



C300/410

Western Tunnels & Caverns Project

Close-Out Monitoring Report

FISHER STREET WORKS ~ Crossover

CRL Document No. **C300-BFK-C4-RGN-CRT00_ST005-53010**

Contract MDL reference: C14.020

1. Contractor Document Submittal History

Revision	Date	Prepared by	Checked by	Approved by	Reason for Issue
3.0	02/08/2016	[REDACTED]	[REDACTED]	[REDACTED]	For CRL Acceptance
		[REDACTED]	[REDACTED]	[REDACTED]	

2a. Stakeholder Review Required? YES NO

Stakeholder submission required:

LU

NR

DLR

RfL

LO

Other: _____

Purpose of submission:

For no objection

For information

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
					<input type="checkbox"/>
					<input type="checkbox"/>

3. Acceptance by Crossrail:

	Crossrail Review and Acceptance Decal This decal is to be used for submitted documents requiring acceptance by Crossrail.		
<input checked="" type="checkbox"/>	Code 1.	Accepted. Work May Proceed	
<input type="checkbox"/>	Code 2.	Not Accepted. Revise and resubmit. Work may proceed subject to incorporation of changes indicated	
<input type="checkbox"/>	Code 3.	Not Accepted. Revise and resubmit. Work may not proceed	
<input type="checkbox"/>	Code 4.	Received for information only. Proceeding as normal	
Reviewed/Accepted by: (signature)	Print Name	Position:	Date: 16/08/16
Acceptance	the designer/supplier confirms that the design, details, calculations, analyses, test methods or materials developed or selected by the designer/supplier.		

This document contains proprietary information. No part of this document may be reproduced without prior written consent from the chief executive of Crossrail Ltd

© Crossrail Limited CRL RESTRICTED

Contents

1.	PURPOSE AND SCOPE	3
2.	WORKS AT FISHER STREET CROSSOVER	5
3.	COMPARISON OF OBSERVED AND PREDICTED SETTLEMENT	7
3.1.	Settlement Overview	7
3.2.	End of Construction (Period F)	9
3.3.	Period A – WB TBM	10
3.4.	Period B – EB TBM	11
3.5.	Period C – WBX-1	13
3.6.	Period D - WBX-1, WBX-2, WBX-3, WB	15
3.7.	Period E - EBX-1, CP5, EBX-2, EBX-3, EBX	17
3.8.	Period F - Crossover, CP1, CP5, CP2, Niche 2, Niche 1	19
3.9.	Period G – Post construction	21
4.	MONITORING DATA	22
4.1.	Proctor Street West	22
4.2.	Proctor Street East	24
4.3.	Red Lion Square West	25
4.4.	Dane Street / Red Lion Gardens	26
4.5.	Red Lion Square North	30
4.6.	Red Lion Square South – Inner Kerblines PLPs	32
4.7.	Red Lion Square South	34
4.8.	Red Lion Square East	36
4.9.	Princeton Street	38
4.10.	Red Lion Street	40
4.11.	Eagle Street	42
4.12.	Ground Instruments	44
Appendix 1.	Reference Documents	49
Appendix 2.	Thames Water Assets summary table	49
Appendix 3.	C300 Buildings Claims	49
Appendix 4.	BRE and PLP Location Plans	50

1. PURPOSE AND SCOPE

The purpose this document is to provide a summary of the observed movements related to the works in the vicinity of Fisher Street Crossover and to provide the information required under Clauses KX10.2113 and KX10.2114 for Final and Close-Out Reports to gain agreement to the de-commissioning of instrumentation.

It is noted that monitoring has been progressively de-scoped by presentation of data at CTC meetings with subsequent confirmation under a number of RFIs, namely C410-RFI-001386, C410-RFI-001395, C410-RFI-001398, C410-RFI-001399, C410-RFI-001446, C410-RFI-001471, C410-RFI-001488, C410-RFI-001500, C410-RFI-001592 and C410-RFI-001602.

The “as-built record and status” required under KX10.4102 will be supplied as co-ordinates and digital data for incorporation into UCIMS.

The overall construction of the Crossover has been divided into a number of Construction Periods. The observed movements are compared to the calculated volume loss movements by presentation of contours for each period. Time – settlement plots relating the observed movements to the construction activities are presented for BRE, PLP and Prisms. Information is provided concerning where trigger levels have been exceeded and on the post construction movements. Location plans for the BRE and PLP are given in Appendix 4.

Data from in ground instruments is included in this report.

Information about Thames Water assets in this area has been provided in the relevant TBM close out reports (see Appendix 2).

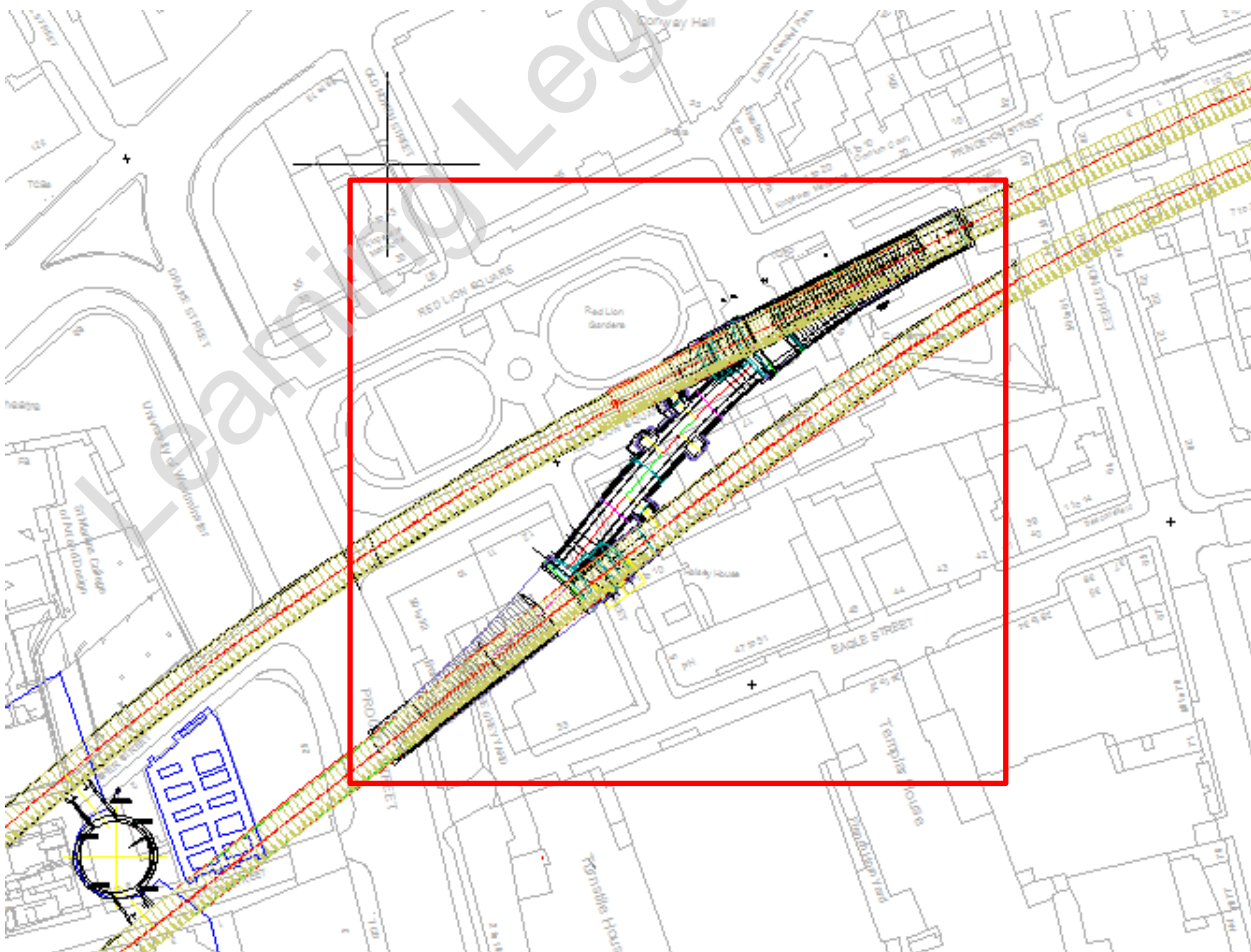


Figure 1.1.1: Location. General overview of the works



Learning Legacy Document

2. WORKS AT FISHER STREET CROSSOVER

The works in this area consisted of TBM running tunnels (WB and EB) and a number of SCL enlargements and SCL tunnels. Figure 2.1 shows the nomenclature used for the different section of the SCL works within Fisher Street crossover area. Table 2.1 includes the start and finish dates for each of the tunnelling sections.

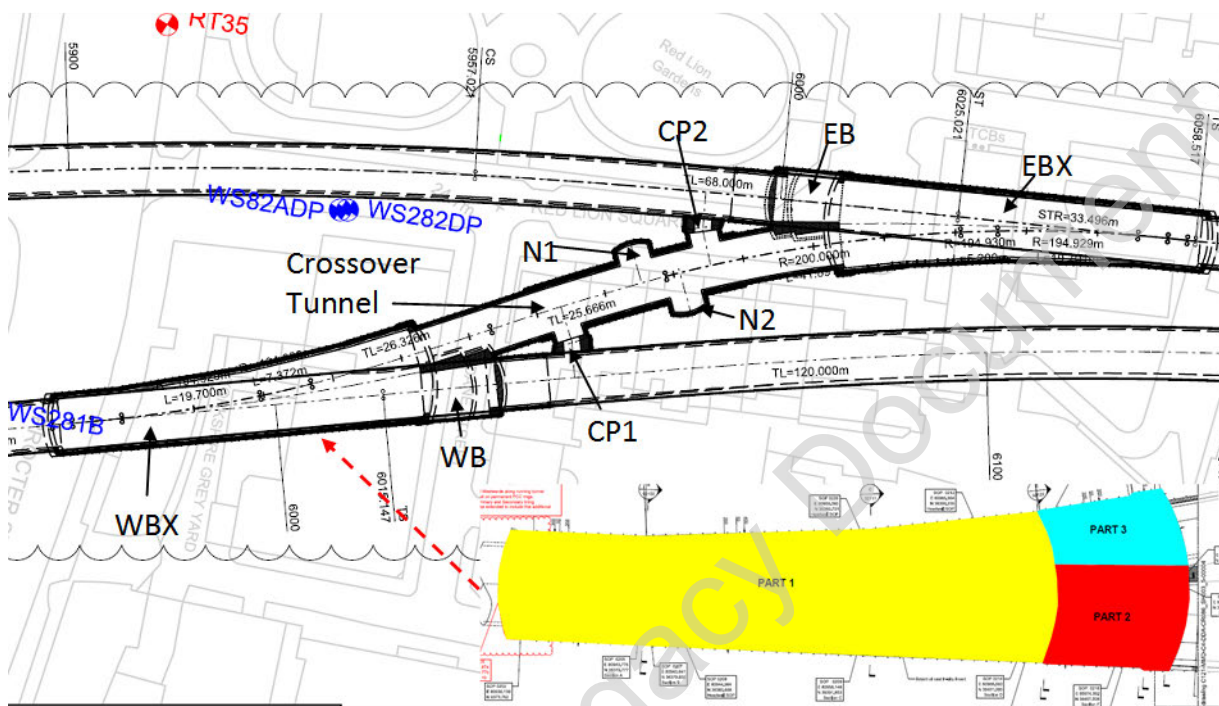


Figure 2.1: Nomenclature for the tunnel elements

Table 2.1. Construction dates for works in FIS crossover area.

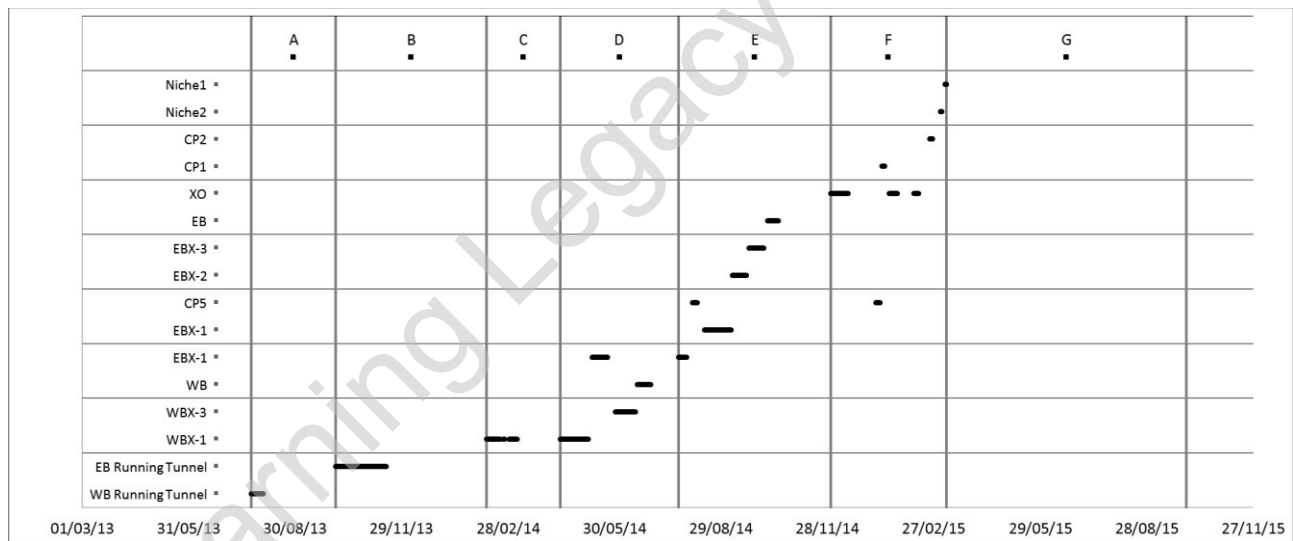
Tunnel section	Start Date	End Date
WBRT	24/07/2013	03/08/2013
EBRT	04/10/2013	16/11/2013
WBX-1	10/02/2014	21/02/2014
	24/02/2014	25/02/2014
	01/03/2014	08/03/2014
	14/04/2014	08/05/2014
WBX-2	11/05/2014	24/05/2014
WBX-3	31/05/2014	17/06/2014
WB	19/06/2014	30/06/2014
EBX-1	24/07/2014	31/07/2014
	15/08/2014	07/09/2014
EBX-2	08/09/2014	20/09/2014
EBX-3	22/09/2014	05/10/2014
EB	08/10/2014	17/10/2014
XO	01/12/2014	16/12/2014
	20/01/2015	27/01/2015
	10/02/2015	14/02/2015
CP1	14/01/2015	16/01/2015
CP2	24/02/2015	26/02/2015
N1	09/03/2015	10/03/2015
N2	05/03/2015	06/03/2015

For clarity of presentation of monitoring data, the overall duration of the works has been divided into a number of Construction Periods (A to G). The dates of the Construction Periods and the sections of tunnel constructed in each are listed in Table 2.2 and illustrated in Figure 2.2

Table 2.2. Construction Periods for works in FIS crossover area.

Period	Start Date	End Date	Main Works
A	24/07/2013	04/10/2013	WB TBM passage
B	04/10/2013	10/02/2014	EB TBM passage
C	10/02/2014	14/04/2014	WBX-1
D	14/04/2014	24/07/2014	WBX-1, WBX-2, WBX-3, WB
E	24/07/2014	01/12/2014	EBX-1, CP5, EBX-2, EBX-3, EBX
F	01/12/2014	10/03/2015	Crossover, CP1, CP5, CP2, Niche 2, Niche 1
G	10/03/2015	01/10/2015	-

Figure 2.1.2: Construction dates and periods for Crossover works at Fisher Street



3. COMPARISON OF OBSERVED AND PREDICTED SETTLEMENT

3.1. Settlement Overview

The following contours of calculated short term (volume loss) settlement and observed settlement are presented in Sections 3.2 to 3.9:

Section 3.1:

- Volume loss settlement for all tunnels (Figure 3.2.1);
- Measured settlement to September 2015, including consolidation settlement during the 20 month construction period (Figure 3.2.2).

Section 3.2:

- Volume loss settlement for tunnels constructed in Period A;
- Observed total settlement at end of Period A.

Sections 3.3 to 3.8:

- Volume loss settlement for tunnels constructed in Periods B to F;
- Change in observed settlement during Periods B to F;
- Observed total settlement at end of Periods B to F.

Section 3.9:

- Change in observed settlement during Periods G;
- Observed total settlement at end of Period G.

