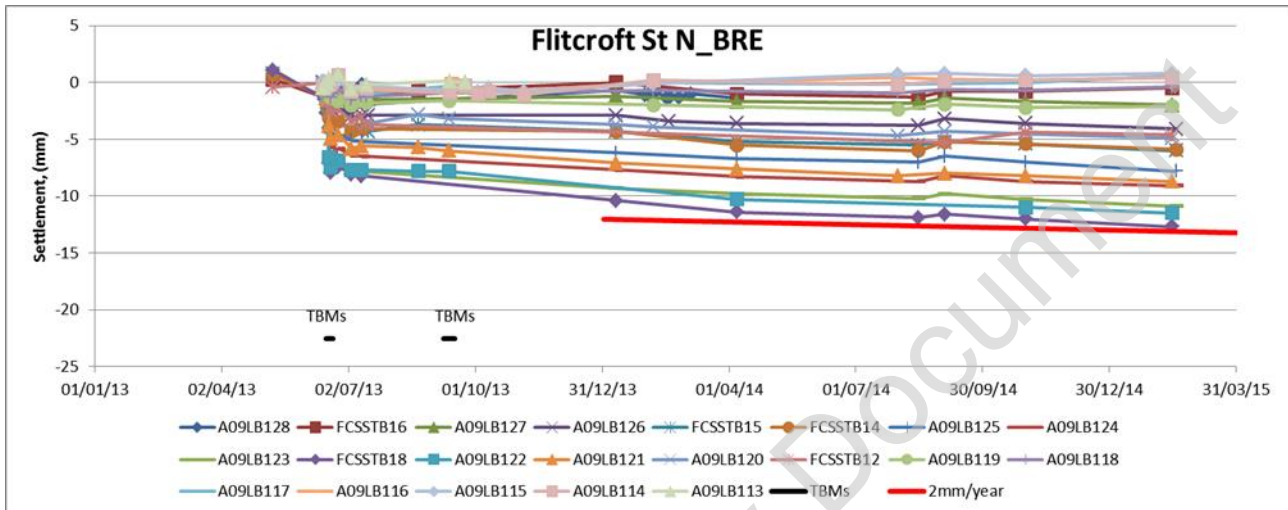


Figure 11: data time-plots - comparison against 2mm/year settlement rate (long-term)

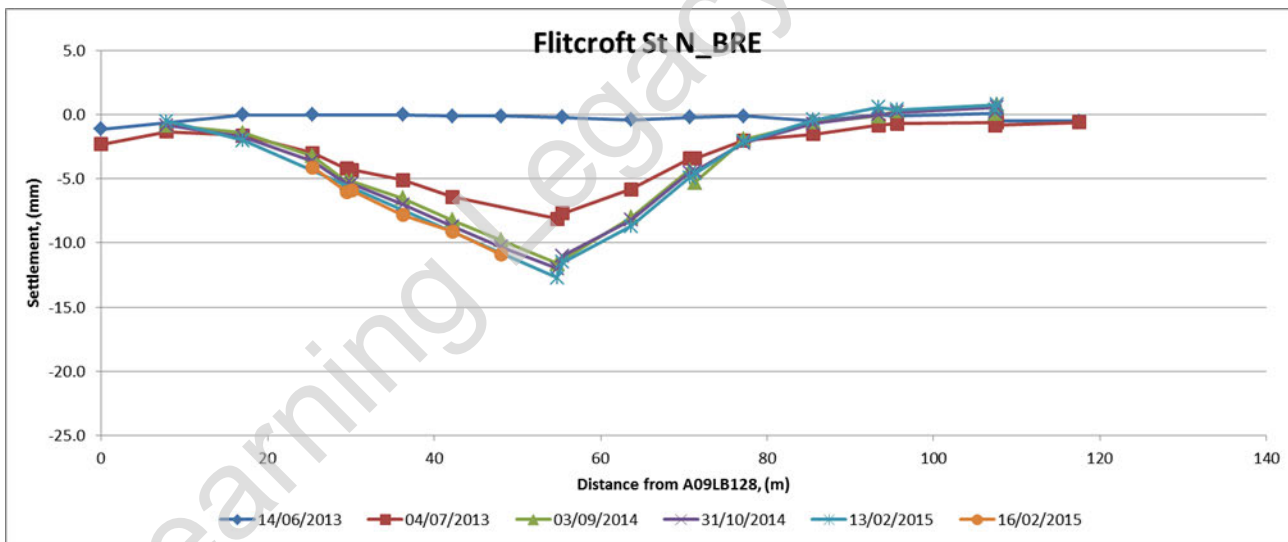


Figure 12: Profile-plot – Flitcroft Street North facade

The points on the north façade of Flitcroft Street settled up to 8mm due to the first C300 WB running tunnel drive. There is no visible effect from the second, EB, TBM drive on the settlement time-plot.

The long term behaviour shows a gradual increase to 13mm at a rate of about 2mm/year. By inspection of the profile plot, no slope triggers have been exceeded. The residual risk associated with long-term settlements is considered to be negligible.

2.7. Stacey Street West

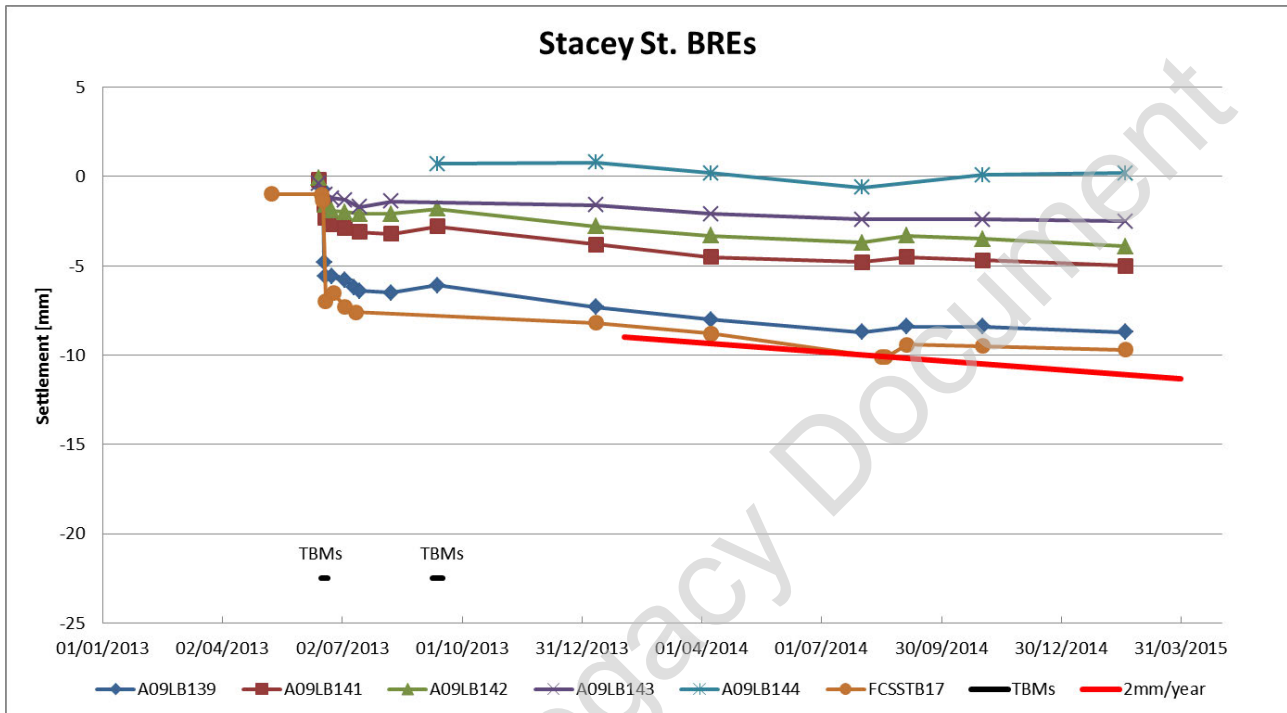


Figure 13: Data time-plot - comparison against 2mm/year settlement rate (long-term)

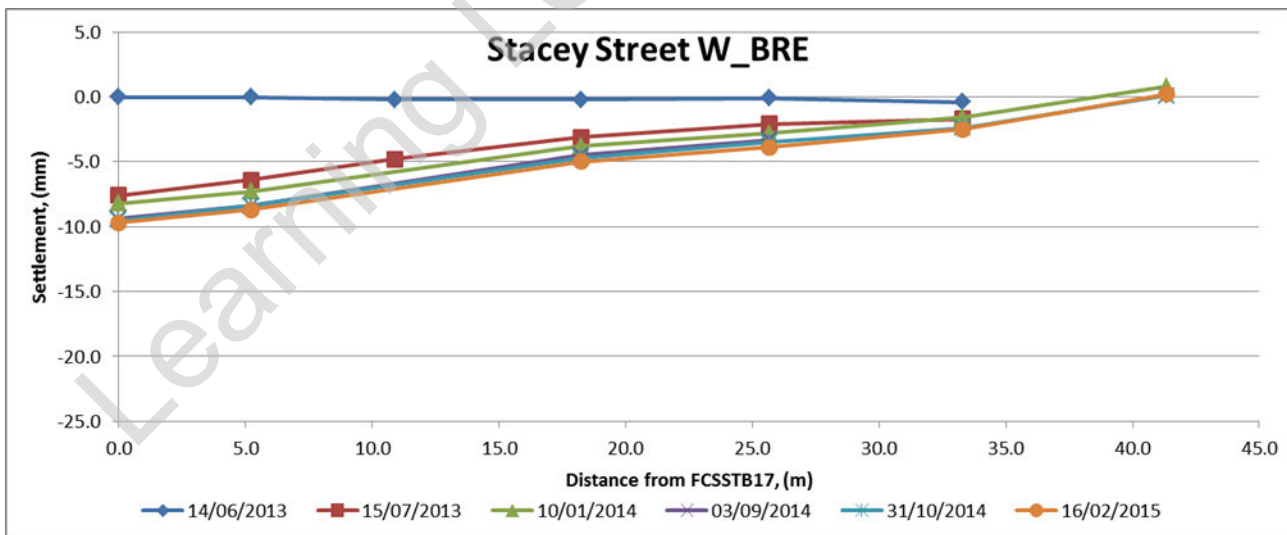


Figure 14: Profile Plot: Stacey Street West facade

The points on the west façade of Stacey Street settled up to 8mm due to the first C300 WB running tunnel drive. There is no visible effect from the second, EB, TBM drive on the settlement time-plot.

The long term behaviour shows a gradual increase to 10mm at a rate of less than 2mm/year. By inspection of the profile plot, no slope triggers have been exceeded. The residual risk associated with long-term settlements is considered to be negligible.

2.8. Denmark Street South

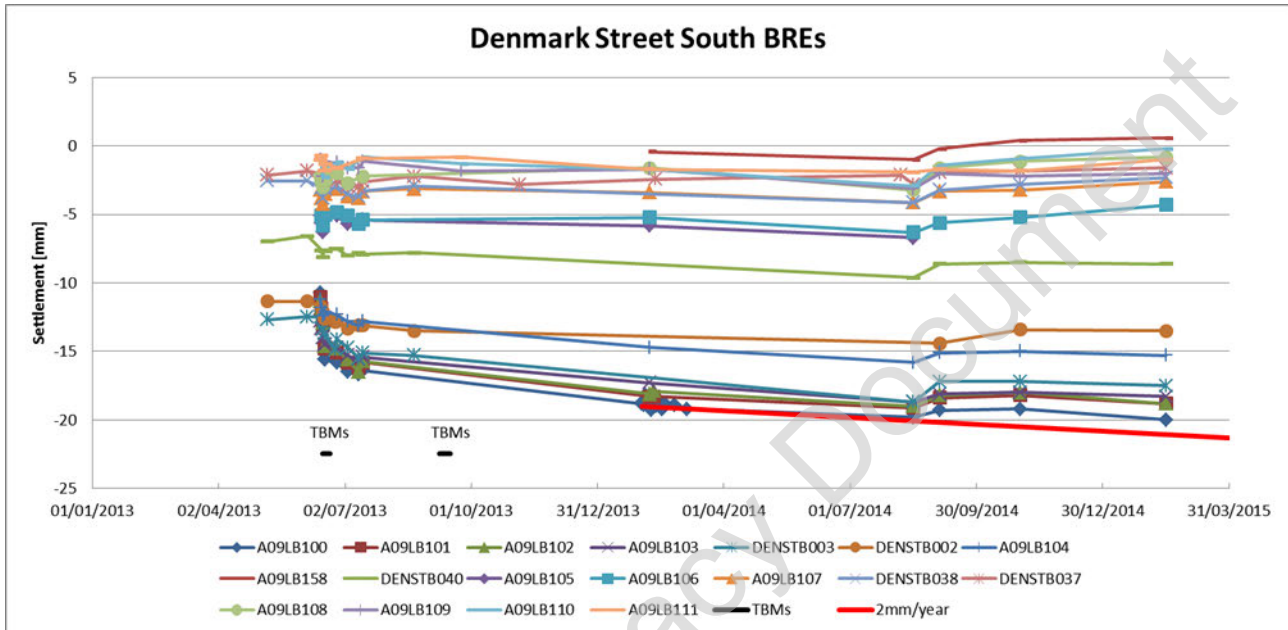


Figure 15: Data time-plot - comparison against 2mm/year settlement rate (long-term)

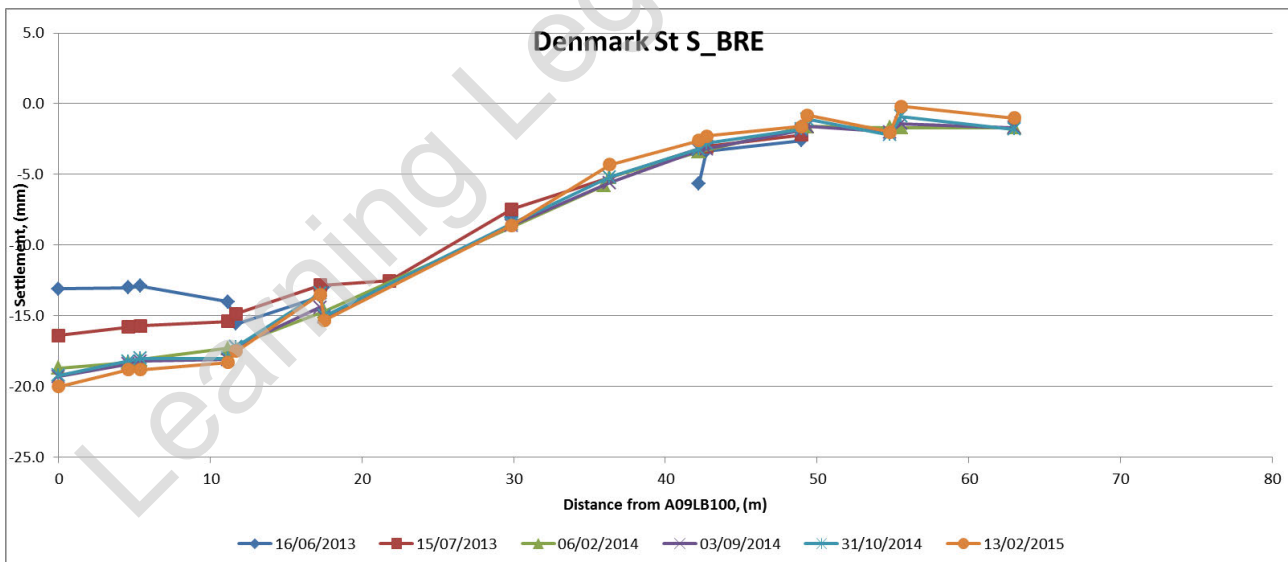


Figure 16: Profile Plot: Denmark St. South facade

The points on the façade on south side of Denmark Street had settlement of up to 13mm prior to C300 works, attributable to TCRSU works. A small effect is evident from the first (WB) TBM, but the maximum increase in settlement is 5mm. Hence the impact of C300 works is negligible compared to that from the TCRSU works.

The overall long term rate of settlement is less than 2mm/year, with a maximum recorded movement of 20mm, an increase of ~7mm on the TCRSU movements. The residual risk associated with long-term settlements is considered to be negligible.

2.9. Denmark Street North

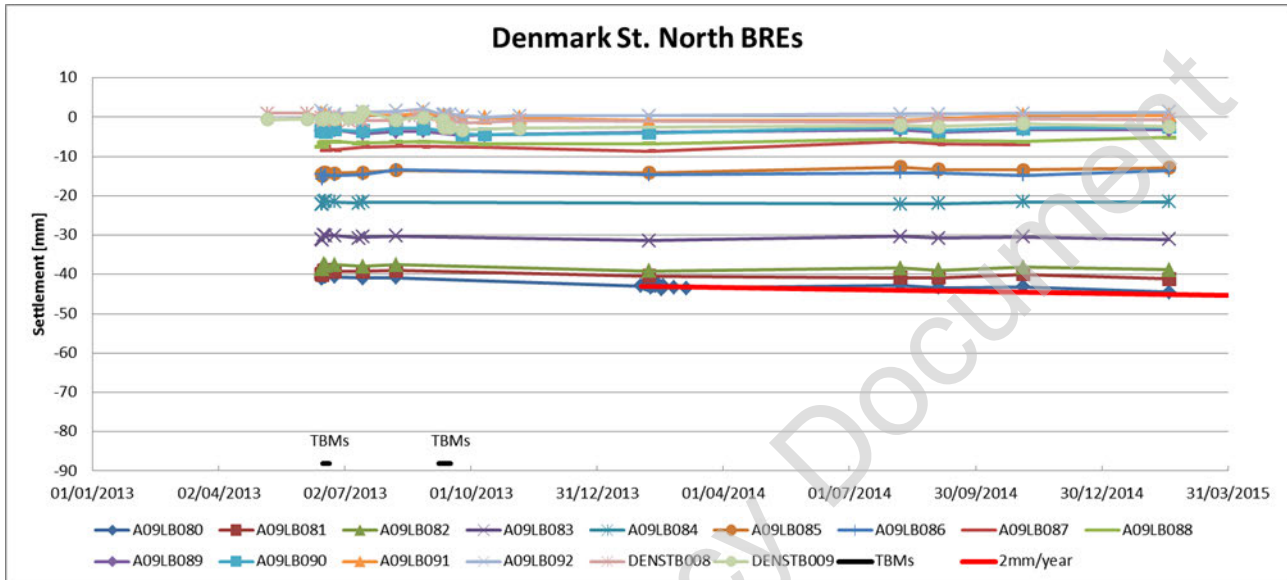


Figure 17: Data time-plot - comparison against 2mm/year settlement rate (long-term)

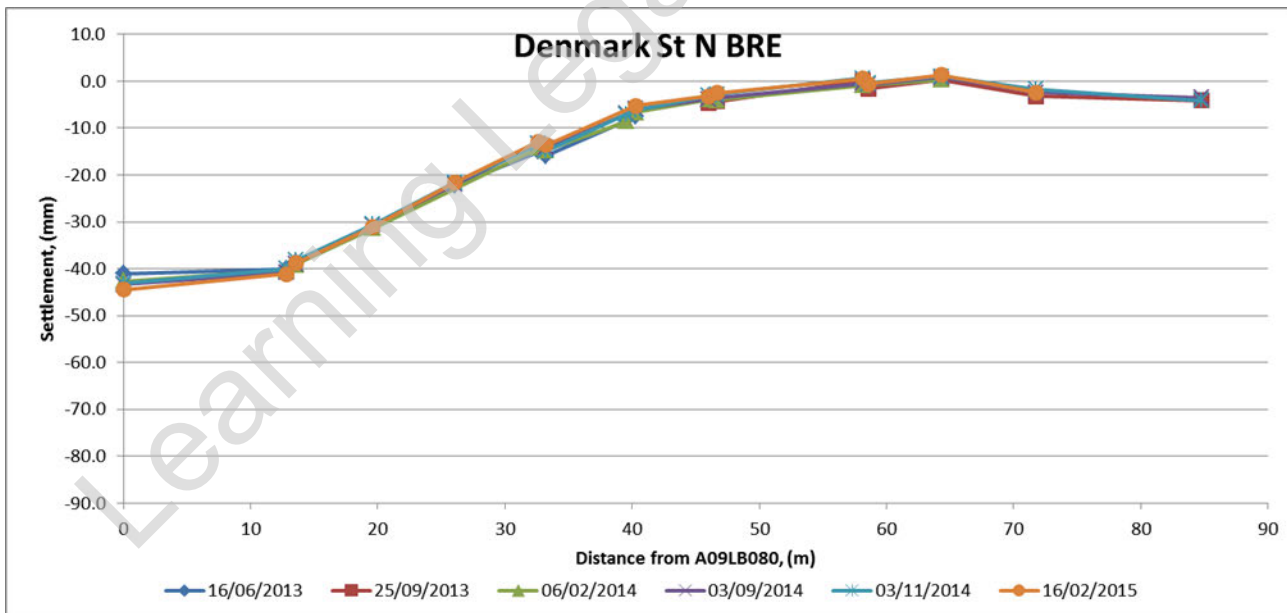


Figure 18: Profile Plot: Denmark Street North facade

The points on the façade on north side of Denmark Street had settlement of up to 40mm prior to C300 works, attributable to TCRSU works. No effect is evident from the first (WB) or second (EB) TBM. The maximum increase in settlement is 5mm over the duration of the C300 monitoring. Hence the impact of C300 works is negligible compared to that from the TCRSU works.

The overall long term rate of settlement is less than 2mm/year. The residual risk associated with long-term settlements is considered to be negligible.