The following points are noted:

- The contours in Section 3.1 show that the predicted and measured settlement contours are generally comparable in both magnitude and extent, notwithstanding that the observed movements include consolidation settlement during the 20 month construction period.
- The maximum observed settlement at the end of construction of 47mm is slightly greater than the calculated value of 41mm, based on the specified volume loss.
- The predicted and observed 1mm contours are approximately in the same offset from the tunnels, suggesting that the trough width is similar to that used in the predicted contours.
- Thus, it can be inferred that the overall volume loss for construction of the whole Crossover is close to the specified values since this is the basis of the predicted contours. However, due to the numerous pauses in the construction it is not practicable to accurately separate volume loss and consolidation settlements.
- For the WBRT (Period A), the maximum contour gives 6mm, (locally 7mm) which is generally less than the 1% volume loss calculated value of 8 - 9mm.
- Similarly in Period B, the maximum contour is 8mm measured settlement, compared to 9mm calculated for 1% volume loss.
- In Period C the maximum contour is 8mm measured settlement, compared to 6mm calculated for 1.5% volume loss.
- In Period D the maximum contour is 20mm measured settlement, compared to 20mm calculated settlement for 1.5% volume loss.
- In Period E the maximum contour is 22mm measured settlement, compared to 20mm calculated settlement for 1.5% volume loss.
- In Period F the maximum contour is 20mm measured settlement, compared to 28mm calculated settlement for 1.5% volume loss.
- In Period G, following the end of construction a maximum contour of 2mm settlement is shown.

- Table 3.1 compares the maximum settlement measured at any individual point with the actual maximum value from the volume loss contour.
- Both the comparisons by contours and by maximum individual values indicate slightly greater maximum observed settlement than given by the volume loss calculation. It is noted that the construction was undertaken over a protracted period of 20 months and hence significant consolidation settlement is included in the measured values.
- Trigger levels were set in terms of absolute settlement (35mm for Green, 45mm for Amber, 55mm for Red). Based on the contour plots, Green triggers were exceeded in Period E and Amber triggers in Period F. No Red triggers were exceeded. The areas in which the triggers have been exceeded can be seen from the contour plots.

Table 3.1 Comparison of calculate and measured maximum settlement in each Construction Period

Period	Max settlement (mm)	Max change in Period (mm)	Predicted max Vol Loss change (mm)	Period duration (days)
A	-8.7	-9.4	~-11	72
B	-14.6	-9.7	~-11	129
C	-16.5	-8.3	-6.6	63
D	-32.3	-20.4	-19.5	101
E	-42.0	-21.7	-20.3	130
F	-46.8	-23.1	-27.5	99
G	-47.4	-4.2	0.0	205

3.2. End of Construction (Period F)

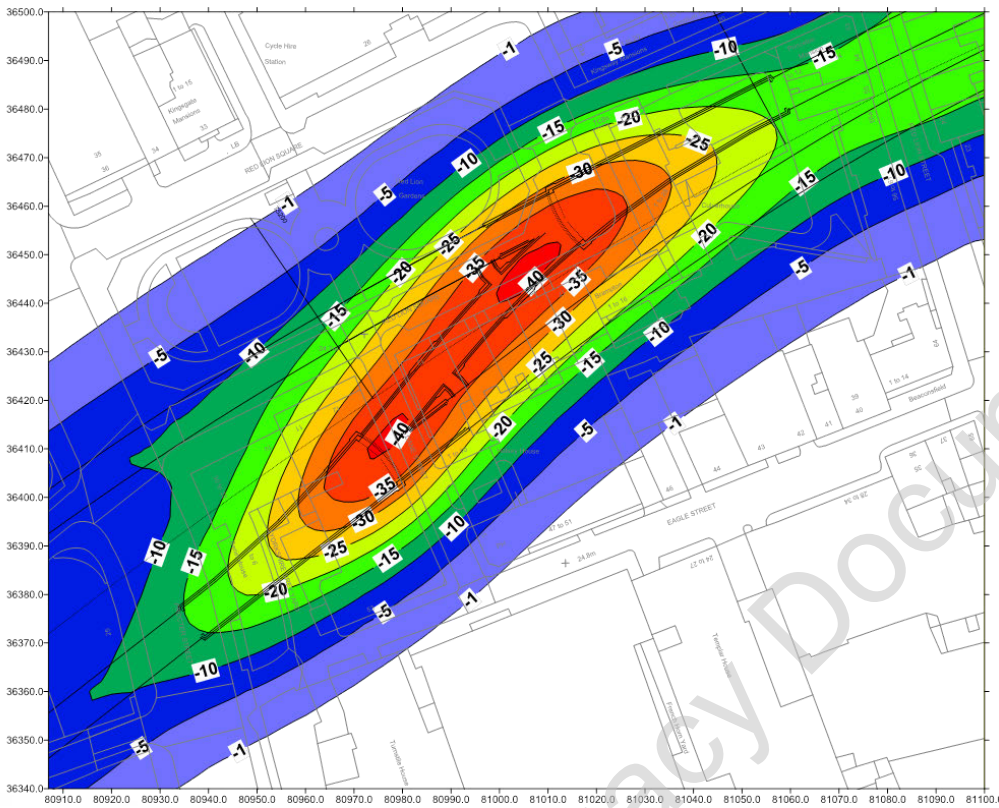


Figure 3.1: predicted settlements at the end of construction based on specified Volume Loss values

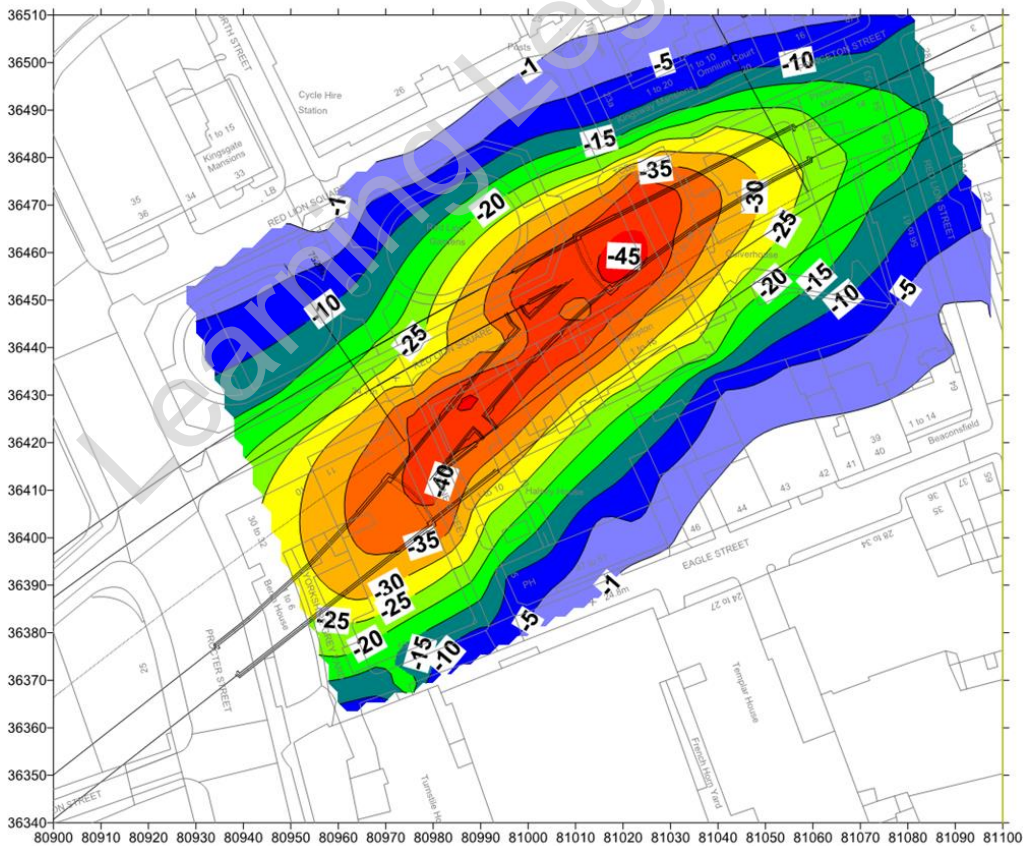


Figure 3.2: measured settlements at the end of construction

3.3. Period A – WB TBM

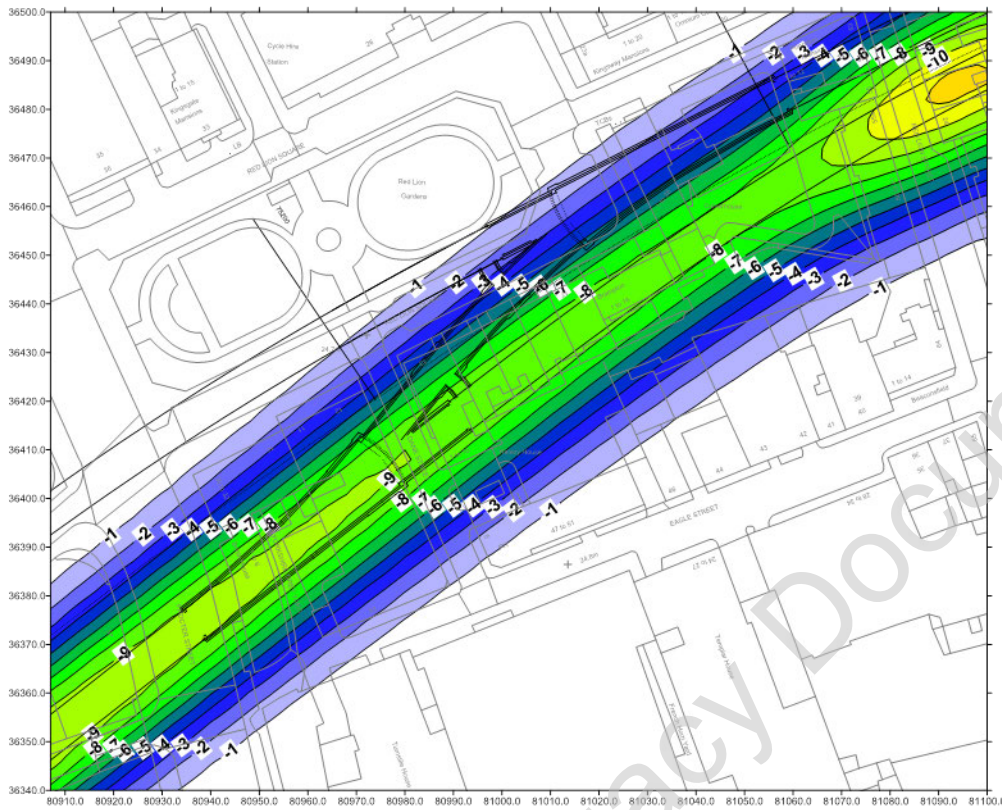


Figure 3.3: Period A – predicted settlements

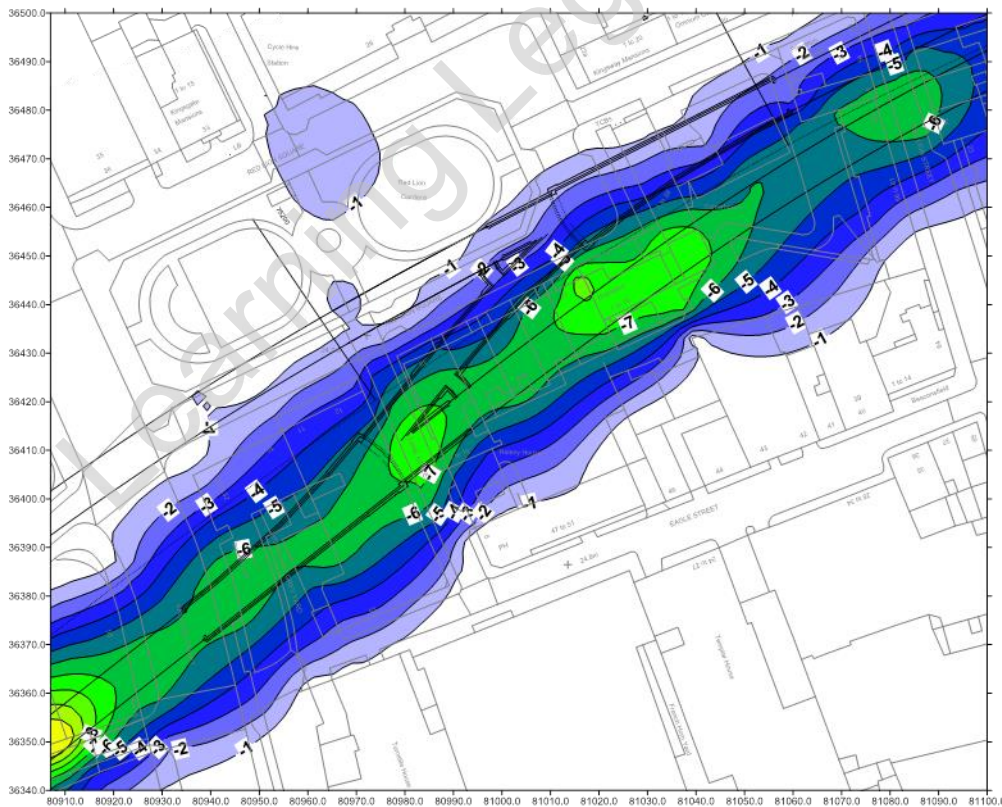


Figure 3.4: Period A – total measured settlement

3.4. Period B – EB TBM

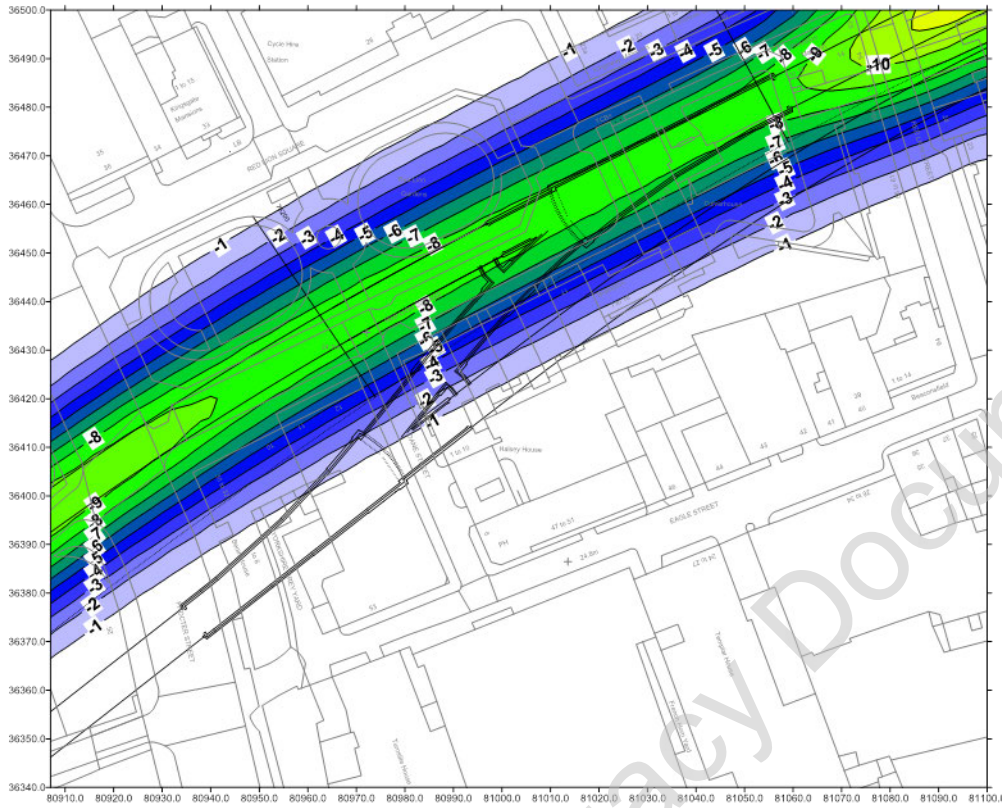


Figure 3.5: Period B – predicted Settlements

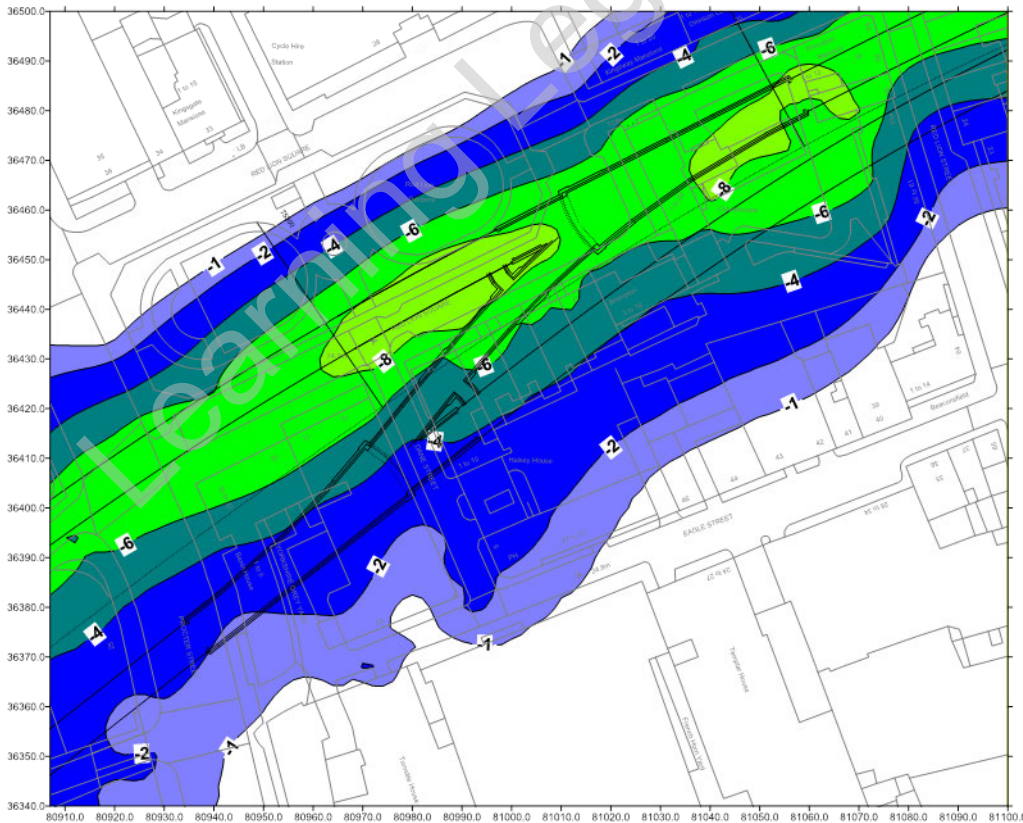


Figure 3.6: Period B – change in Measured Settlements

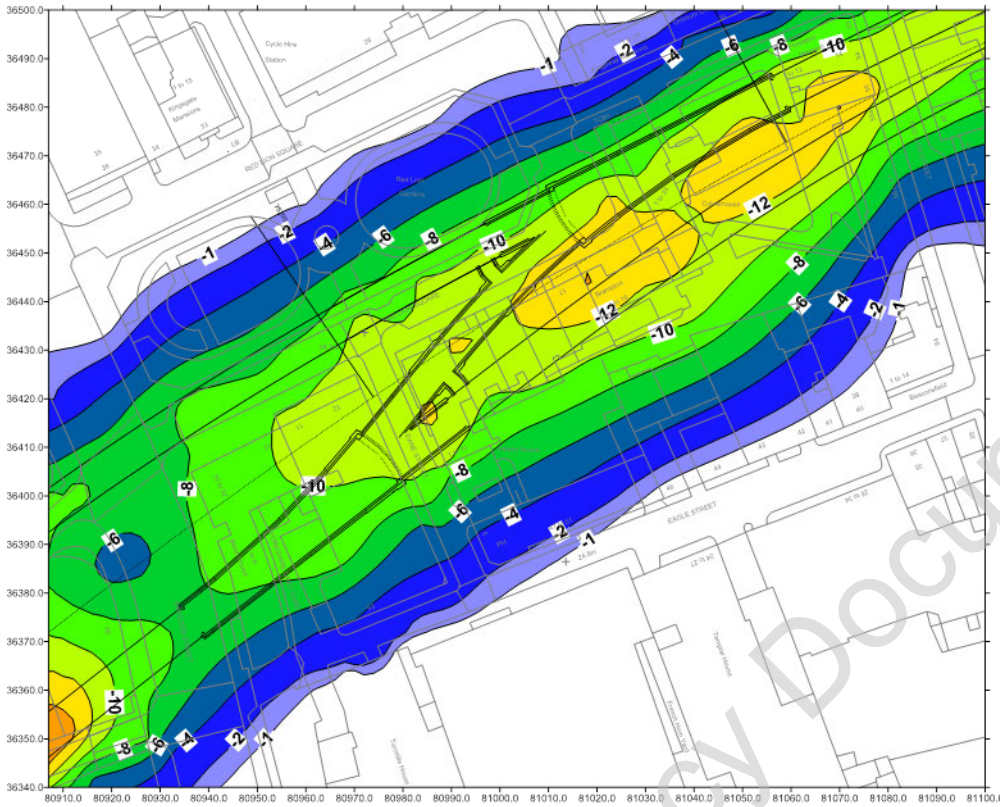


Figure 3.7: Period B – total measured settlement

Learning Legacy Document

3.5. Period C – WBX-1

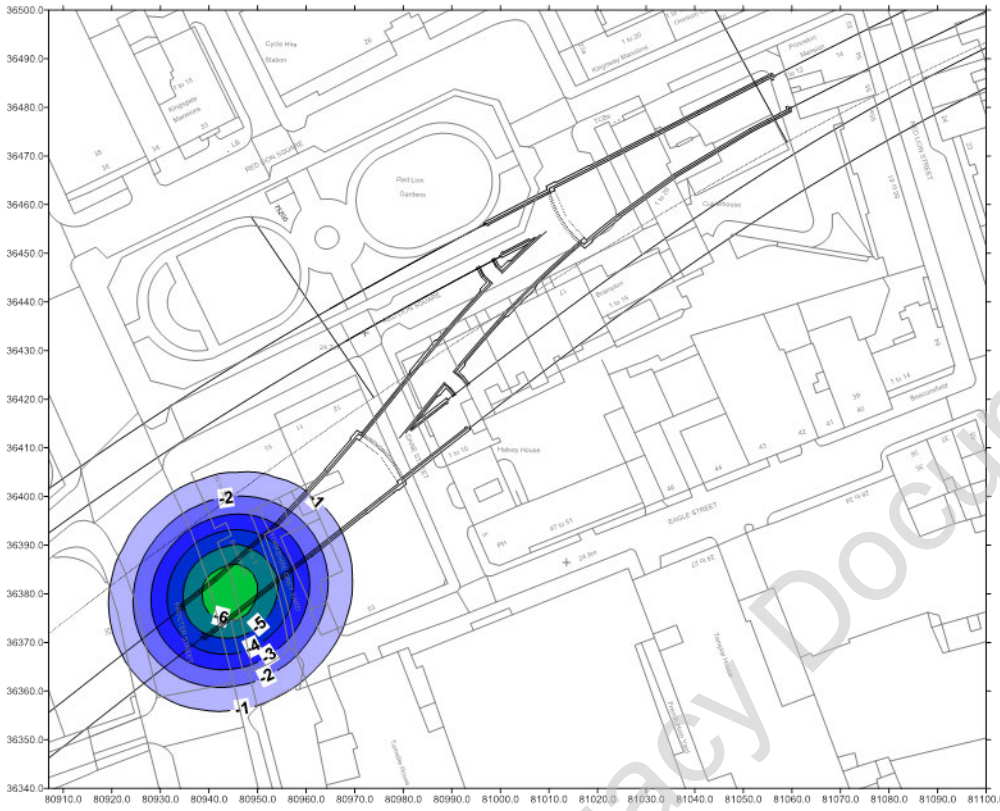


Figure 3.8: Period C – predicted settlements

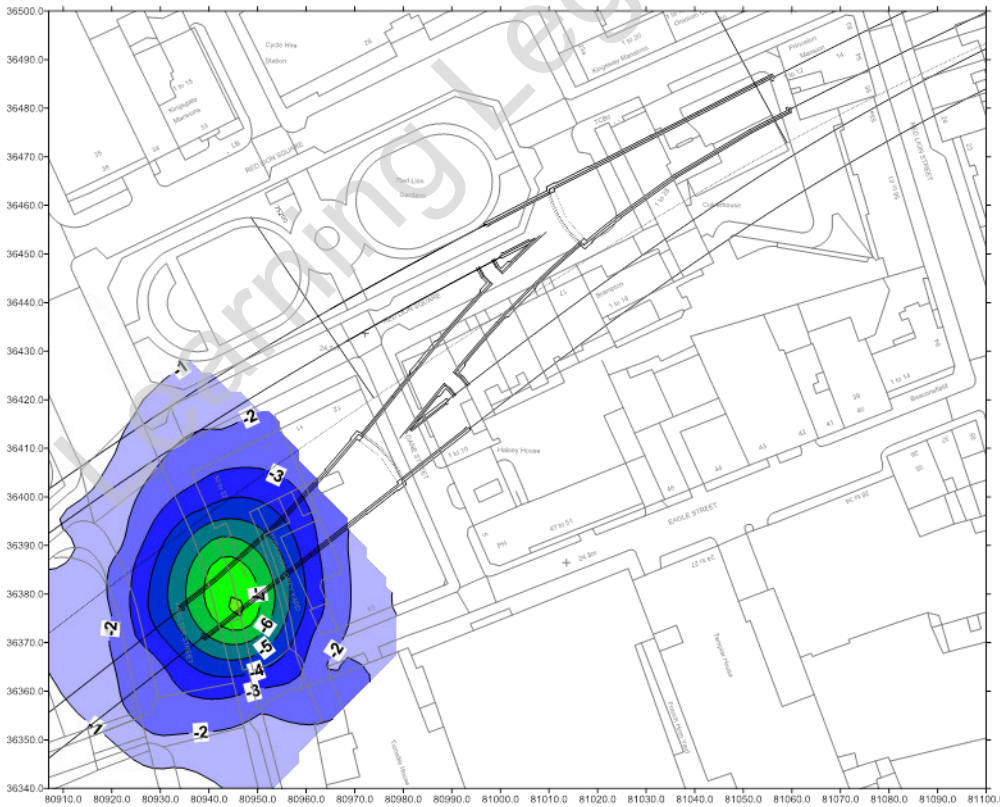