2.10. Denmark Place South

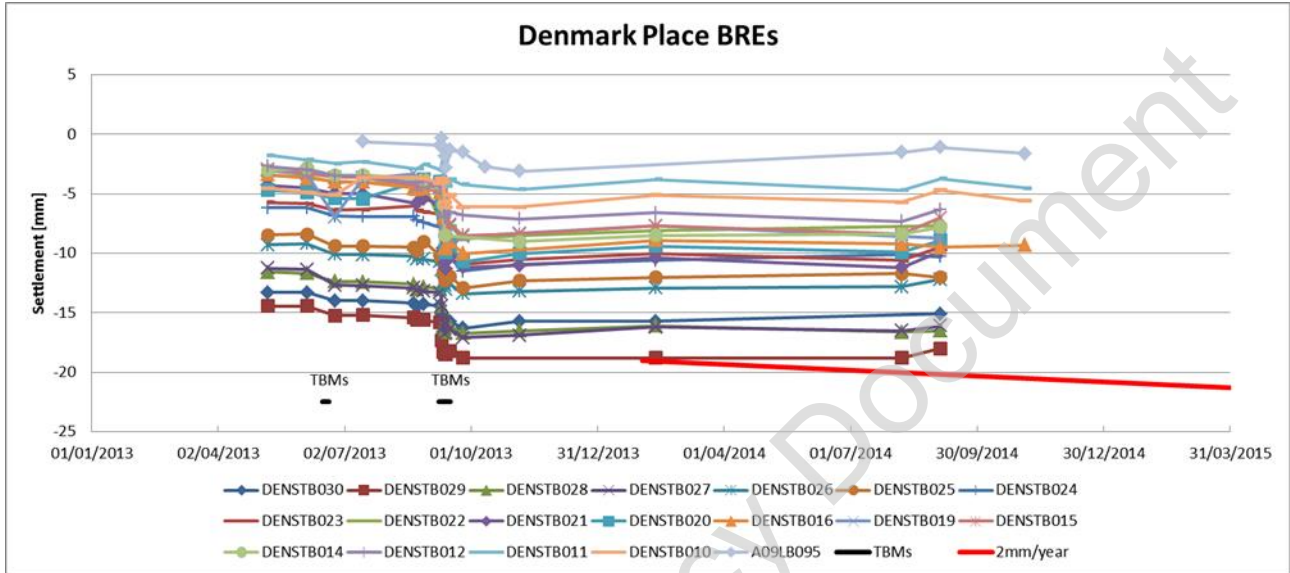


Figure 19: Data time-plot - comparison against 2mm/year settlement rate (long-term)

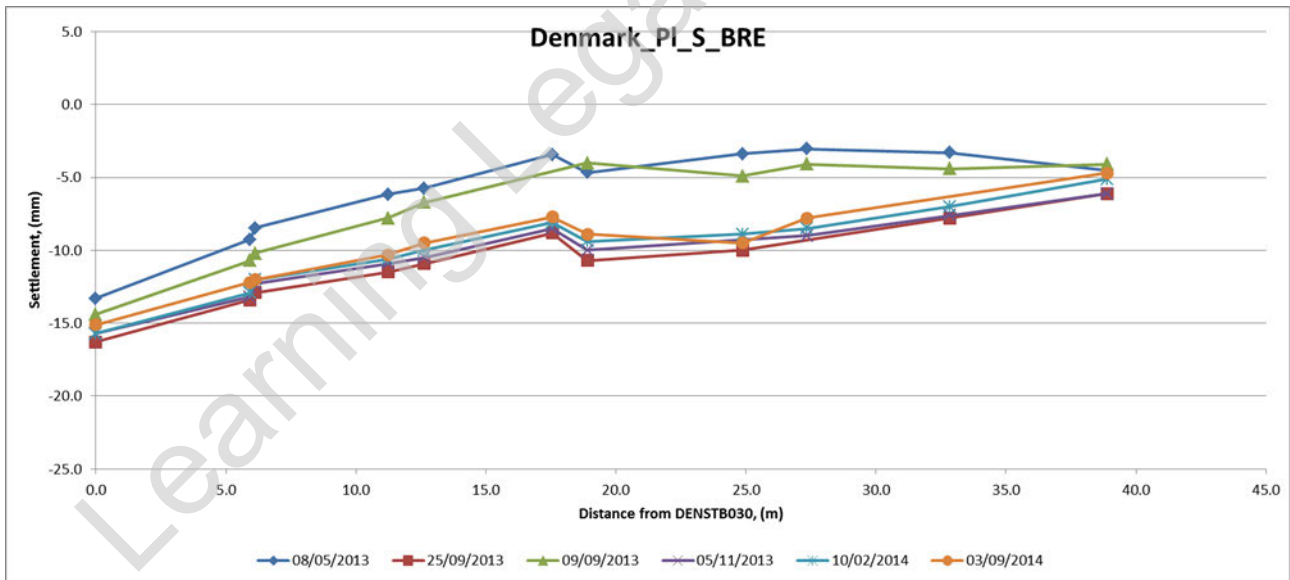


Figure 20: Profile Plot: Denmark Place South facade

The points on the façade on south side of Denmark Place had settlement of up to 14mm prior to C300 works, attributable to TCRSU works. A small effect is evident from the second (EB) TBM, but the maximum increase in settlement is ~3mm. Hence the impact of C300 works is negligible compared to that from the TCRSU works.

The overall long term rate of settlement is less than 2mm/year, with a maximum recorded movement of 18mm, an increase of ~4mm on the TCRSU movements. The residual risk associated with long-term settlements is considered to be negligible.

2.11. St. Giles High Street

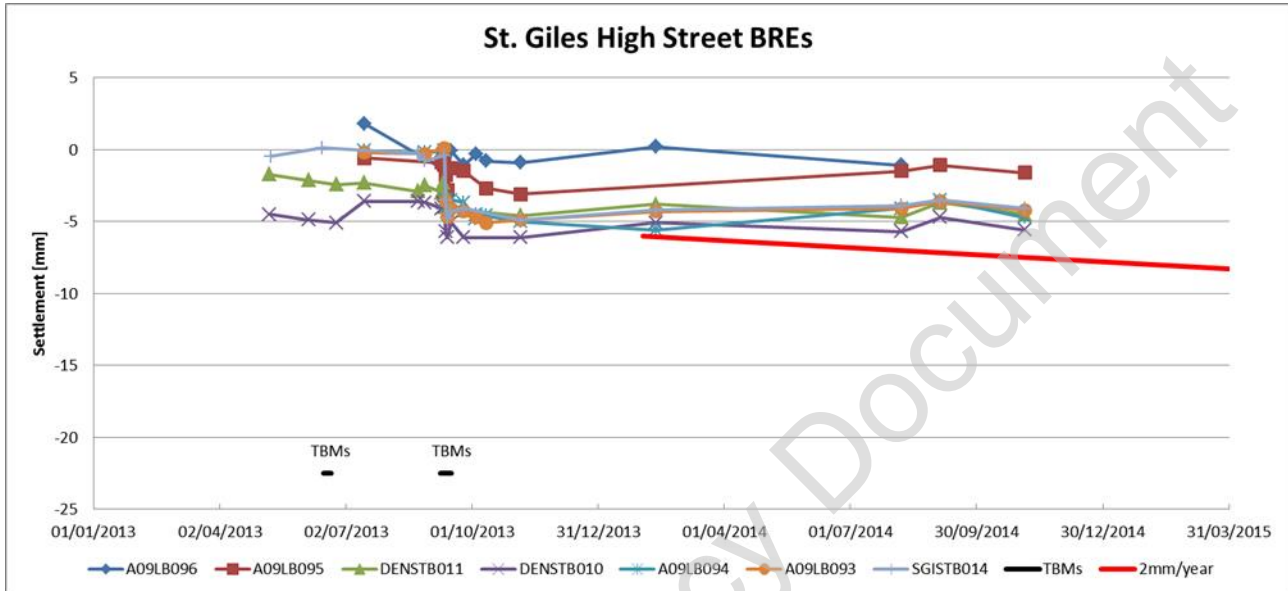


Figure 21: Data time-plot - comparison against 2mm/year settlement rate (long-term)

The points on the façade on west side of St. Giles High Street settled by up to 6mm during the second (EB) TBM, with negligible increase thereafter.

The overall long term rate of settlement is less than 2mm/year. The residual risk associated with long-term settlements is considered to be negligible.

3. PLP data

3.1. Great Chapel Street West - north

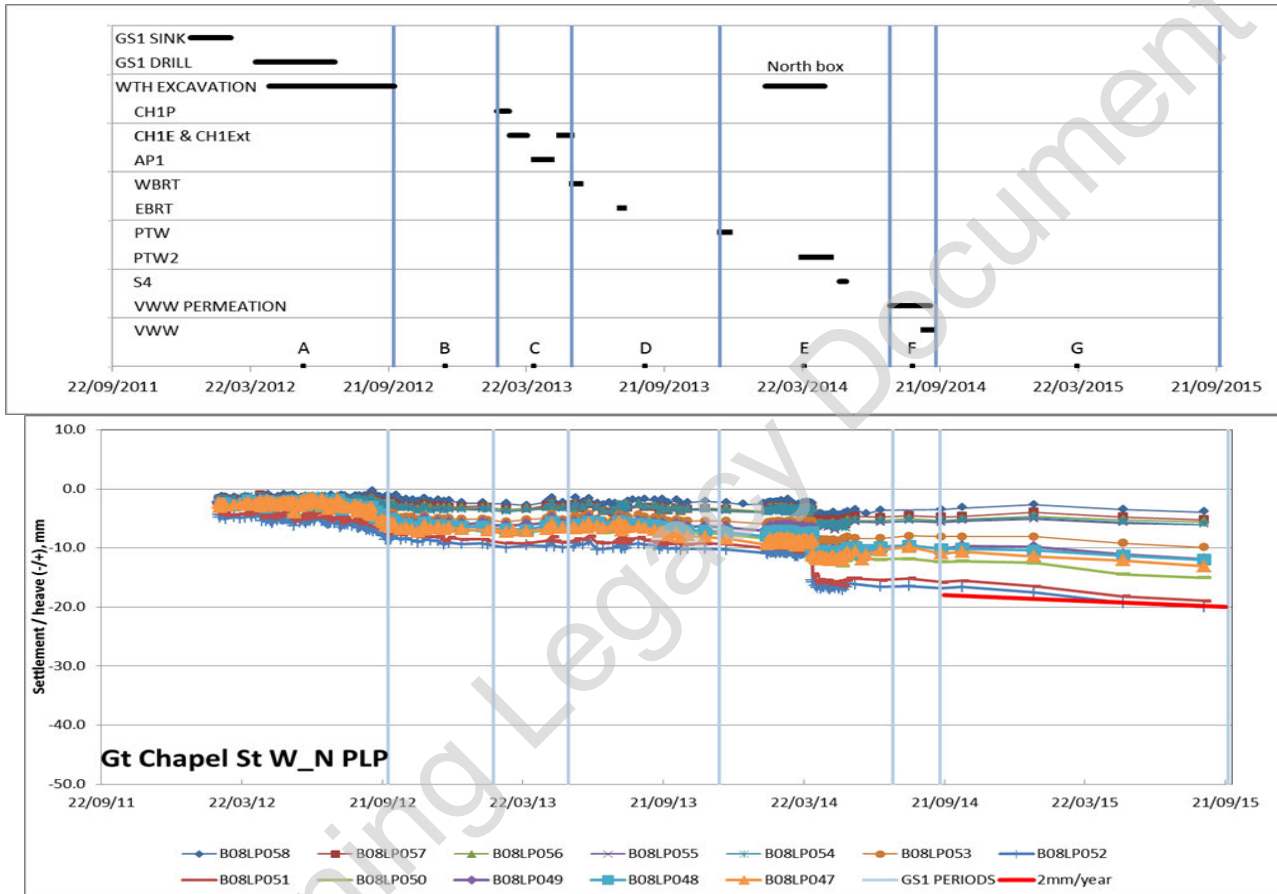


Figure 22: Data time-plot - comparison against 2mm/year settlement rate (long-term)