Figure 3.9: Period C – change in measured settlements

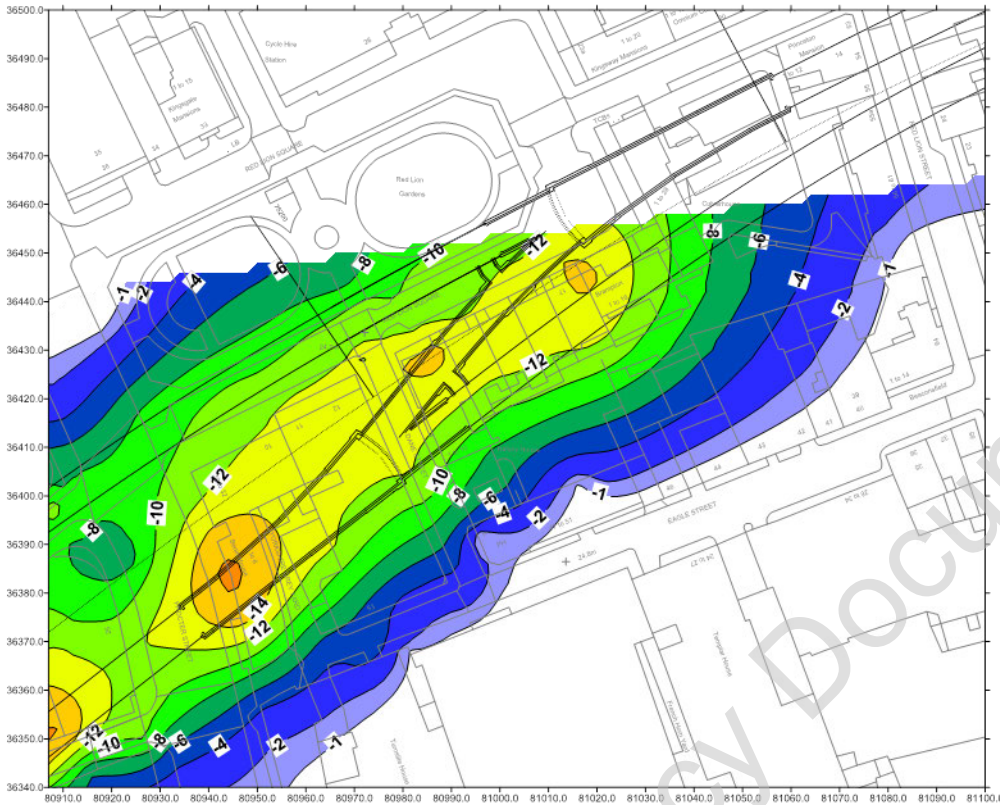


Figure 3.10: Period C – total measured settlements

Learning Legacy Document

3.6. Period D - WBX-1, WBX-2, WBX-3, WB

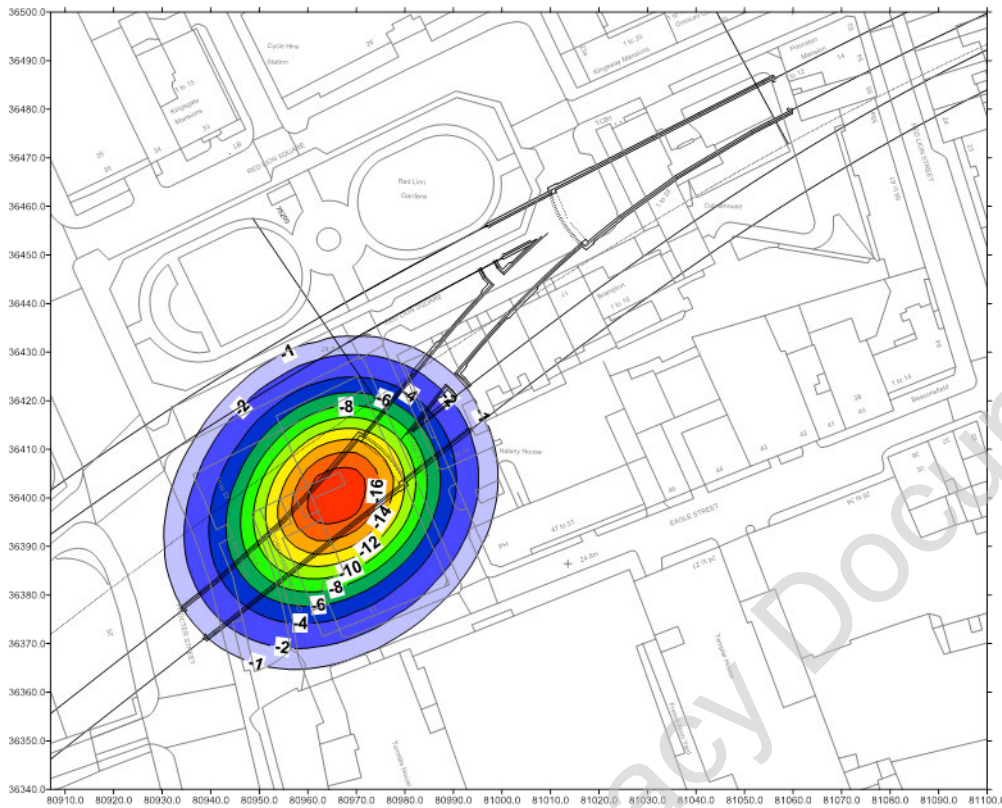


Figure 3.11: Period D – predicted settlements

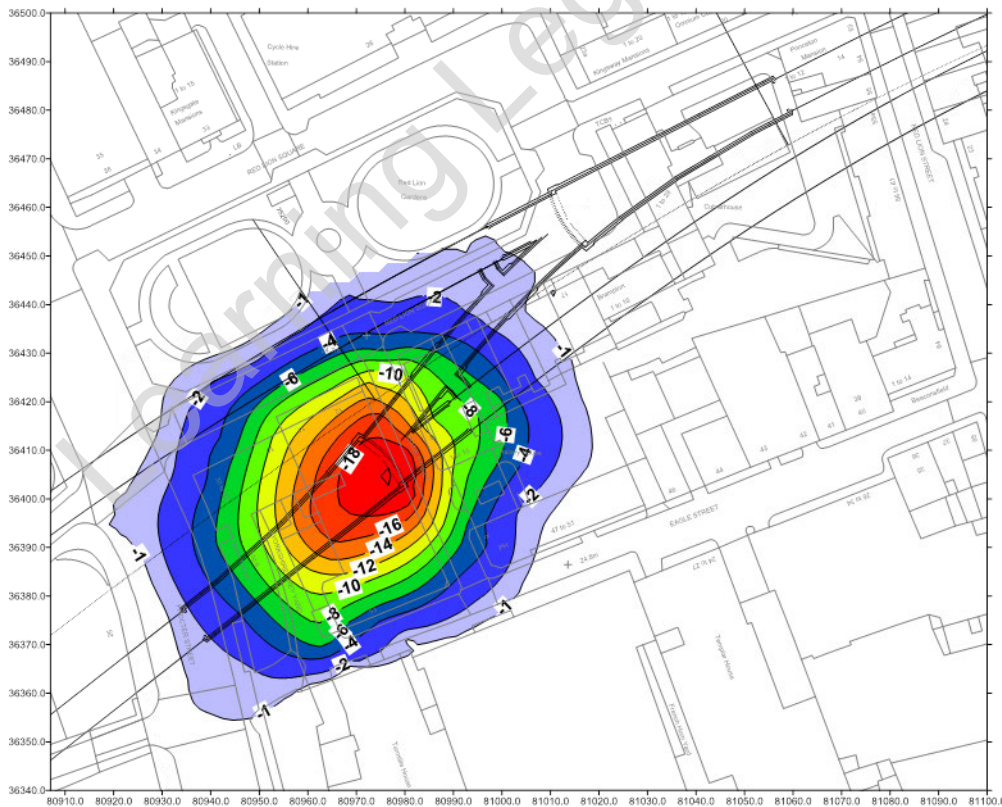


Figure 3.12: Period D – Change in measured settlements

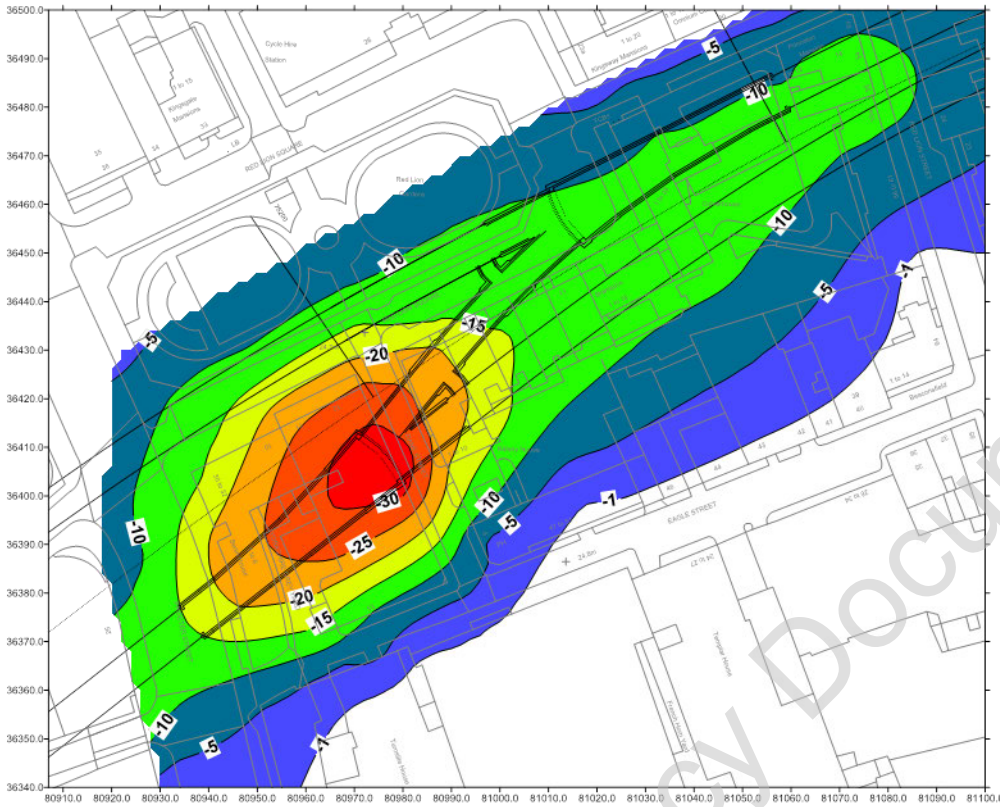


Figure 3.13: Period D – total measured settlements

Learning Legacy Document

3.7. Period E - EBX-1, CP5, EBX-2, EBX-3, EBX

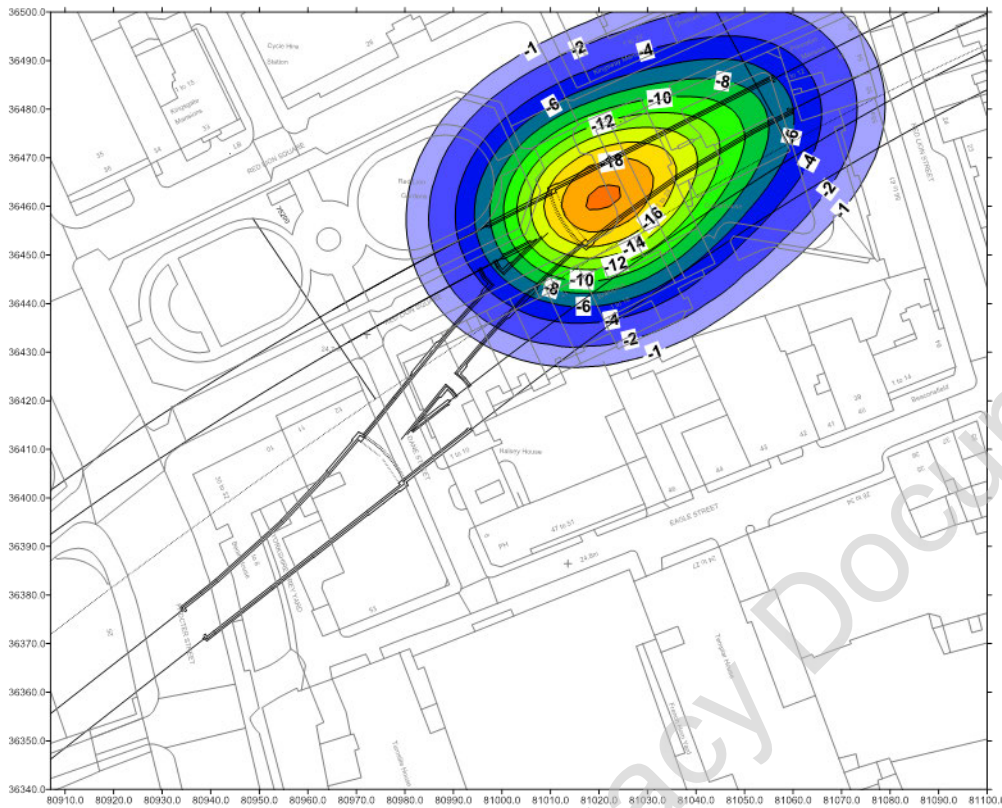


Figure 3.14: Period E – Predicted settlements

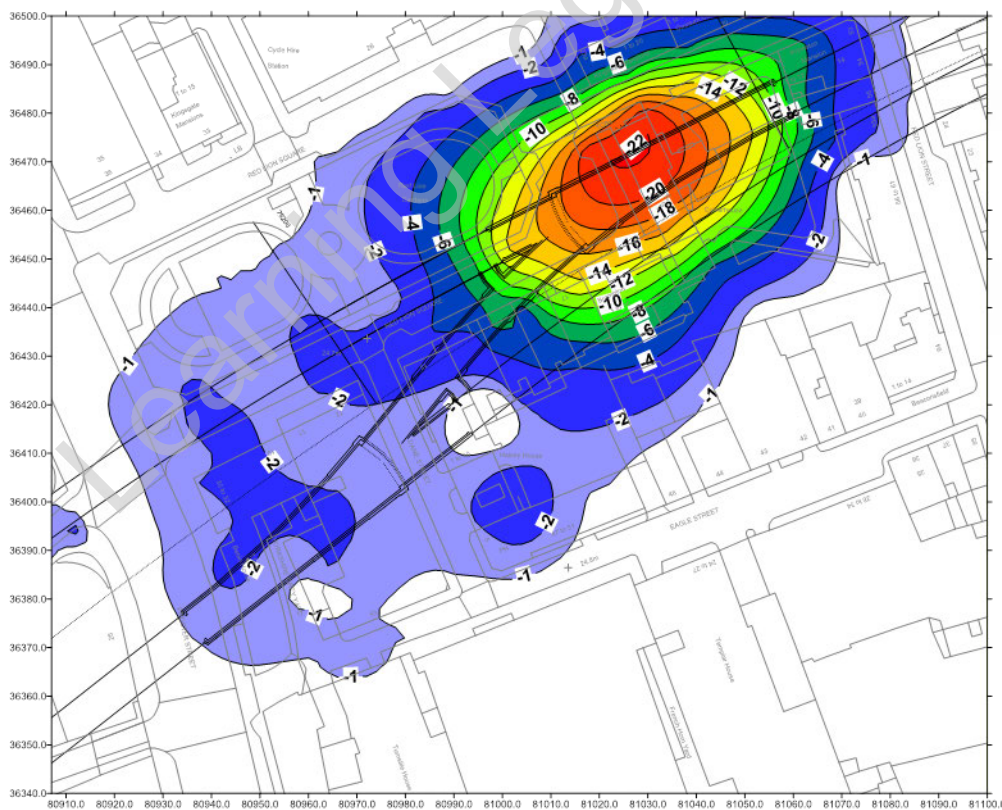


Figure 3.15: Period E – change in measured settlements

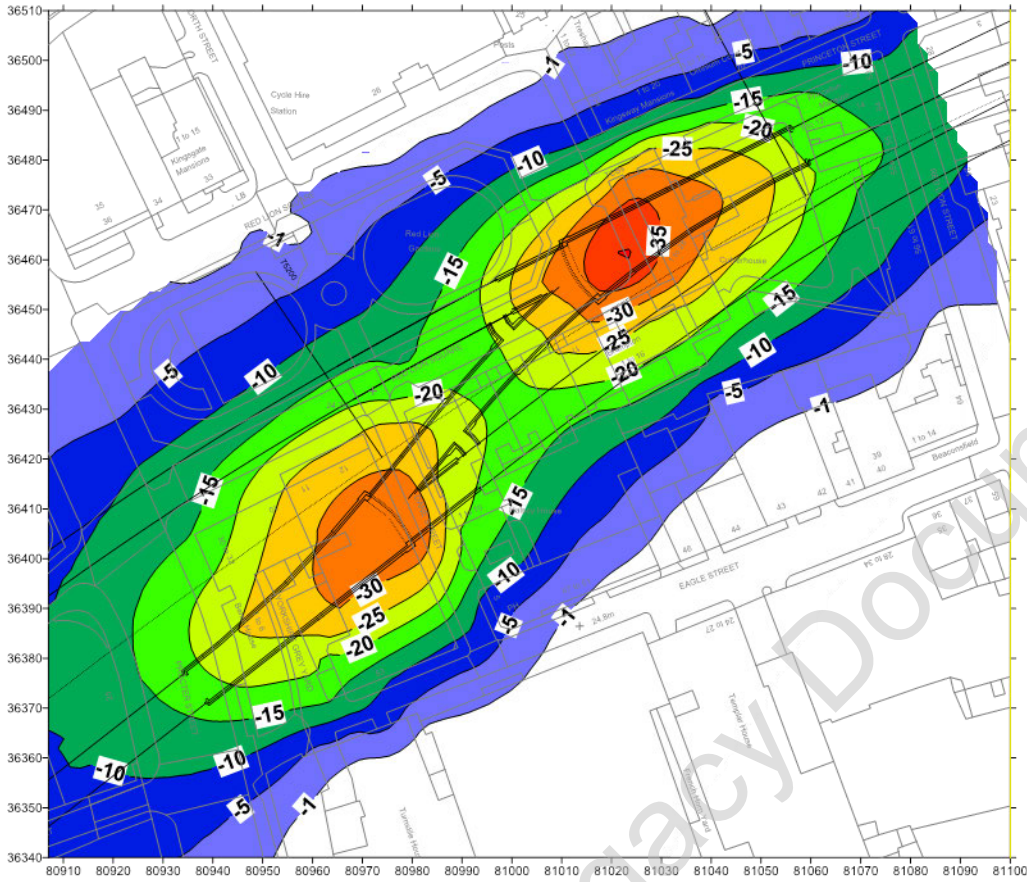


Figure 3.16: Period E – total measured settlements

Learning Legacy Document

3.8. Period F - Crossover, CP1, CP5, CP2, Niche 2, Niche 1

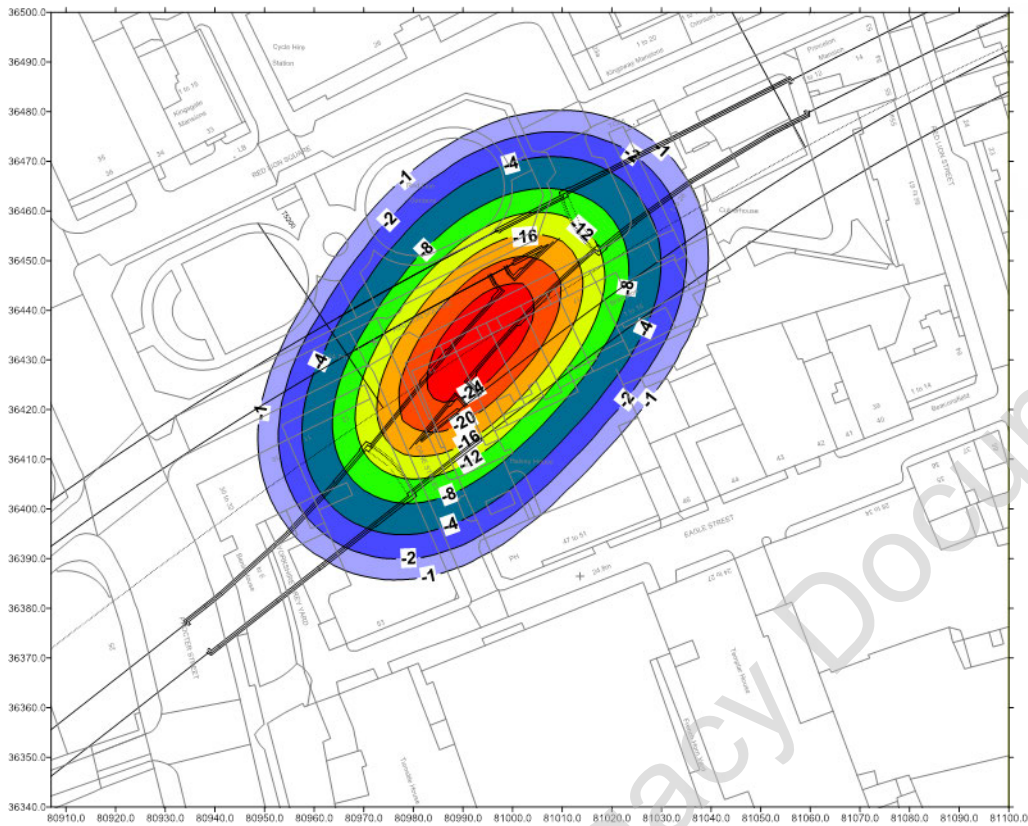


Figure 3.17: Period F – predicted settlements

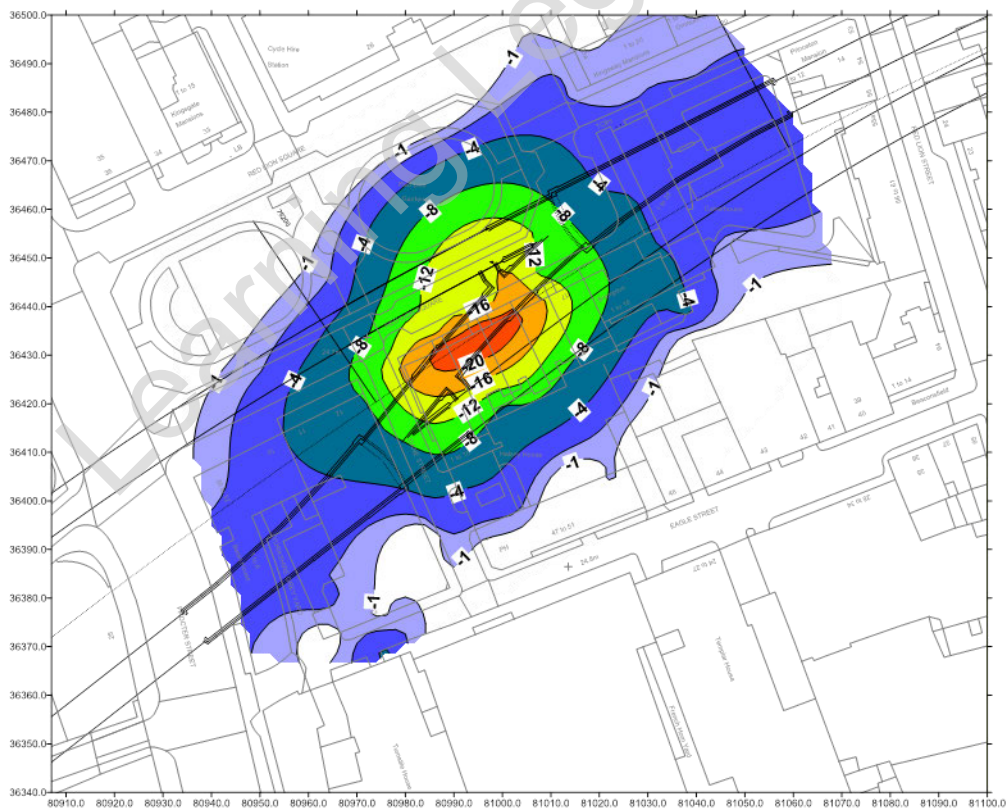


Figure 3.18: Period F – change in measured settlements

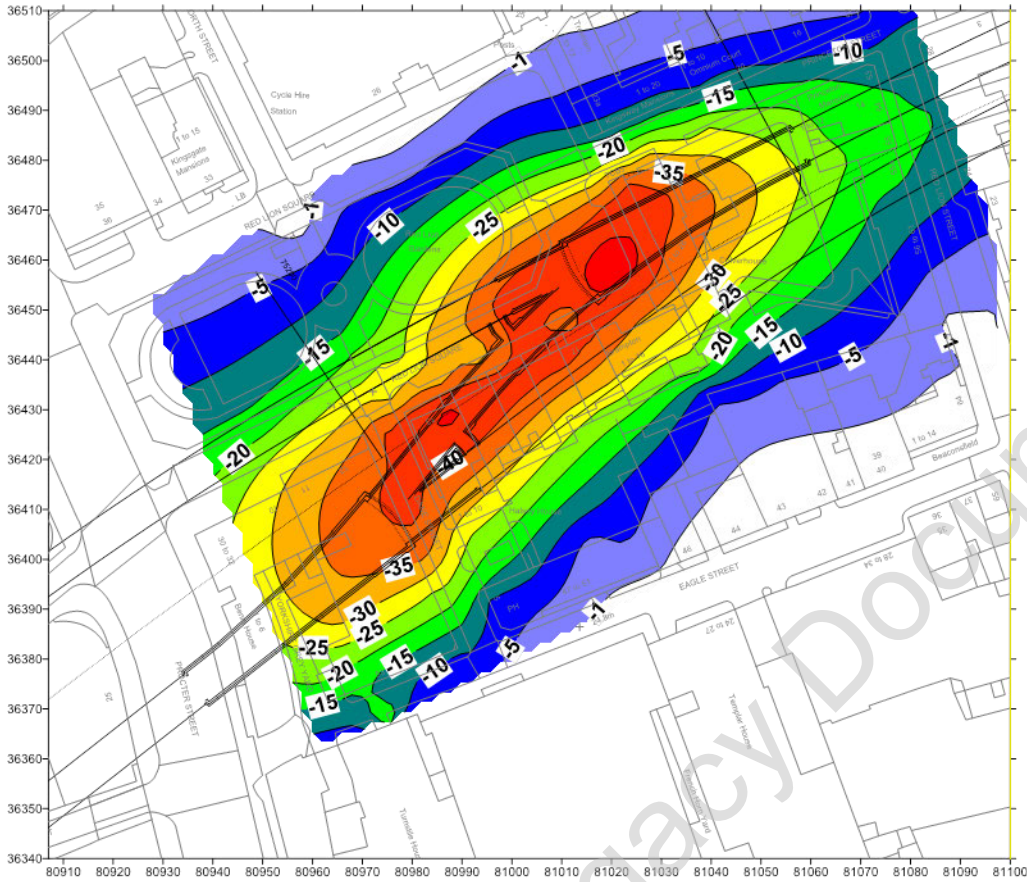


Figure 3.19: Period F – total measured settlements

Learning Legacy Document

3.9. Period G – Post construction

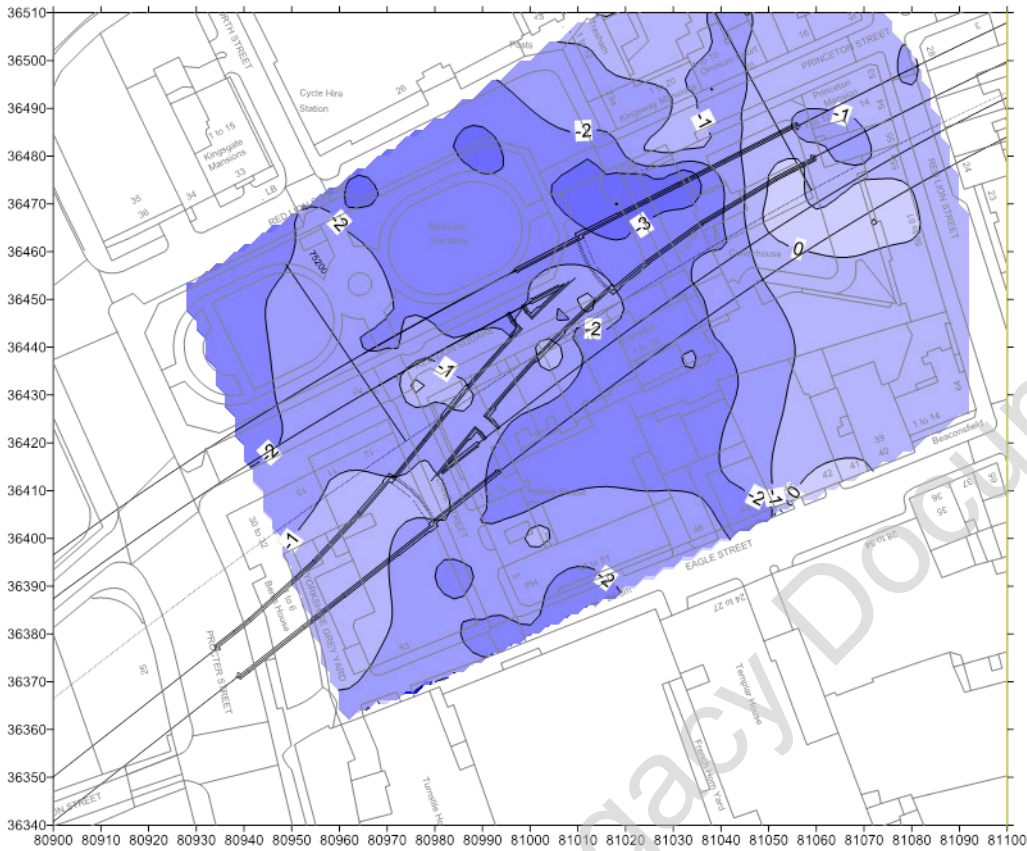


Figure 3.20: Period G – change in measured settlements

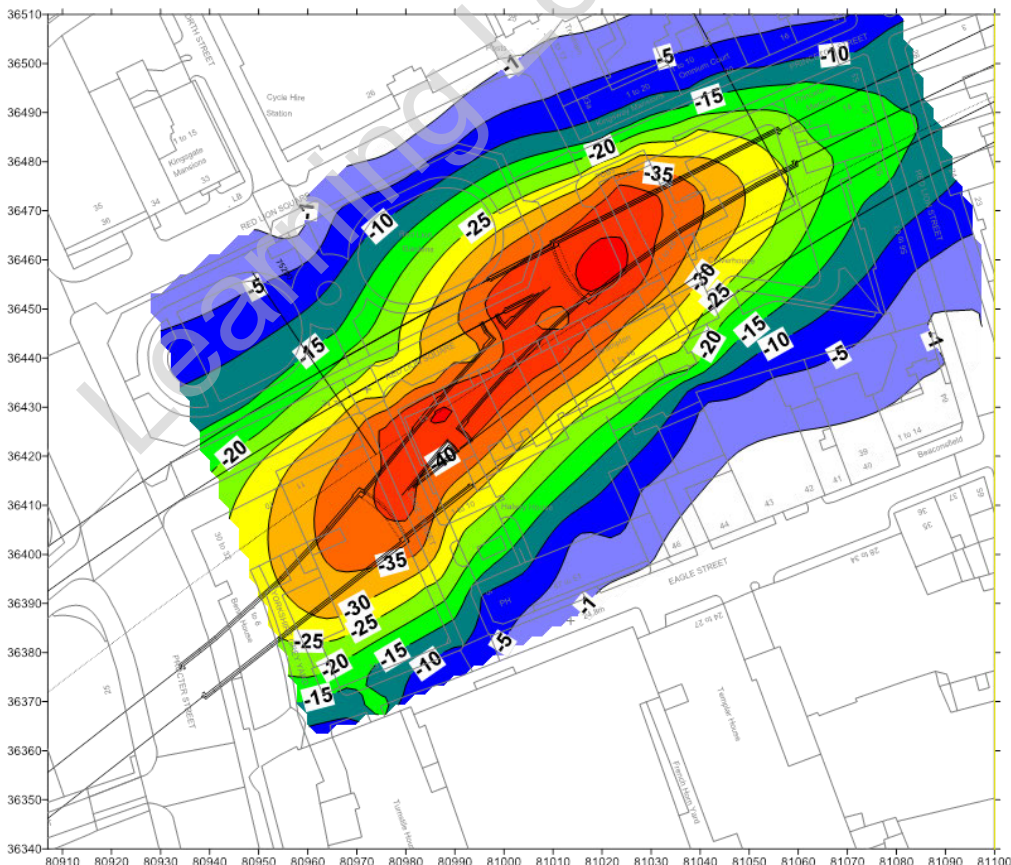


Figure 3.21: total measured settlements

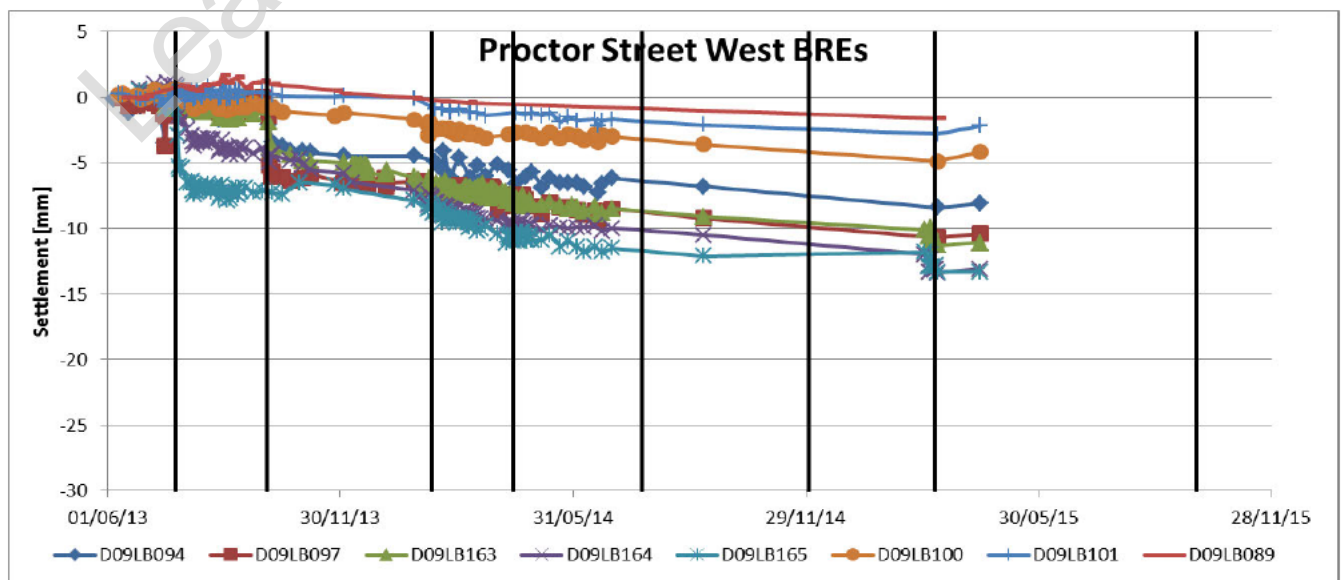
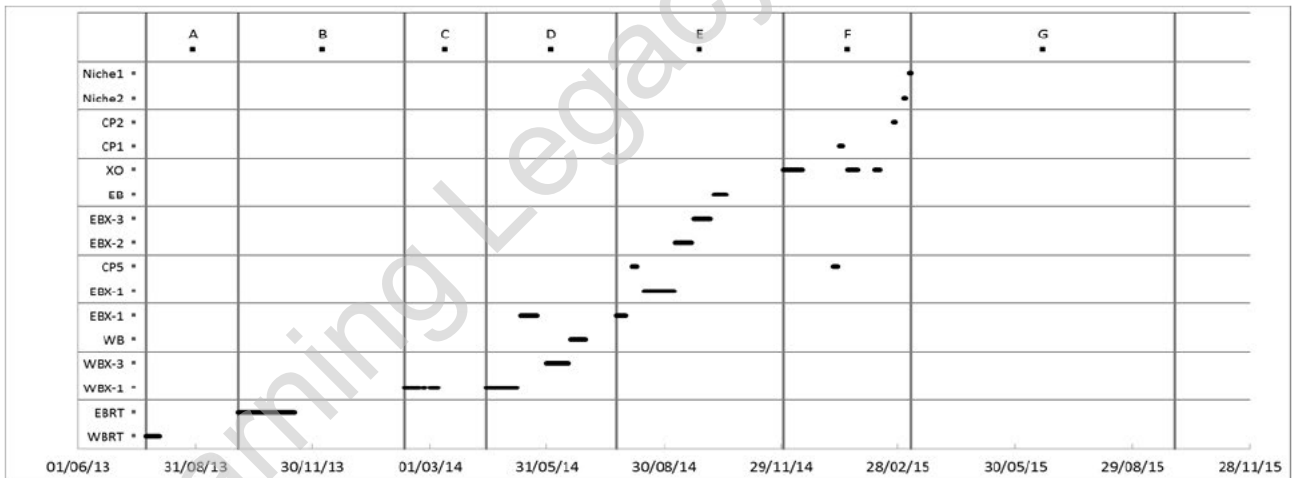
4. MONITORING DATA