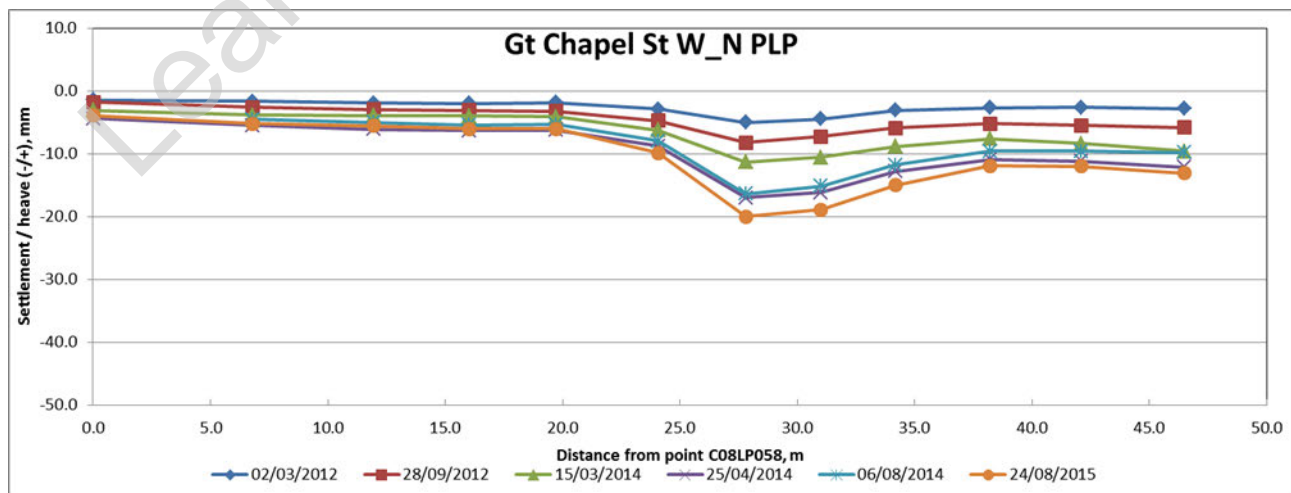


Figure 23 Profile Plot: Great Chapel Street PLP

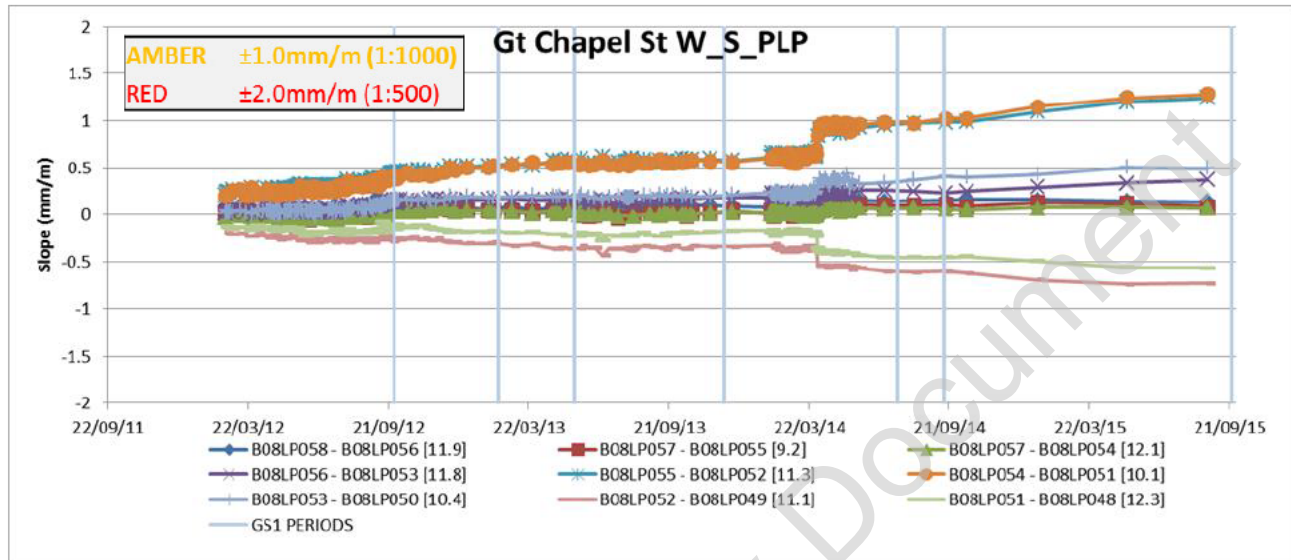


Figure 24 Slope time plot: Great Chapel Street PLP

The points on the west kerb line of Great Chapel Street (north of Hollen Street) settled up to 5mm prior to C300 works, from the installation of diaphragm walls and piles for the WTH and Over Site Development by C421. Settlement increased by about 3mm by the end of the WTH South Box excavation. A somewhat larger effect is evident in the settlement time plot associated with the WTH north box increasing the maximum settlement by about 8mm to 18mm. Post-construction, the overall long term behaviour gives a settlement rate of about 2mm/year.

By inspection of the profile plot, significant slopes have developed with a localised feature produced from C421 works and persisting and increasing throughout C300 works and post-construction. The development of slopes along this transect are shown on Figure 23. Two slopes (B08LP054 – B08LP051 and B08LP055 – B08LP052) approached the Amber trigger level (1mm/m) during excavation of the WTH north box and have subsequently exceeded the trigger due to post-construction movements.

The rate of settlement is about 2mm/year and as such the residual risk associated with long-term settlements is considered to be acceptably low.

3.2. Oxford Street South

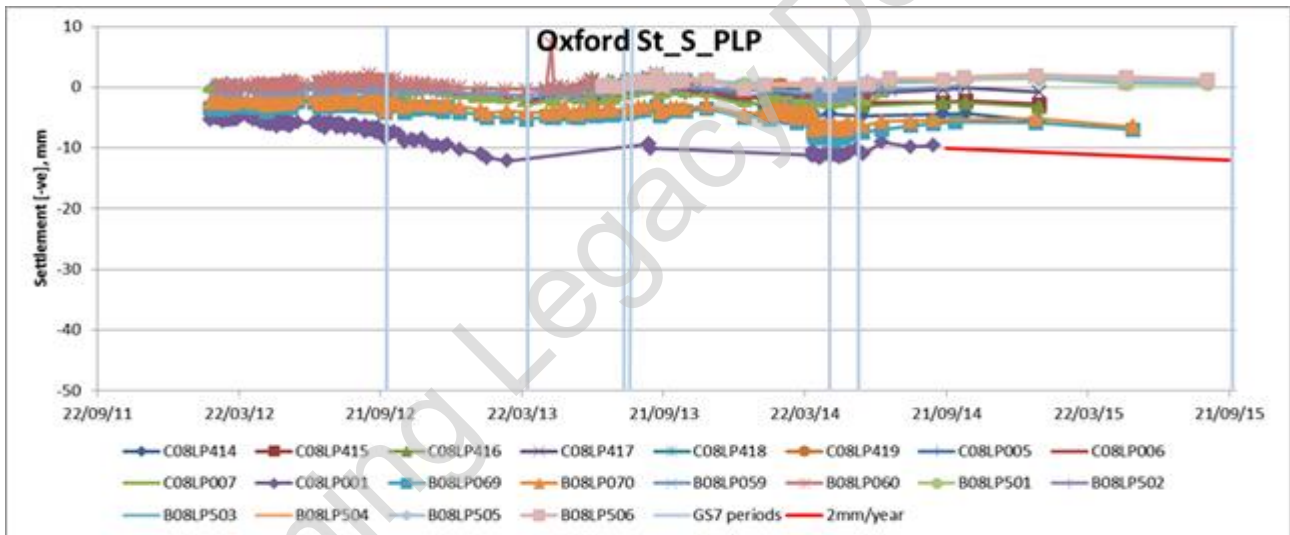
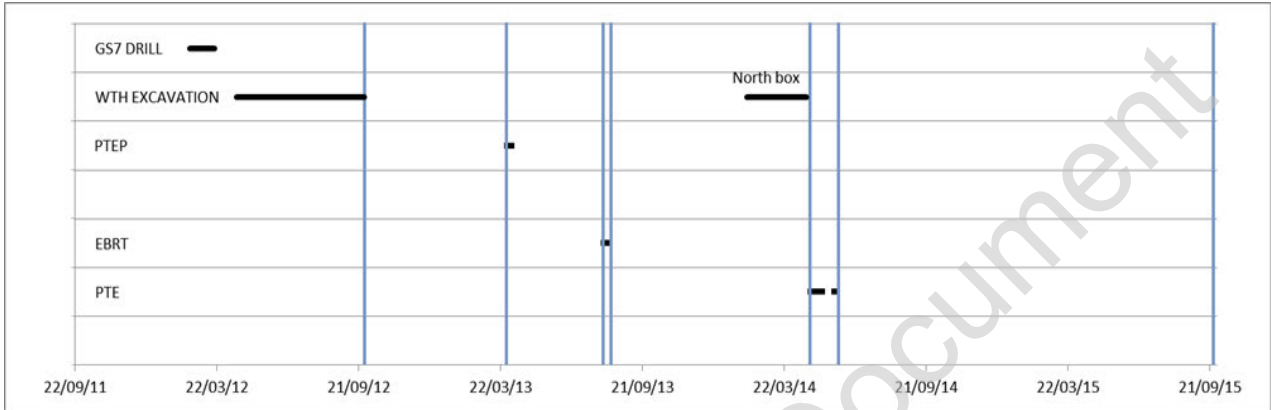


Figure 25: Data time-plot - comparison against 2mm/year settlement rate (long-term)

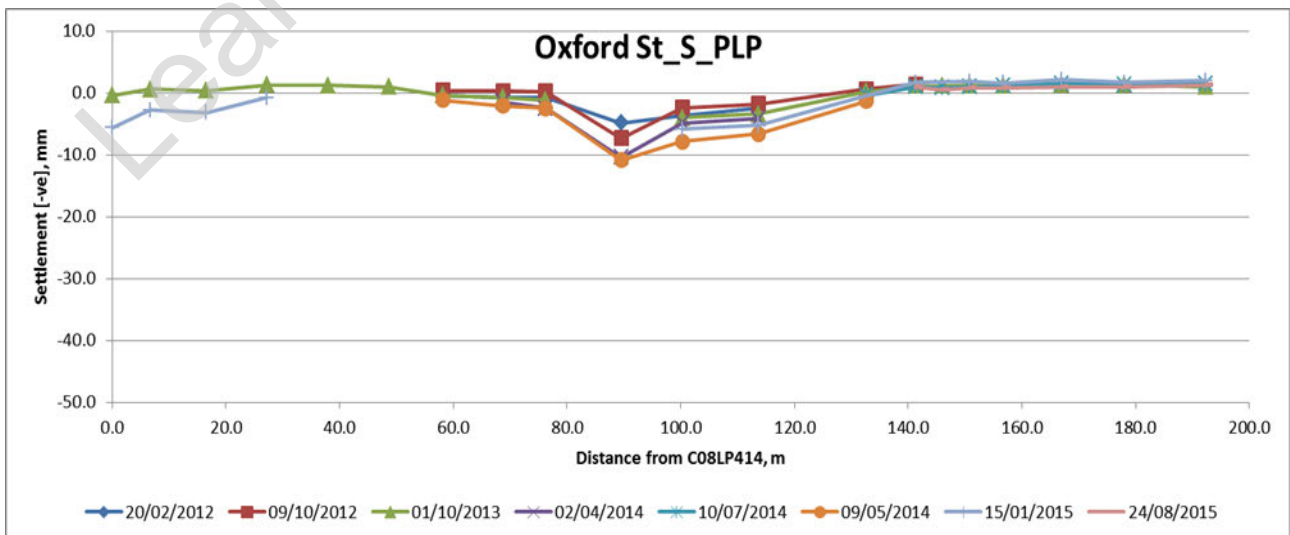


Figure 26 Profile Plot: Oxford Street South PLP



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The points on the south kerb line of Oxford Street show up to 6mm settlement prior to C300 works from the installation of diaphragm walls and piles for the WTH and Over Site Development. The point with maximum movement continued to settle during excavation of the South Box and subsequently reaching a maximum of 12mm, some 6 months later. There was negligible movement on this point throughout the remainder of construction and subsequently. A minor increase in the settlement of 2 points during excavation of the North Box (B08LP069 and B08LP070) is evident time-plot and in the profile plot. By inspection, no slope triggers have been exceeded.

The overall long term behaviour gives a settlement rate of less than 2mm/year. The residual risk associated with long-term settlements is considered to be negligible.

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3.3. Oxford Street North

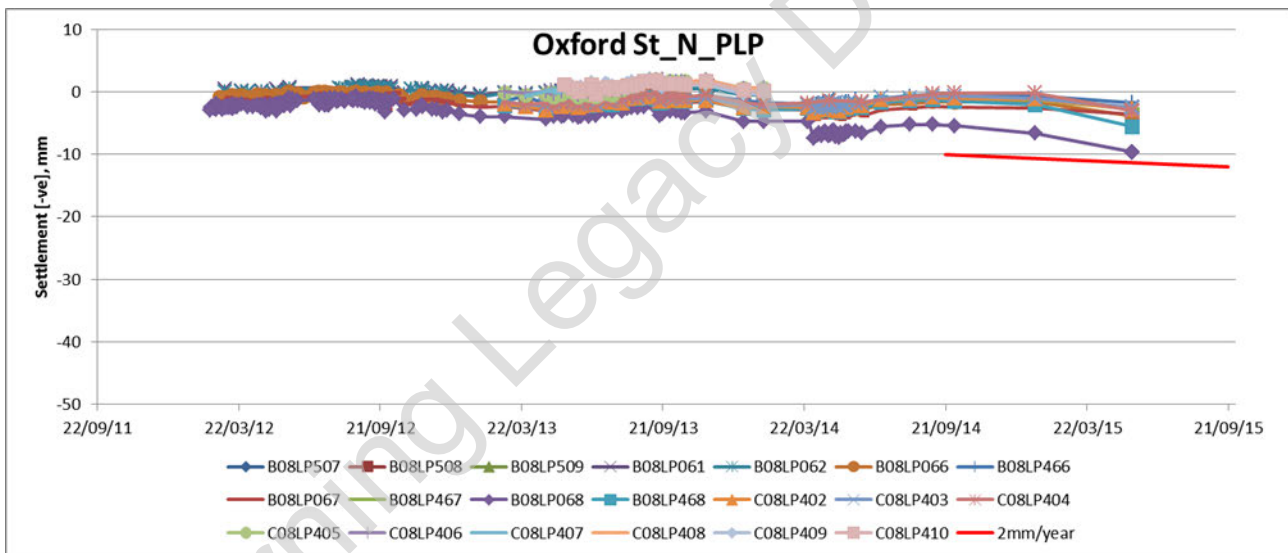
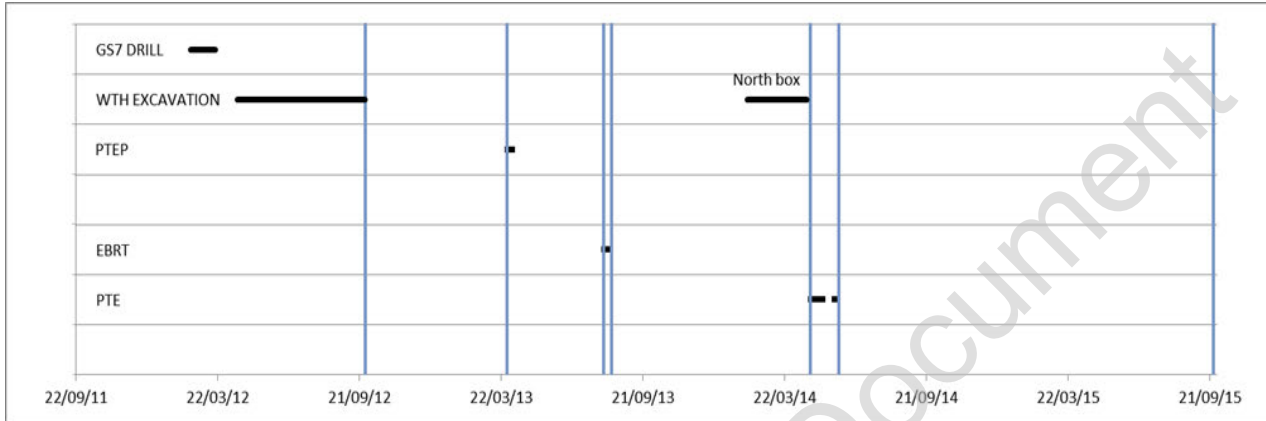


Figure 27 Data time-plot - comparison against 2mm/year settlement rate (long-term)

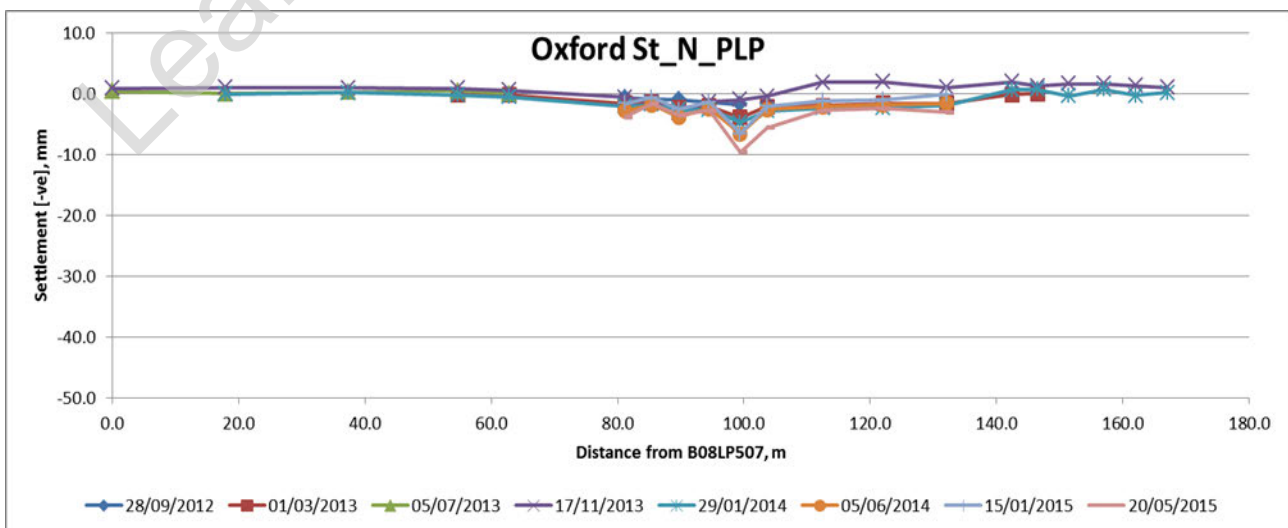


Figure 28 Profile Plot: Oxford Street North PLP

The points on the north kerb line of Oxford Street show up to 3mm settlement prior to C300 works during the installation of diaphragm walls and piles for the WTH and Over Site Development. A minor increase in the settlement of 2 points after excavation of the North Box (B08LP068 and B08LP468) is evident in both the time-plot and the profile plot. It is not clear how localised movements of 1 or 2 points at distances over 30m from the WTH North Box could be associated with these works. An enlarged plot of the central section of the profile is shown in Figure 28. It is noted that there were a lot of street works undertaken during this period.

The overall long term behaviour generally has a settlement rate of less than 2mm/year. The residual risk associated with long-term settlements is considered to be negligible.

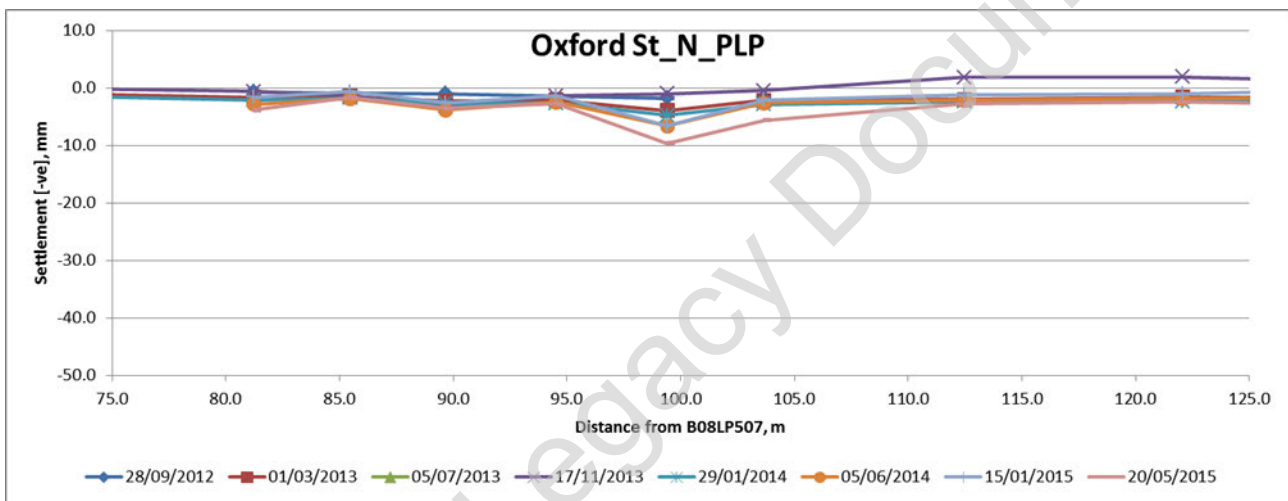


Figure 29 Profile Plot: Oxford Street North PLP (central section)