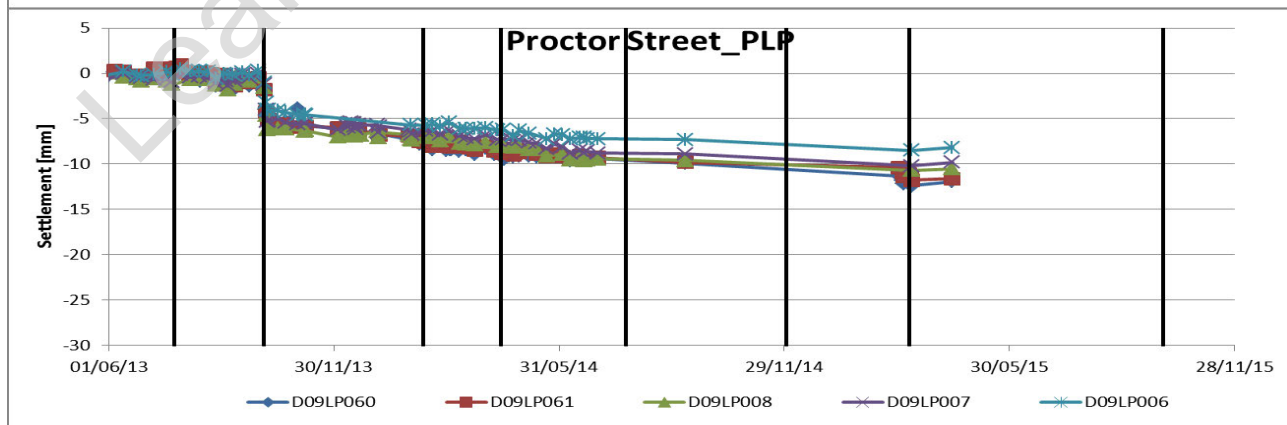
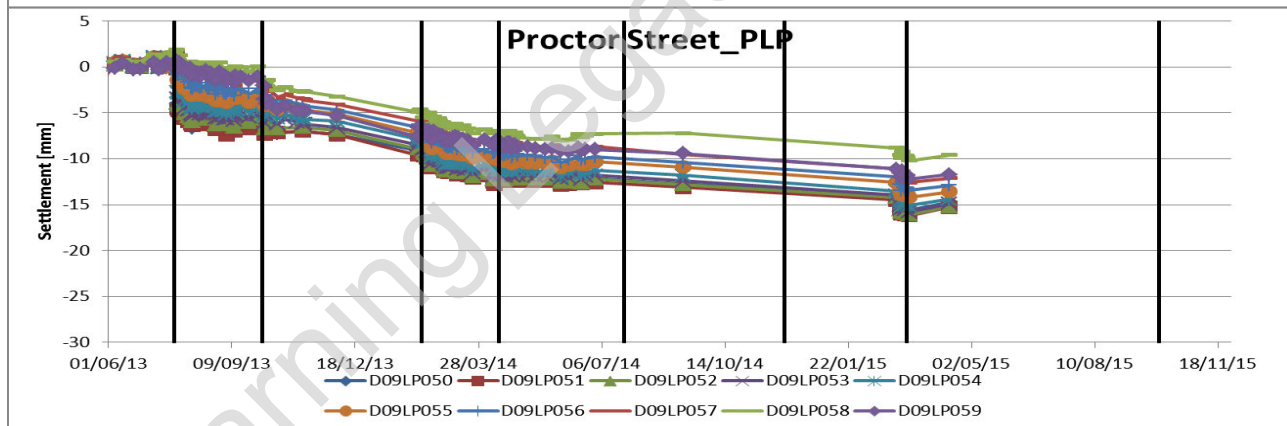
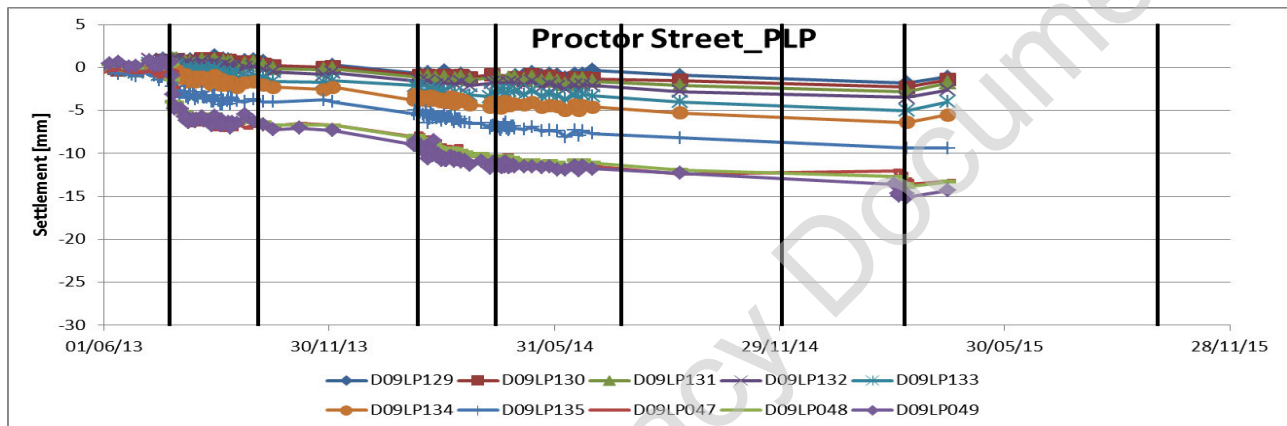
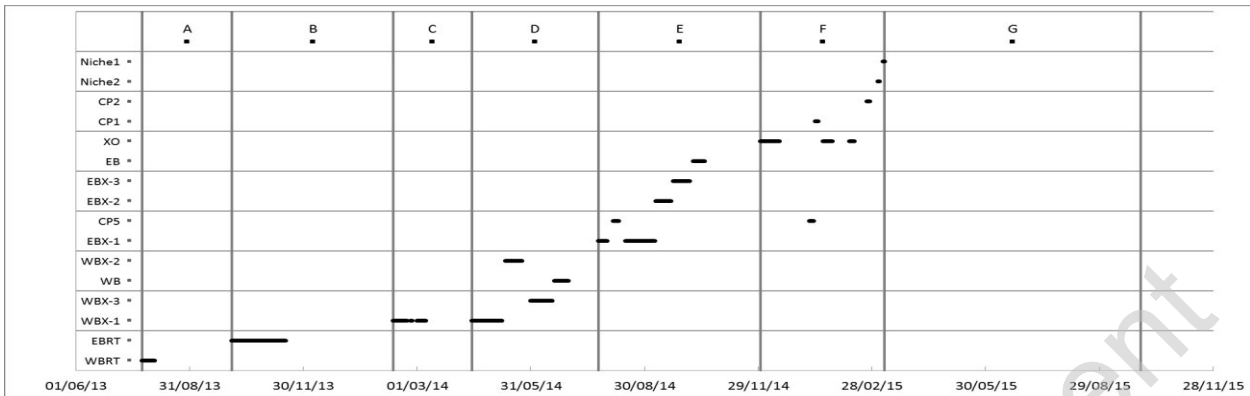
4.1. Proctor Street West

4.1.1. Data



Figure 4.1 Location





4.1.2. Comments

The EBRT and WBRT generated about 8mm maximum settlement in Periods A and B. A small influence of WBX-1 is apparent in Period C which, together with time related movements, resulted in a maximum settlement at the end of Period C of 13mm. The maximum settlement recorded on Proctor Street West was ~15mm in Period G. The results show a post construction rate of settlement of ~2 to 3mm/year. The residual risk is considered to be negligible.

4.2. Proctor Street East

4.2.1. Data

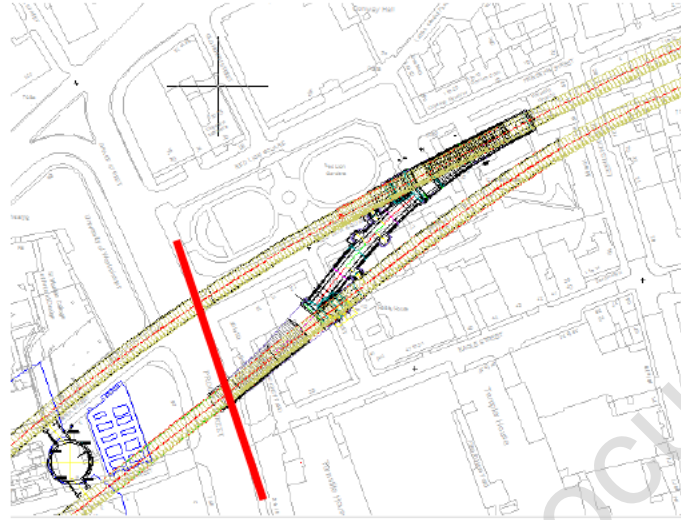
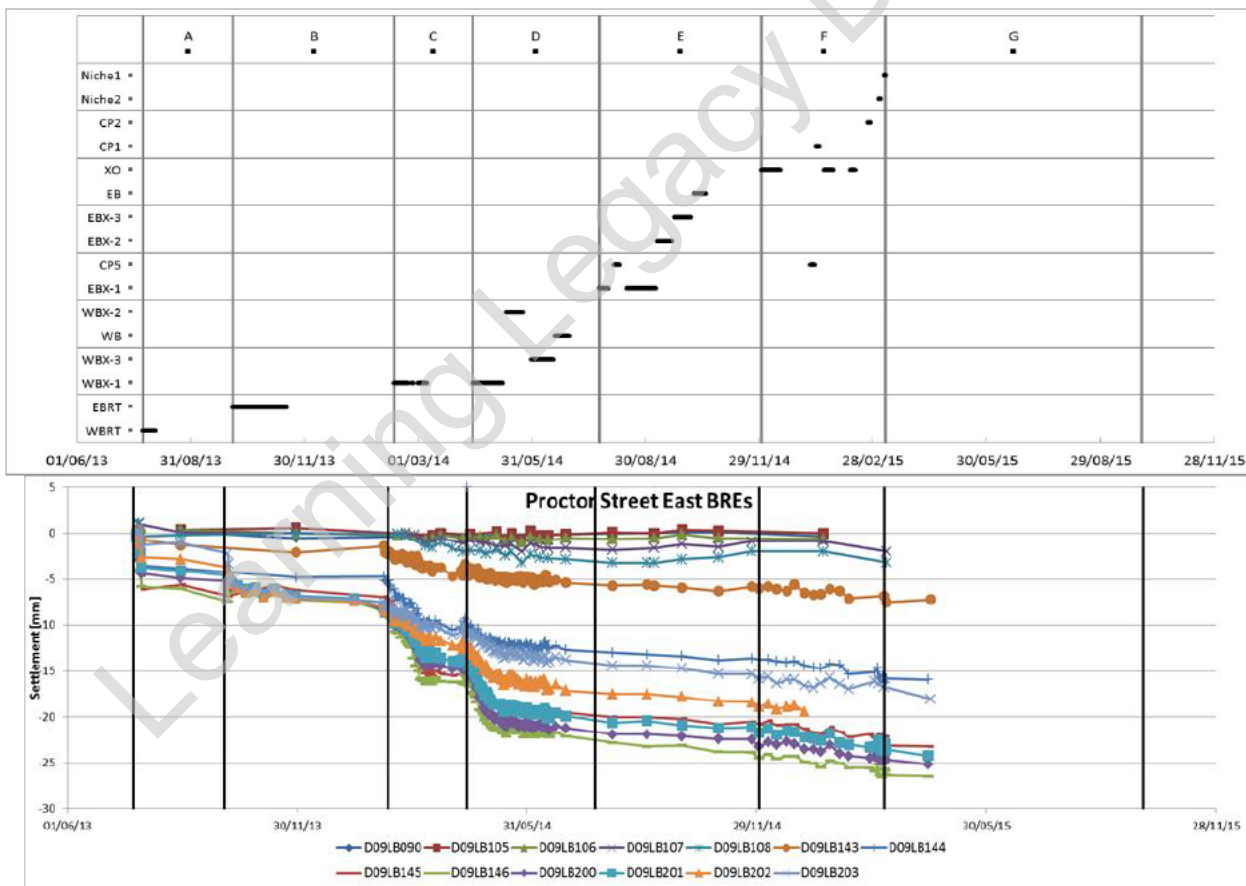


Figure 4.2: Location



4.2.2. Comments

The EBRT and WBRT generated about 8mm maximum settlement in Periods A and B. Influence from WBX-1 is apparent in Periods C and D which, together with time related movements, resulted in a maximum settlement at the end of Period D of 22mm. The maximum settlement measured on the east façade of Proctor Street is about 26mm. The readings stabilized during Period G. The residual risk is considered to be negligible.

4.3. Red Lion Square West

4.3.1. Data

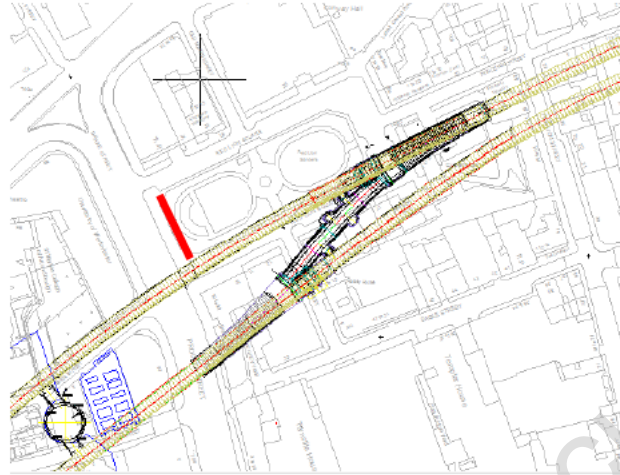
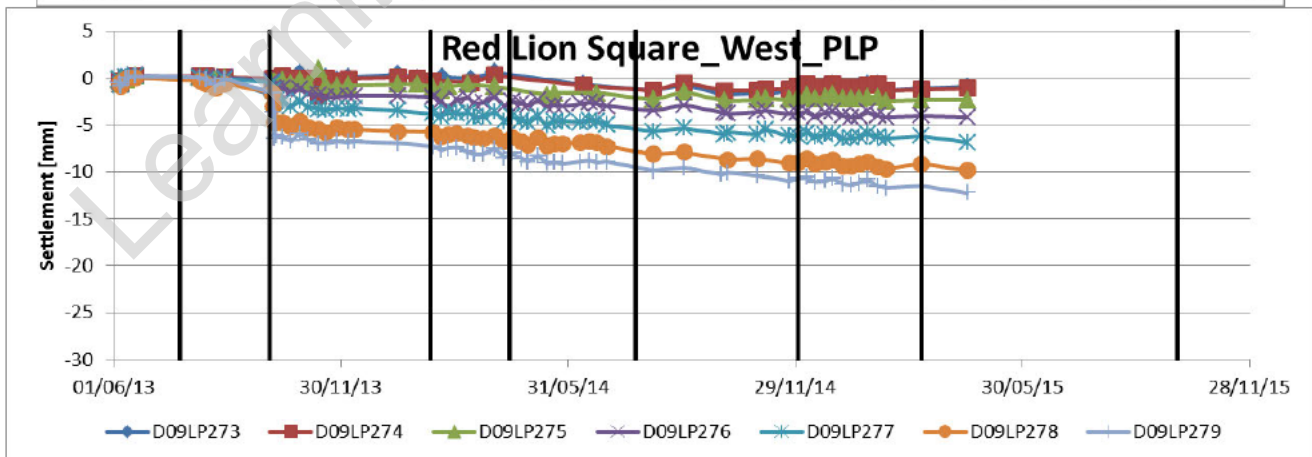
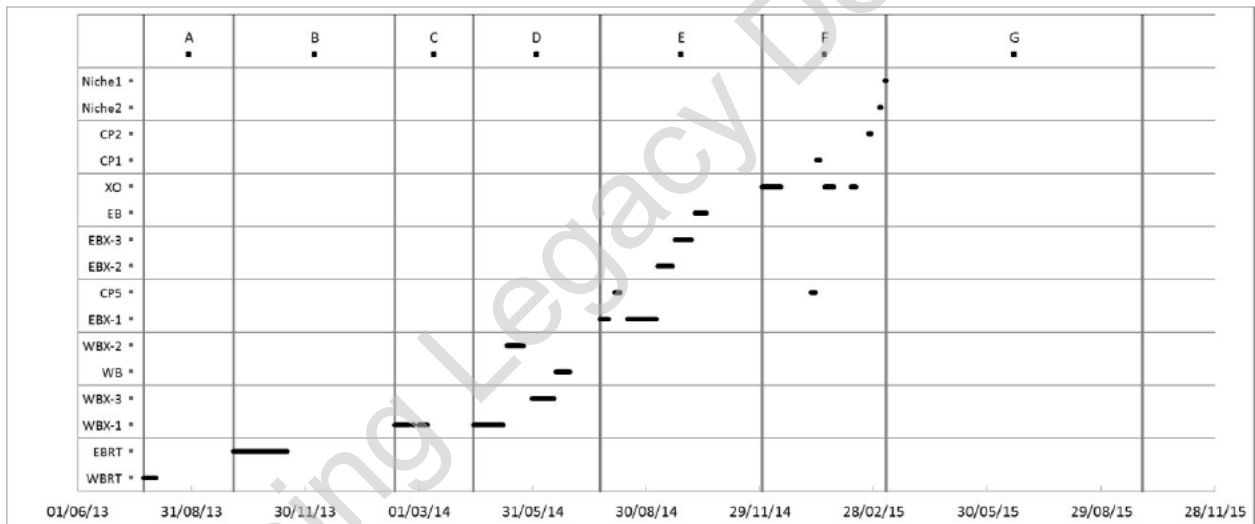


Figure 4.3: Location



4.3.2. Comments

The maximum settlement measured on Red Lion Square West PLPs is less than 13mm. The only direct influence is from the EBRT in Period B which produced a maximum of 7mm settlement. Post construction the settlement has continued to increase at an almost constant rate of 3.7mm / year. The residual risk is considered to be negligible.