3.4. Charing Cross Road East

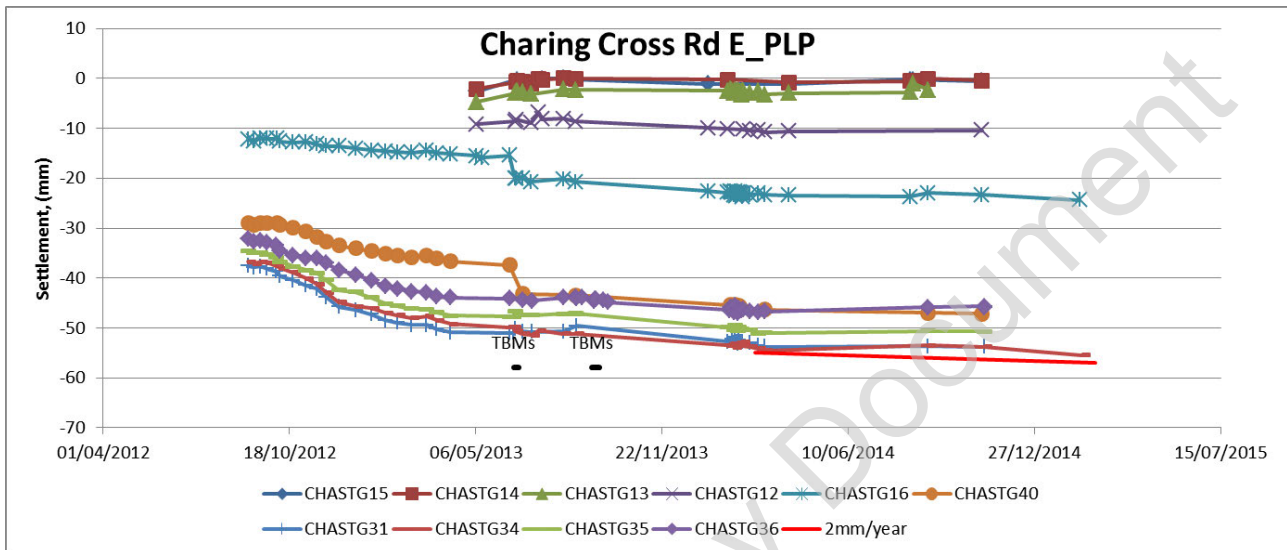


Figure 30 Data time-plot - comparison against 2mm/year settlement rate (long-term)

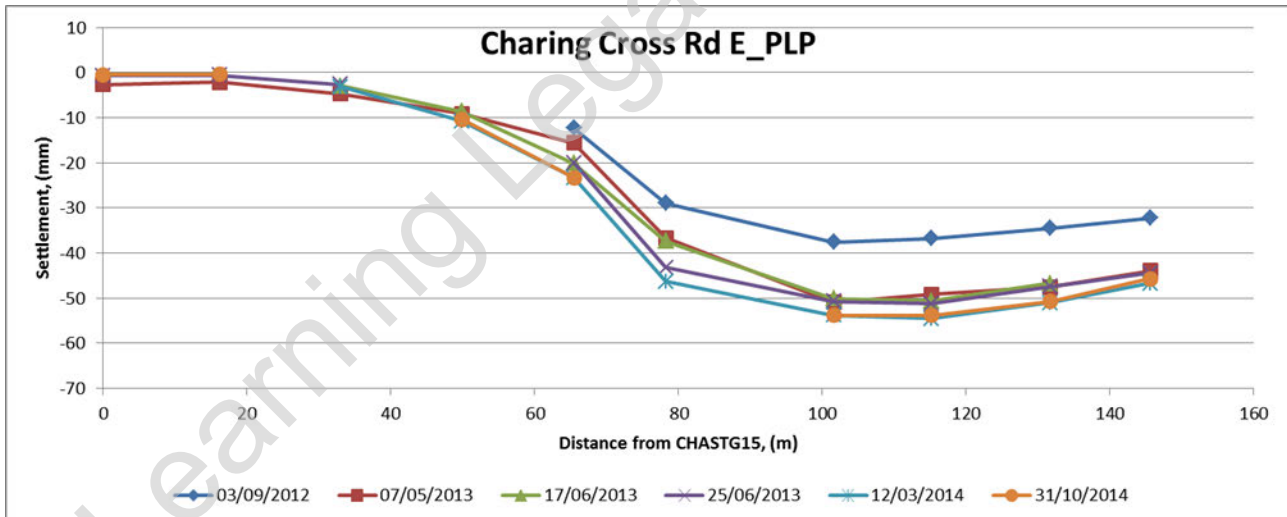


Figure 31 Profile Plot: Charing Cross Road East PLP

The points on the kerb line on east side of Denmark Place had settlement of up to 40mm prior to C300 works, attributable to TCRSU works. A small effect is evident from the first (WB) TBM, but the maximum increase in settlement is ~7mm. Hence the impact of C300 works is negligible compared to that from the TCRSU works.

The overall long term rate of settlement is less than 2mm/year, with a maximum recorded movement of ~70mm. The residual risk associated with long-term settlements is considered to be negligible.

3.5. Flitcroft Street South

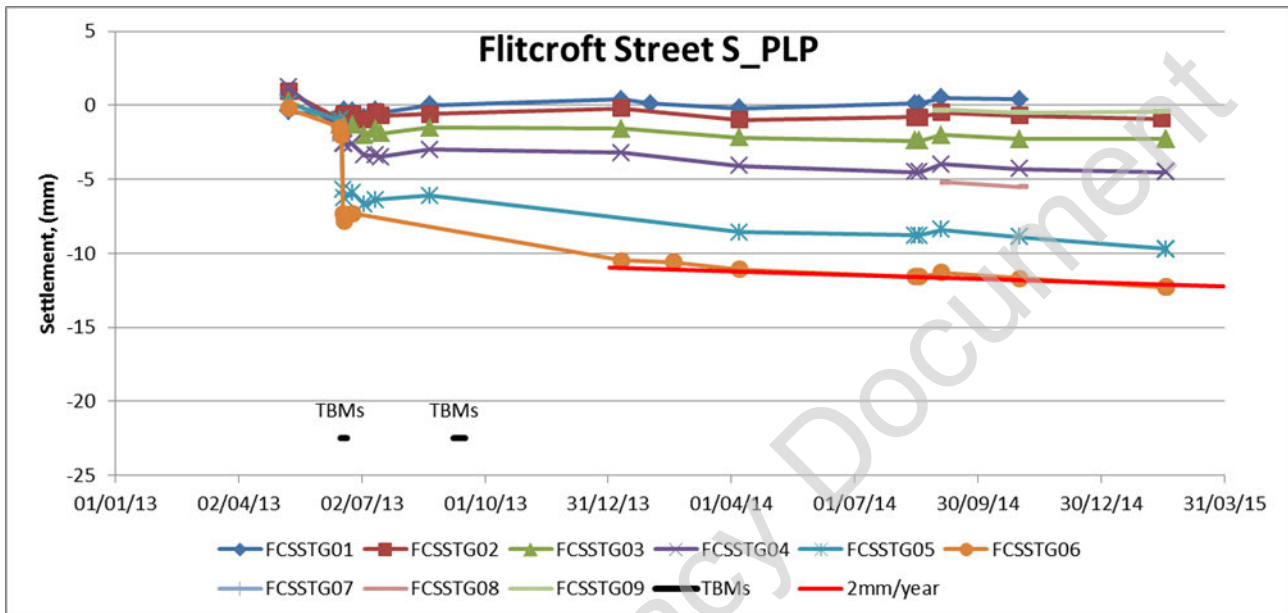


Figure 32 Data time-plot - comparison against 2mm/year settlement rate (long-term)

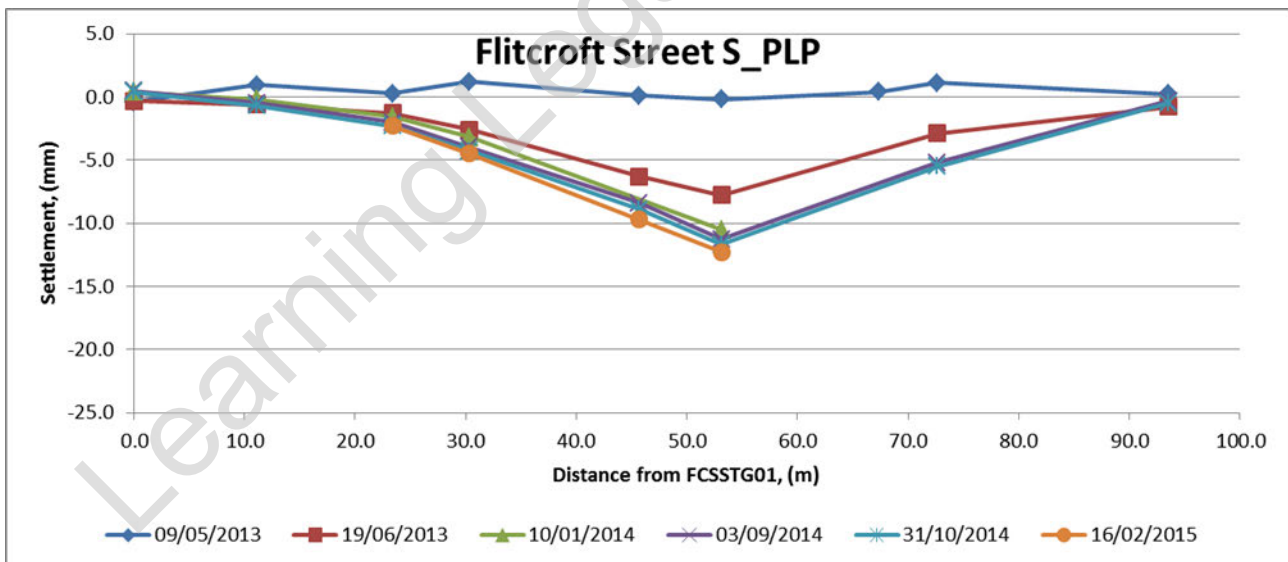


Figure 33 Profile Plot: Flitcroft Street South PLP

The points on the south kerb line of Flitcroft Street settled up to 8mm due to the first C300, WB, running tunnel drive. There is no visible effect from the second, EB, TBM on the settlement time-plot.

The long term behaviour shows a gradual increase to 13mm at a rate of about 2mm/year. The residual risk associated with long-term settlements is considered to be negligible.

3.6. Denmark Place South

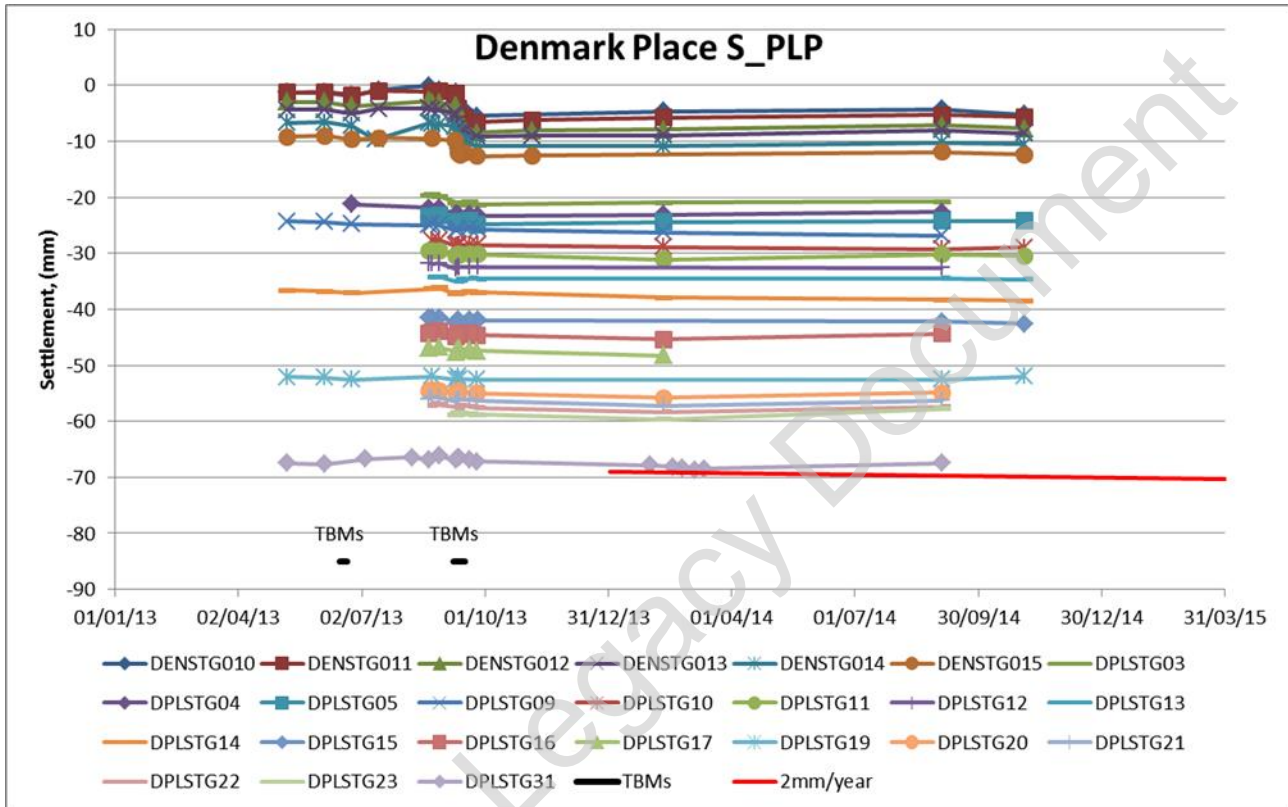


Figure 34 Data time-plot - comparison against 2mm/year settlement rate (long-term)

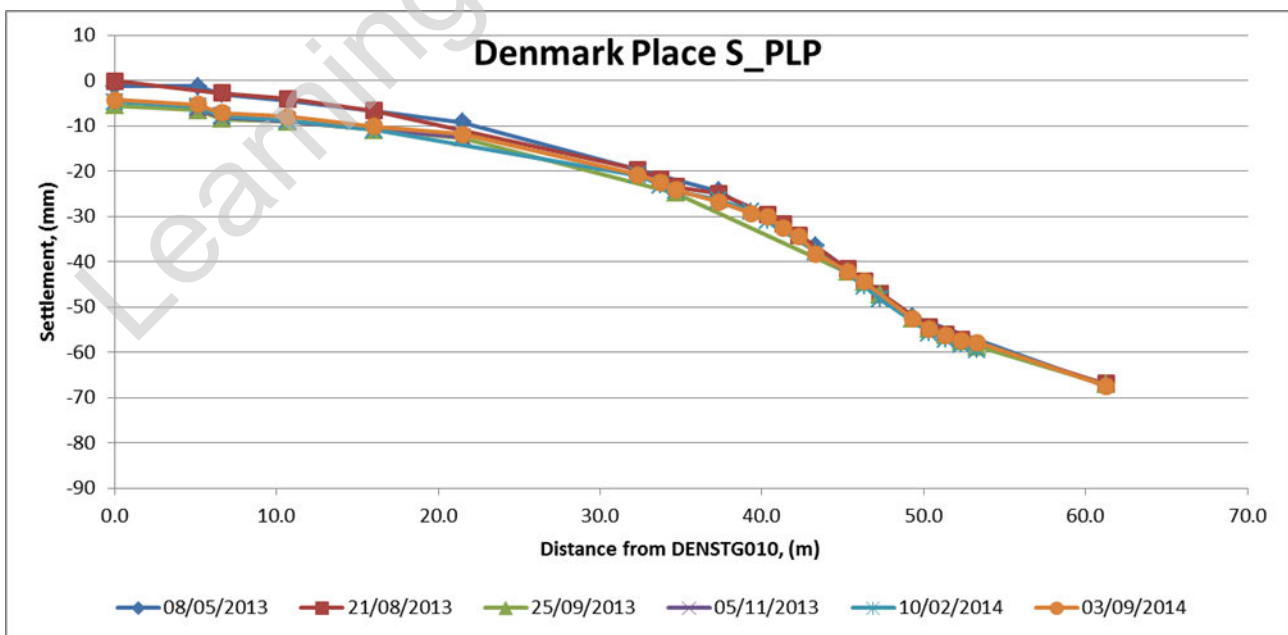


Figure 35 Profile Plot: Denmark Street South PLP



C300/410

Western Tunnels & Caverns Project



Final Monitoring Report: C300-BFK-C4-RGN-CRT00_ST005-53006 Rev 5.0

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The points on the kerb line on south side of Denmark Place had settlement of up to 70mm prior to C300 works, attributable to TCRSU works. A small effect is evident from the second (EB) TBM, but the maximum increase in settlement is ~5mm. Hence the impact of C300 works is negligible compared to that from the TCRSU works.

The overall long term rate of settlement is less than 2mm/year, with a maximum recorded movement of ~70mm. The residual risk associated with long-term settlements is considered to be negligible.