4.4. Dane Street / Red Lion Gardens

4.4.1. Data

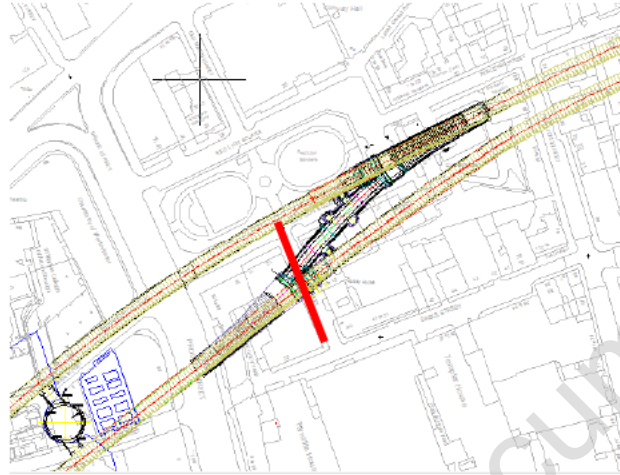
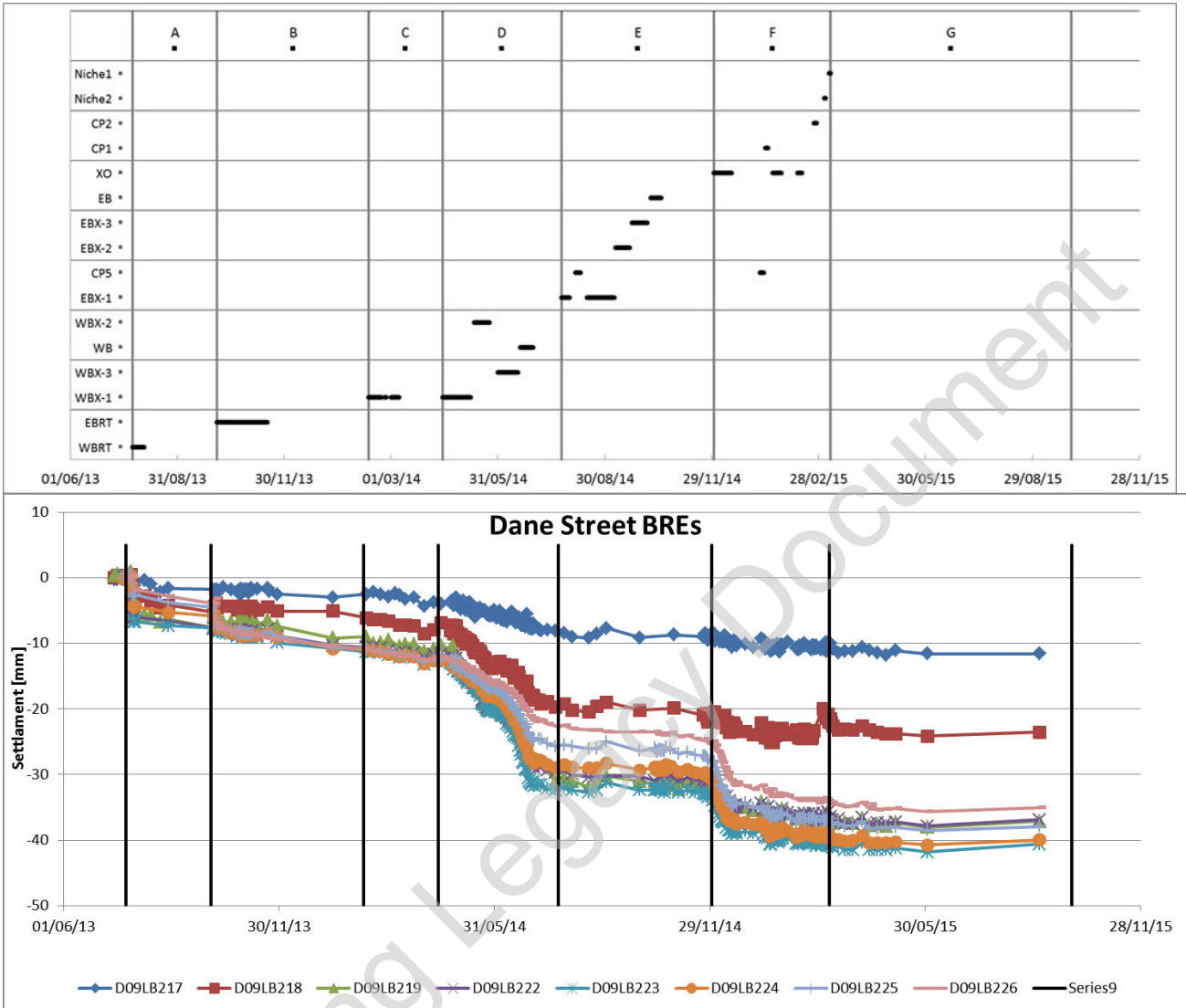
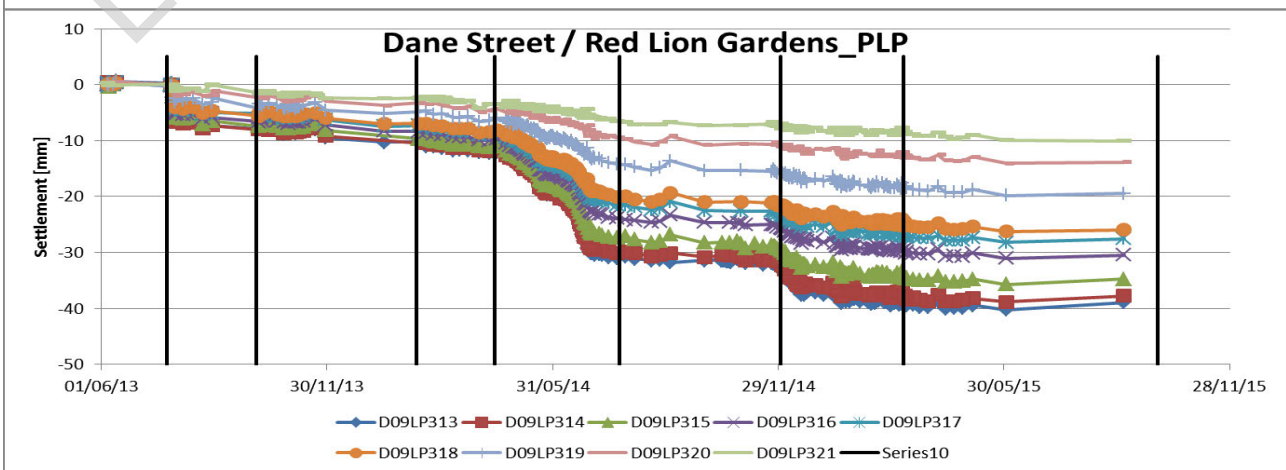
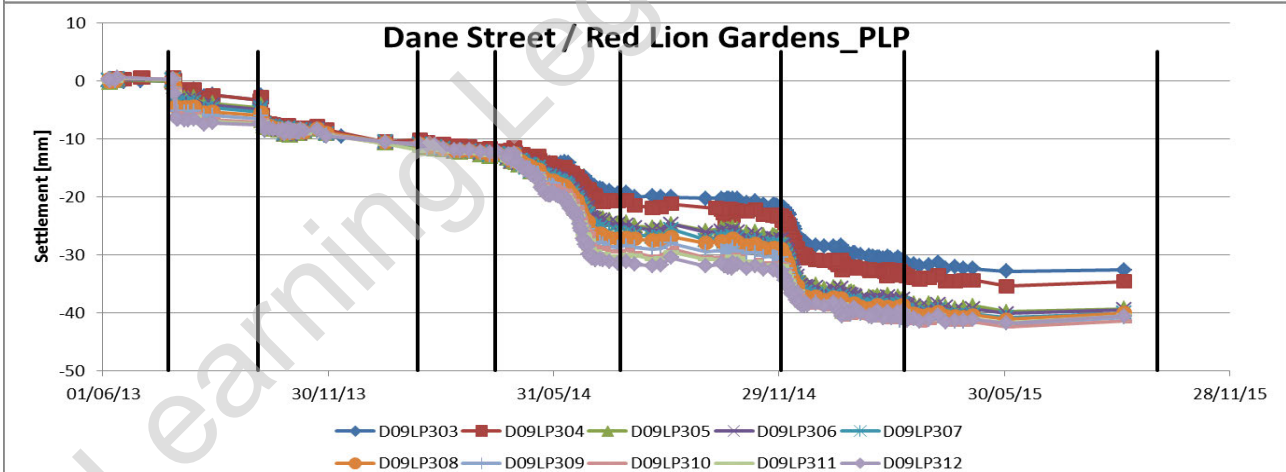
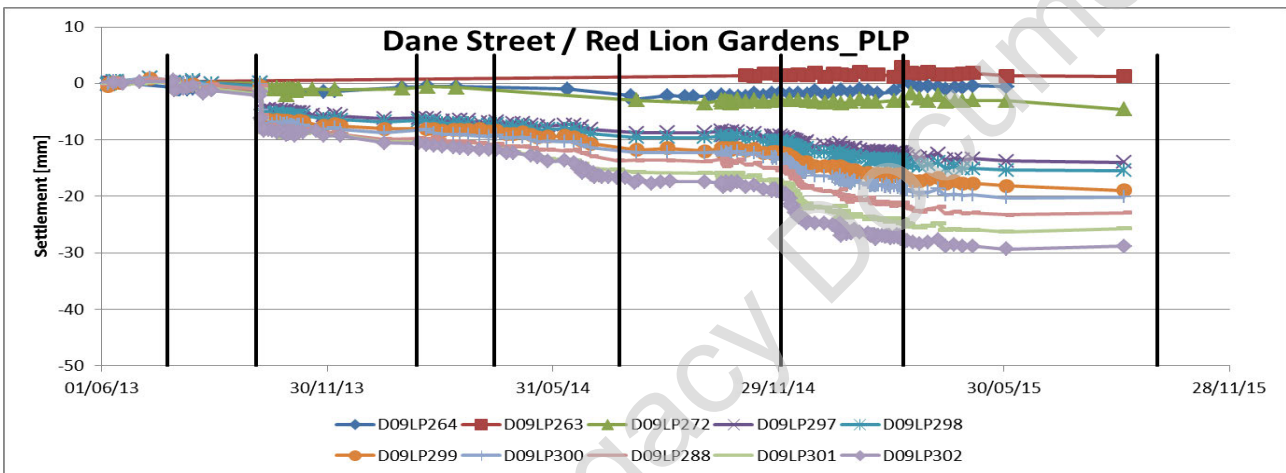
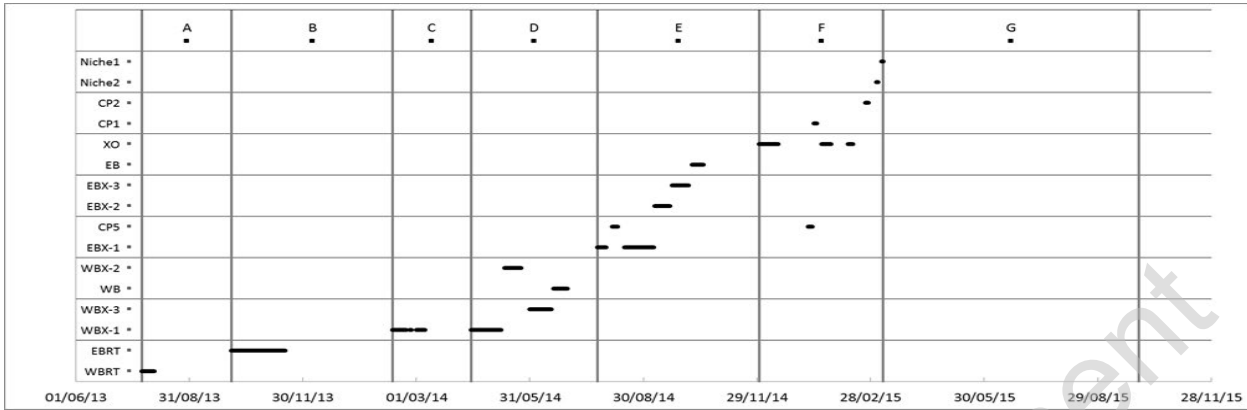


Figure 4.4: Location

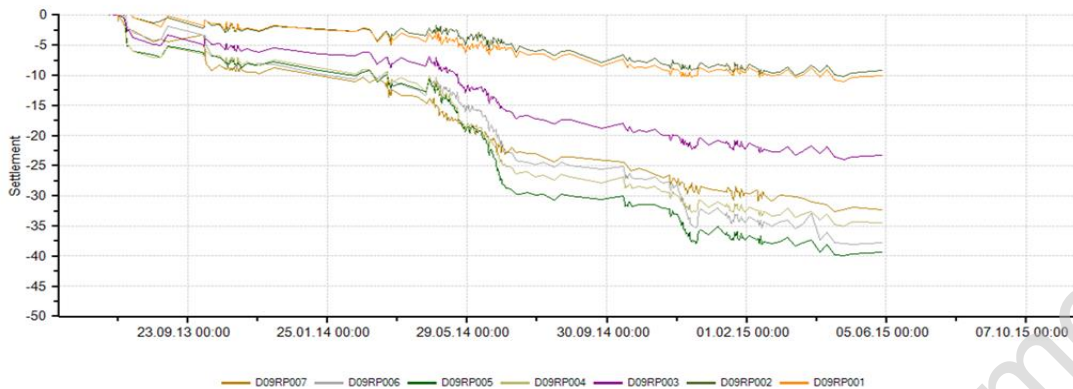
Table 4.1: triggers

Point Code	Point type	Achieved Trigger
D09LP305	PLP	Green
D09LP306	PLP	Green
D09LP307	PLP	Green
D09LP308	PLP	Green
D09LP309	PLP	Green
D09LP310	PLP	Green
D09LP311	PLP	Green
D09LP312	PLP	Green
D09LP313	PLP	Green
D09LP314	PLP	Green
D09LB226	BRE	Green
D09LB225	BRE	Green
D09LB224	BRE	Green
D09LB223	BRE	Green
D09LB222	BRE	Green
D09LB219	BRE	Green

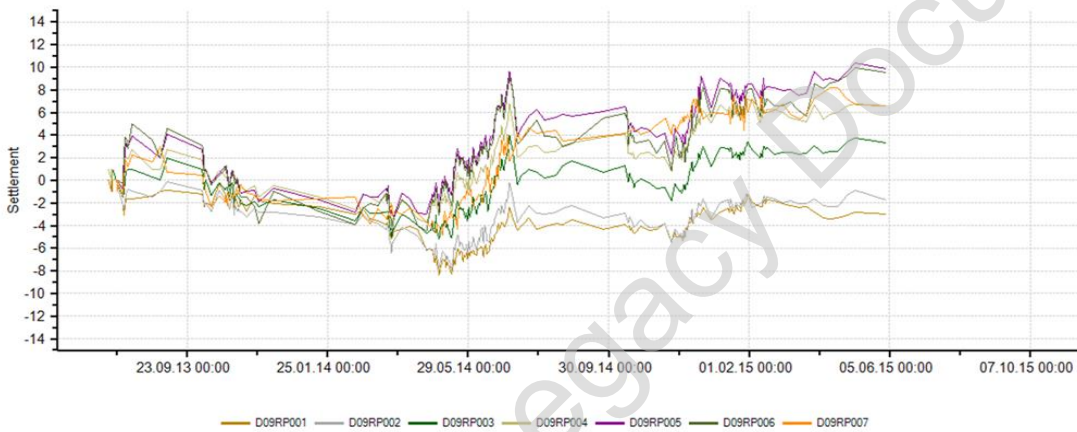




Dane Street Prisms - Z



Dane Street Prisms - Easting



Dane Street Prisms - Northing



4.4.2. Comments

The maximum settlement measured on Dane Street / Red Lion Gardens PLPs is about 40mm. Significant effects can be attributed to both running tunnels (Periods A and B) and WB enlargements Period D and the crossover tunnel in Period F. The BRE, PLP and prisms all show similar trends. The horizontal movements occurred at the same time as the settlements. The majority of the movement occurred in the east-west direction with an initial rotation to the west followed by rotation to the east giving a net maximum movement of 10mm to the east.

The readings stabilized during Period G, with no increase in settlement over a 6 month period. The residual risk is considered to be negligible.