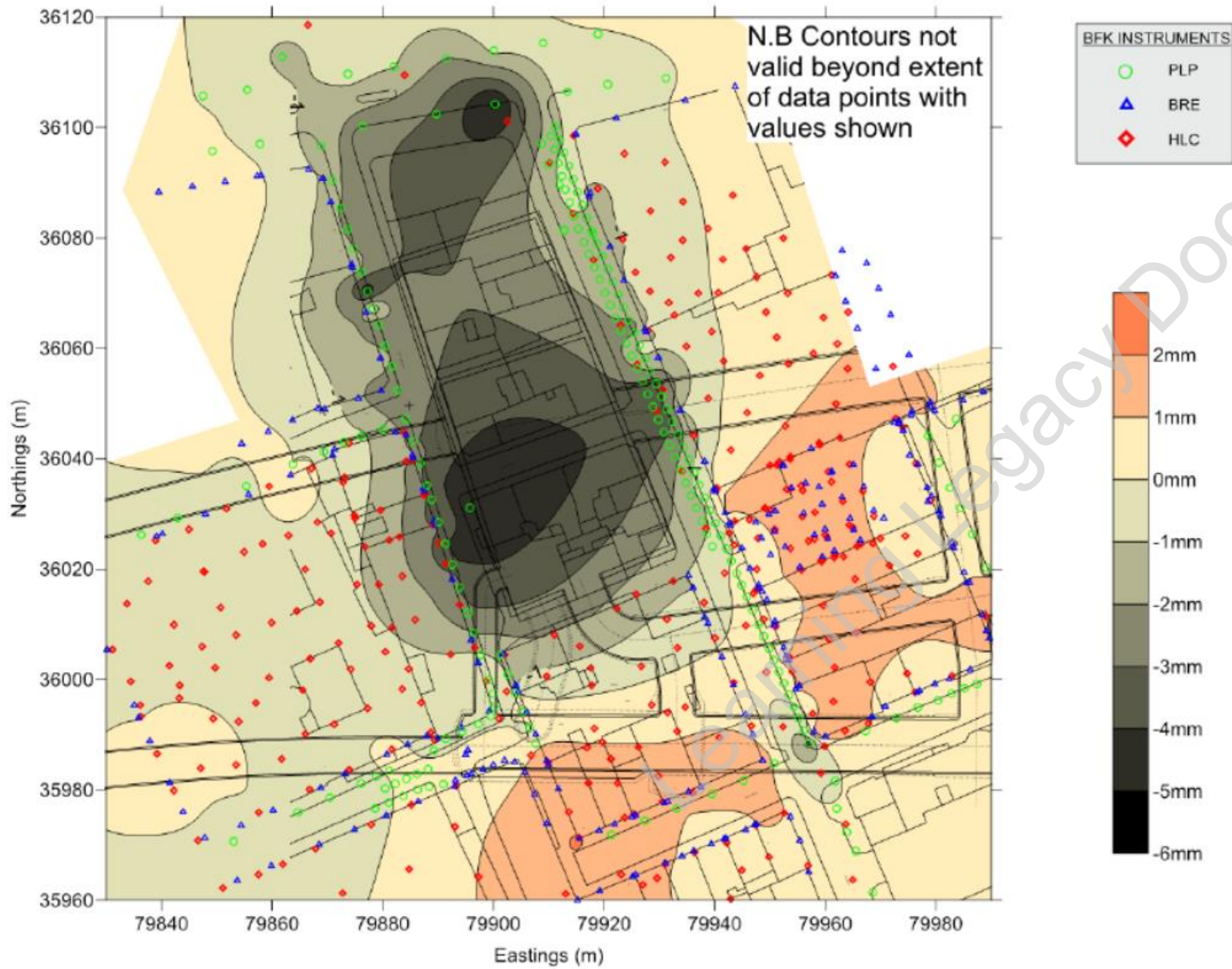
Learning Legacy Document

Appendix 1. Reference Documents

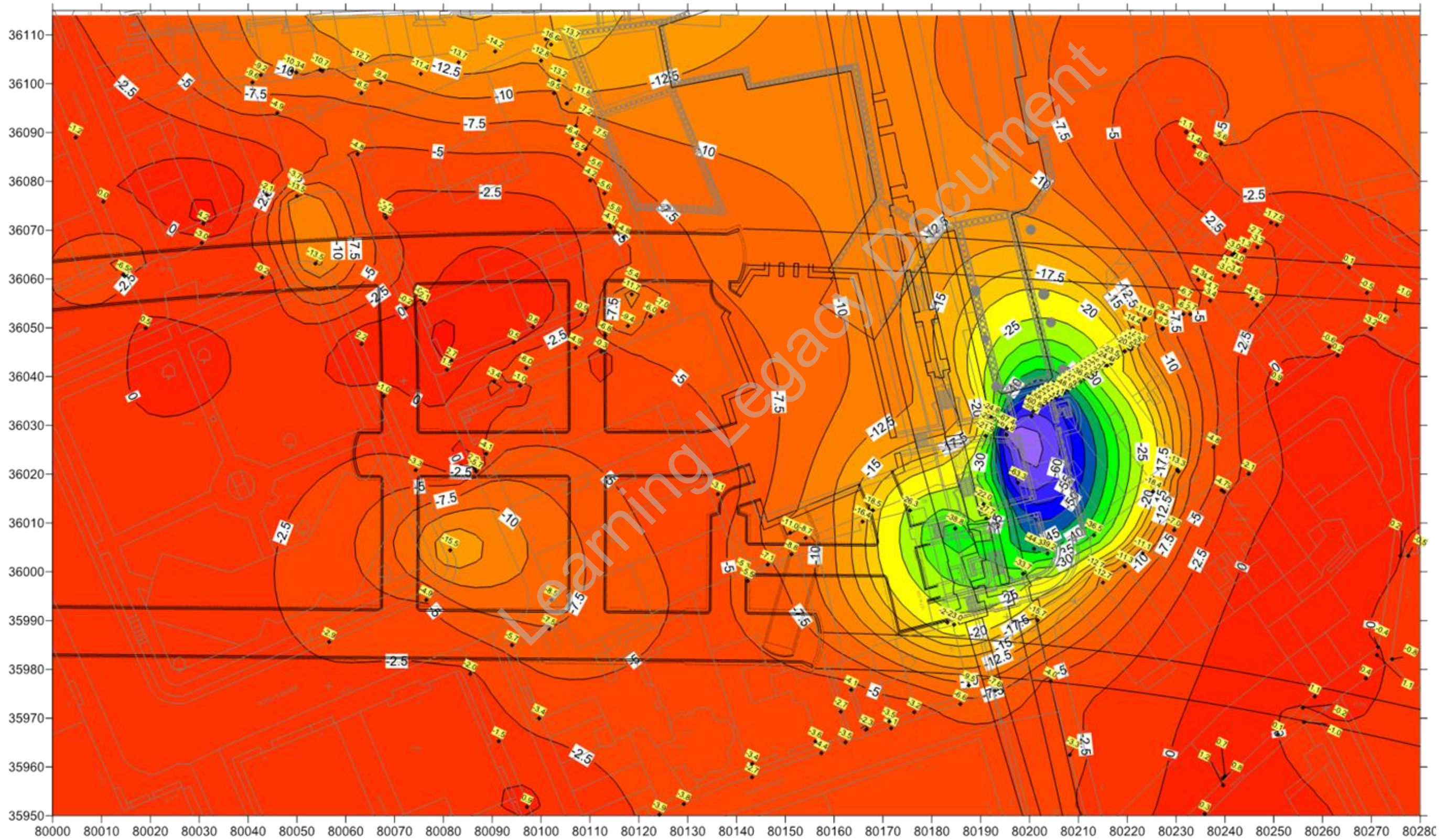
Code	Document
C300-BFK-C4-STP-CRT00_ST005-50006	Management Plan for the control of ground movement - Addendum 5 - TCR – WTH excavation
C300-BFK-C4-STP-CRT00_ST005-50062	Management Plan for Control of Ground Movements - Addendum 27 - TCR SCL Phase 1
C300-BFK-C4-STP-CRT00_ST005-50063	Management Plan for Control of Ground Movements - Addendum 28 - TCR SCL Phase 2
C300-BFK-C4-STP-CRT00_ST005-50154	Management Plan for the Control of Ground Movements - Addendum 33 - TBM Drives 6 - BOS to TCR
C300-BFK-C4-STP-CRT00_ST005-50196	Management Plan for the Control of Ground Movements - Addendum 41 - TCR Station - WTH North Box Excavation
C122-OVE-C2-RGN-CRG01-50011	Instrumentation and Monitoring Plans: Strategy
C122-OVE-C2-RGN-C125-50014	Instrumentation and Monitoring Plan: Tottenham Court Road Station. Ground Movement and Asset Protection
C121-MMD-C4-RAN-N105-00016	C121 Tottenham Court Road Station Monitoring Plan
C300-BFK-C4-RGN-CRT00_ST005-50569	Installation Report for Geodetic Prisms and BREs in TCR
C300-BFK-C4-RGN-CRT00_ST005-50583	Installation of PLPs in TCR area (Carlisle st) PMI-212
C300-BFK-C4-RGN-CRT00_ST005-50696	Installation Report for Extra PLP's in Dean Street TCR (PMI284)
C300-BFK-C4-RGN-CRT00_ST005-50760	Installation of Precise level points and Barcodes in Soho Square Gardens TCR (PMI312)
C300-BFK-C4-RGN-CRT00_ST005-50761	Installation of Precise levelling points in Soho Square TCR (PMI328)
C300-BFK-C4-RGN-CRT00_ST005-50767	Pre installation report for Crown Estates Properties on Regent St (PMI341)
C300-BFK-C4-RGN-CRT00_ST005-50769	Installation of Precise level points in TCR
C300-BFK-C4-RGN-CRT00_ST005-50799	Installation of Precise levelling points near deep pins at Soho square TCR (PMI177)
C300-BFK-C4-RGN-CRT00_ST005-50845	TCR station Upgrade Installation Report

Appendix 2. Initial Settlement adjustments and summary of TCRSU works progress

West Area – C421 data 08 & 09/02/12



East Area – TCRSU data 24/04/13



Summary of TCRSU works progress (supplied by C122)

Table 1: Surface excavation

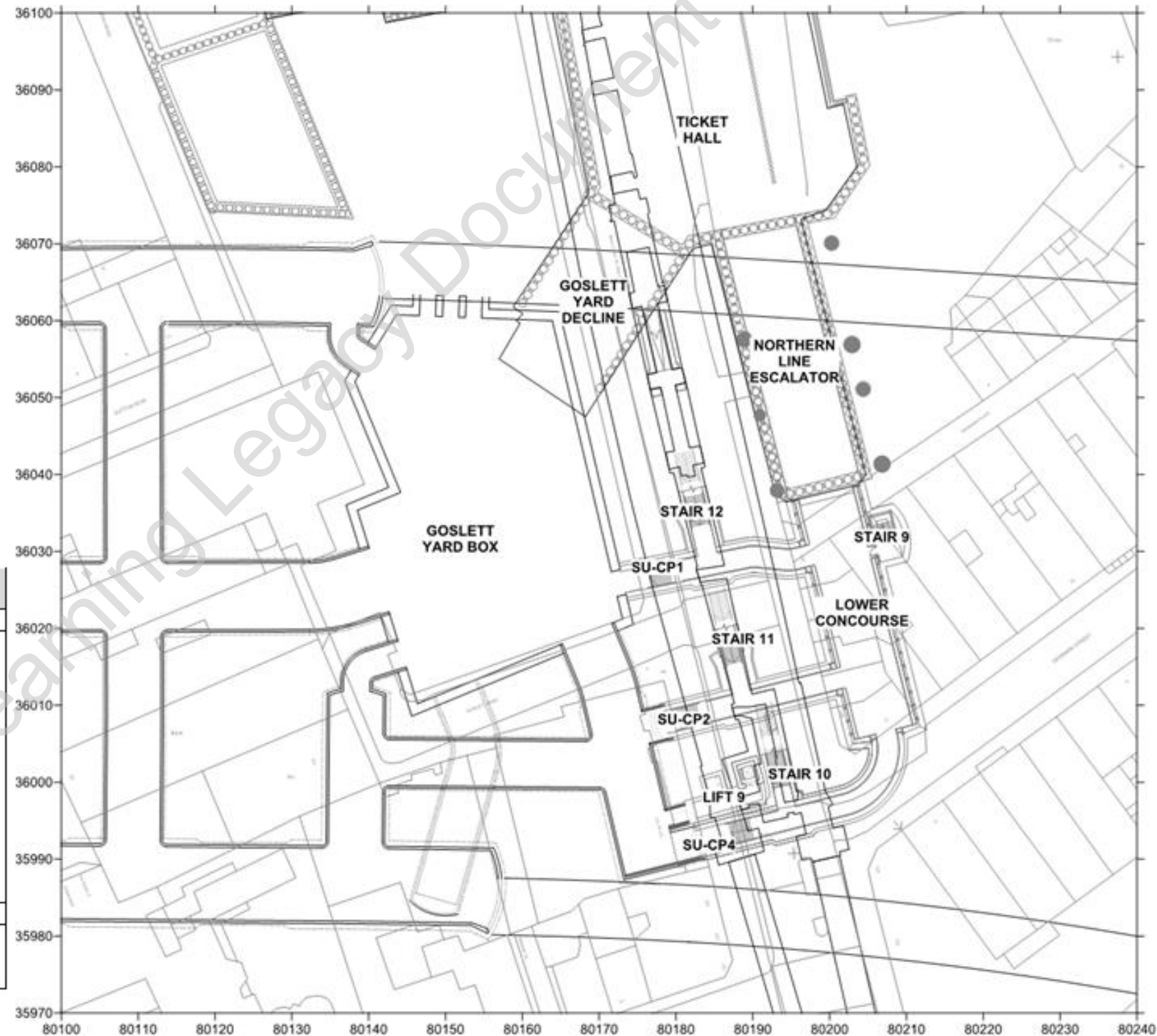
Completed Surface Excavations	Maximum Depth of Excavation	Main Dates of Excavation
Falconburg Shaft	98.25 mATD	14/02/2011 - 27/05/2011
Falconburg Basement	110.25 mATD	01/10/2012 - 28/11/2012
Ticket Hall	112.6 mATD	27/05/2011 - 06/09/2012
Goslett Yard Box	97.0 mATD	11/01/2012 - 14/10/2013
Goslett Yard Decline	106.0 mATD	04/04/2012 - 25/01/2013
Oxford Street Entrance	119.6 mATD	02/06/2011 - 21/05/2012
Northern Line Escalator	94.9 mATD	05/11/2010 - 16/06/2011

Table 2: Goslett Yard Detailed Excavation Dates

Construction Stage	From	To
Install Diaphragm Walls	08/11/2010	20/04/2011
Excavate Level -1 West Side	11/01/2012	09/02/2012
Excavate Level -1 East Side	08/02/2012	17/02/2012
Excavate Level -2 West	12/04/2012	14/05/2012
Excavate Level -2 East	14/05/2012	29/05/2012
Excavate Level -3	07/09/2012	12/12/2012
Excavate Level -4	07/01/2013	10/05/2013
Excavate Level -5	22/04/2013	12/08/2013
Level -1 Slab Pour	22/03/2012	03/04/2012
Level -2 Slab Pour	07/06/2012	05/09/2012
Level -3 Slab Pour	08/11/2012	24/06/2013
Level -4 Slab Pour	08/02/2013	24/05/2013
Level -5 Slab Pour	15/08/2013	12/10/2013

Table 3: Underground

Completed Underground Construction Works	From	To
Northern Line		
Lift 4 Excavation	19-Nov-10	14-Apr-11
Stair 11 Platform Works	09-May-11	03-Sep-11
Stair 12 Platform Works	09-May-11	03-Sep-11
Lift 4 Platform Works	27-Jun-11	05-Nov-11
Northern Line Lower Concourse Excavation	19-Feb-12	10-May-12
CP2 Excavation	12-May-12	23-May-12
CP4 Excavation Stage 1	02-Jul-12	09-Jul-12
CP1 Excavation	10-Jul-12	20-Jul-12
Stair 11 Excavation	24-May-12	24-Aug-12
Stair 12 Excavation	20-Jul-12	05-Nov-12
CP4 Excavation Stage 2	25-Oct-12	09-Nov-12
Stair 10 Excavation	20-Aug-12	21-Dec-12
Lift 9 Excavation	20-Aug-12	21-Dec-12
Lift 2 Works	23-Mar-12	15-May-12
Central Line		
Central Line Interchange Tunnel Excavation	21-Jun-11	28-Nov-11
Overbridge 2 Excavation and primary lining	15-Feb-12	09-Mar-12
Overbridge 1 Excavation and primary lining	06-Mar-12	28-Mar-12



Appendix 3. Summary Plots including spreadsheet relating BFK and UCIMS IDs

West Area: Location and Final Settlement for data presented (a) BRE; (b) PLP



East Area: Location and Final Settlement for data presented (a) BRE; (b) PLP