4.5. Red Lion Square North

4.5.1. Data

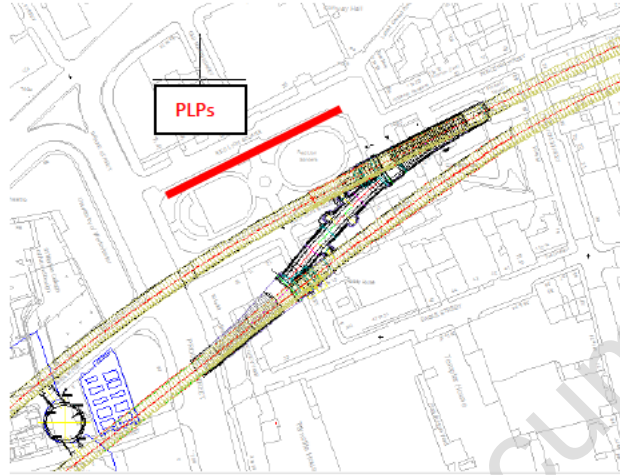
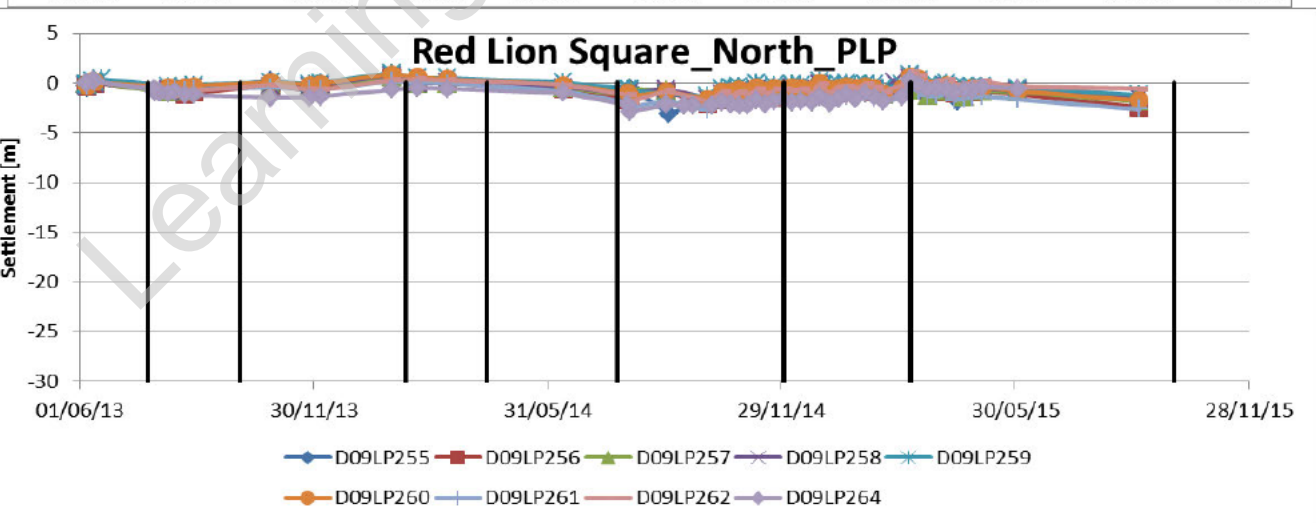
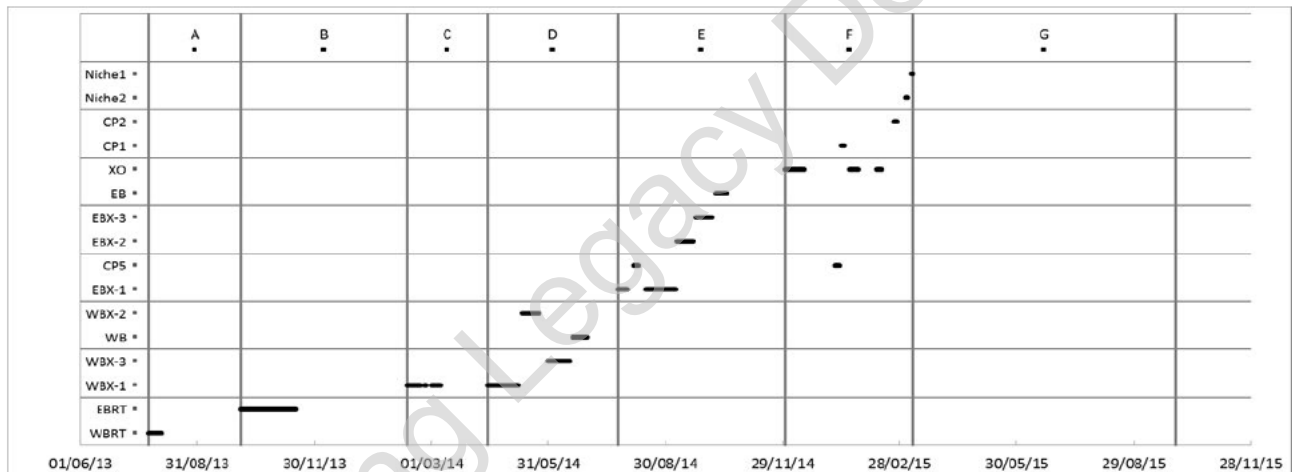
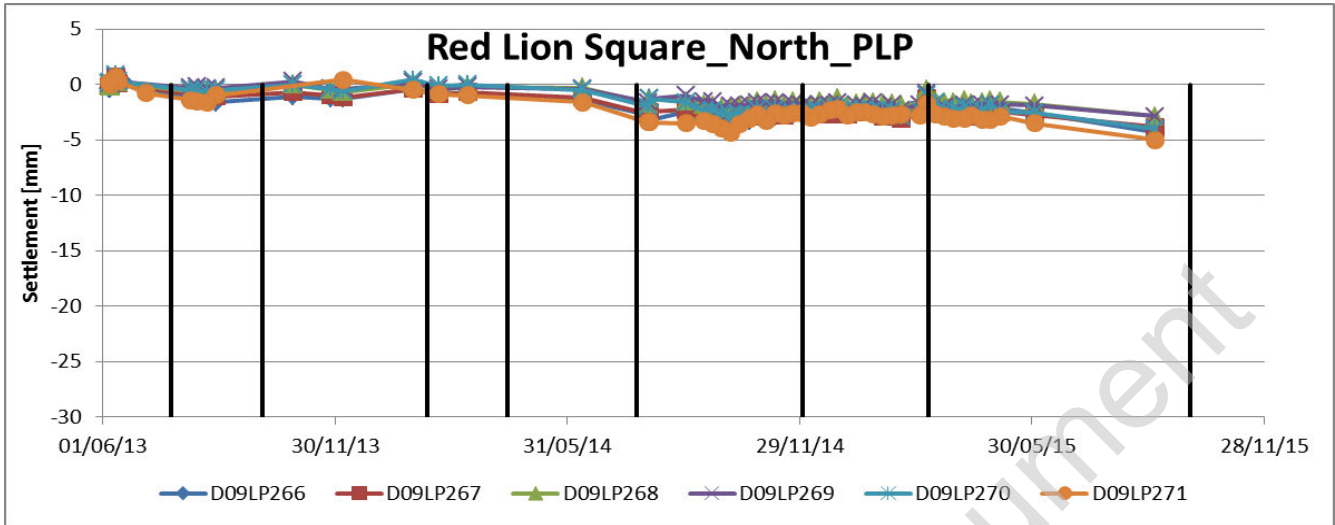


Figure 4.5: Location





4.5.2. Comments

The maximum settlement measured on Red Lion Square North PLPs is about 5mm with no direct relationship with any of the construction activities. The residual risk is considered to be negligible.

Learning Legacy Document

4.6. Red Lion Square South – Inner Kerbline PLPs

4.6.1. Data

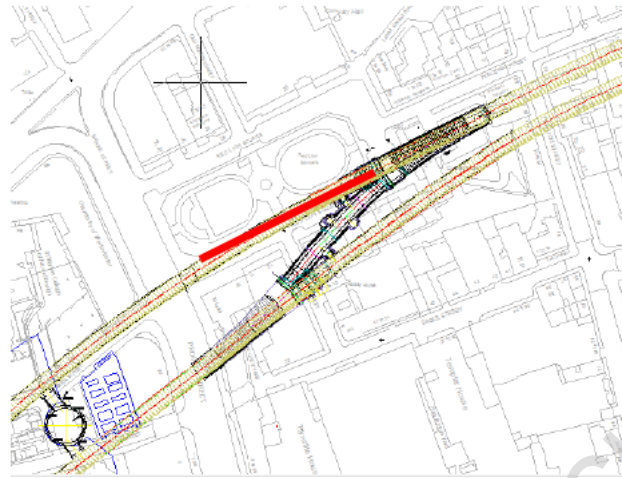
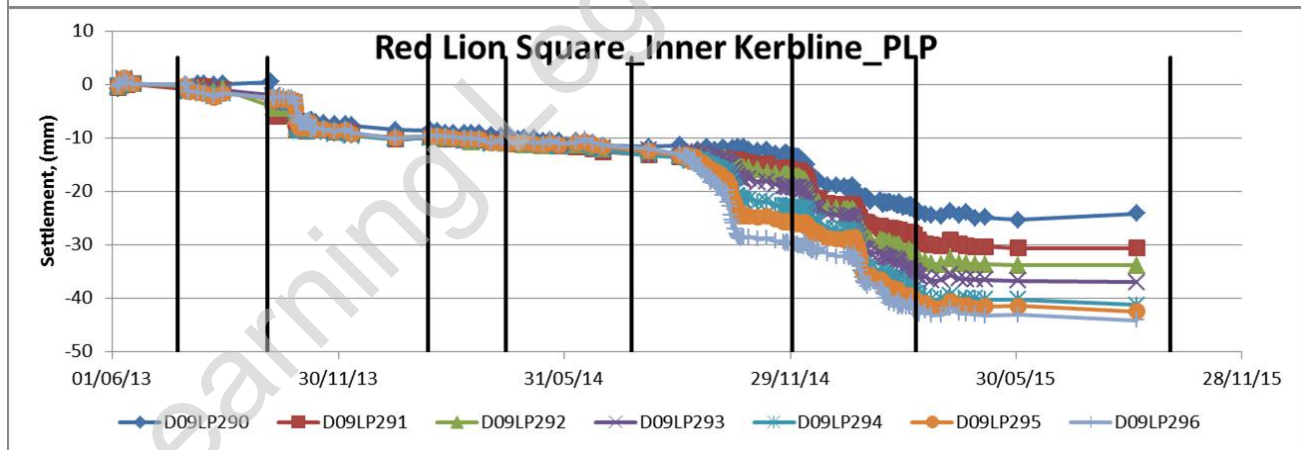
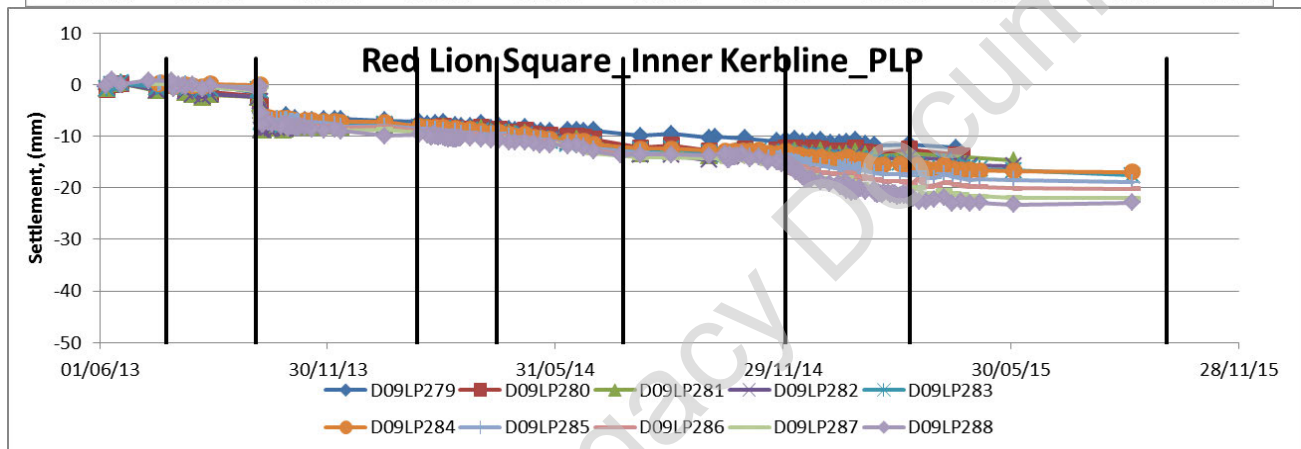
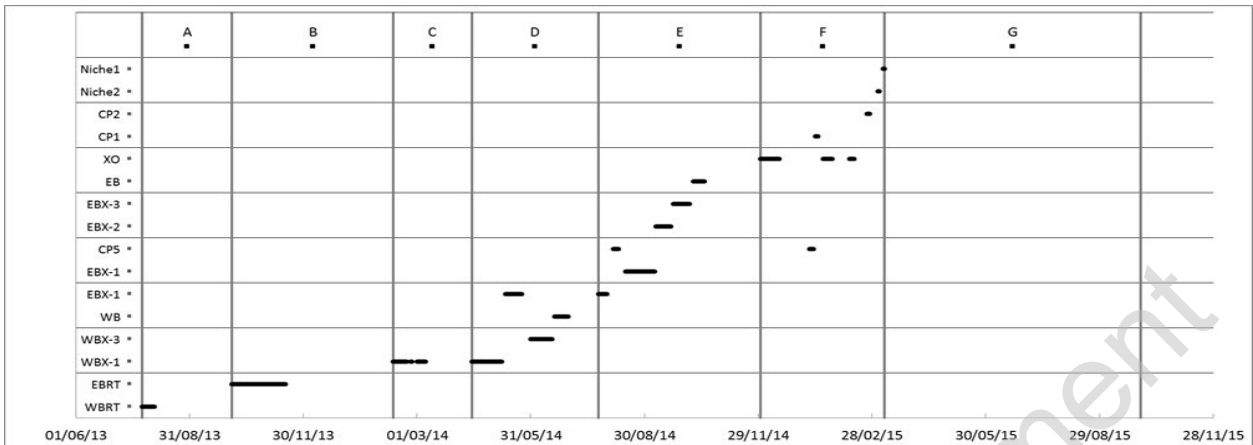


Figure 4.6: Location

Table 4.2 Triggers

Point Code	Point type	Achieved Trigger
D09LP293	PLP	Green
D09LP294	PLP	Green
D09LP295	PLP	Green
D09LP296	PLP	Green



4.6.2. Comments

The maximum settlement measured on Red Lion Square Inner Kerbline PLPs is about 45mm. Significant effects can be attributed to both running tunnels (Periods A and B) and EB enlargements in Period E and the crossover tunnel in Period F. The readings stabilized during Period G, with no increase in settlement over a 6 month period. The residual risk is considered to be negligible.

4.7. Red Lion Square South

4.7.1. Data

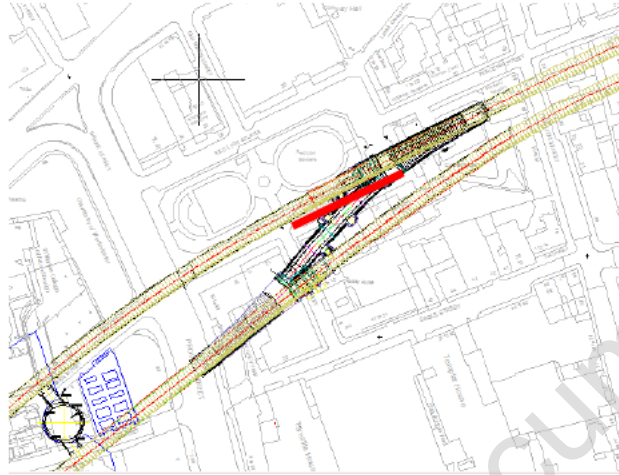
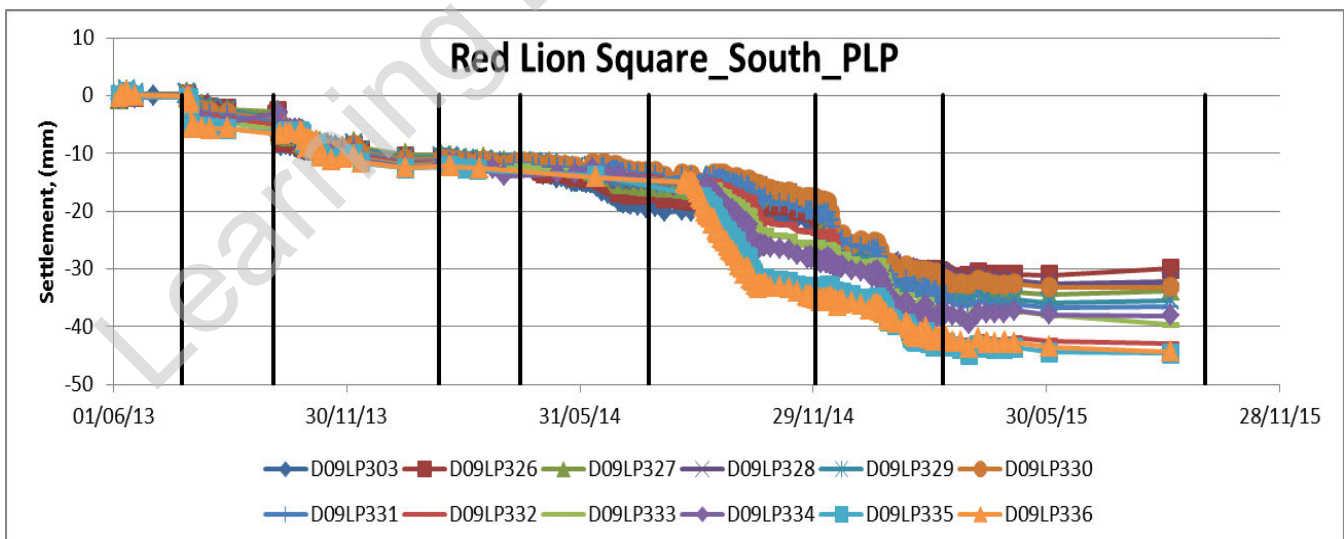
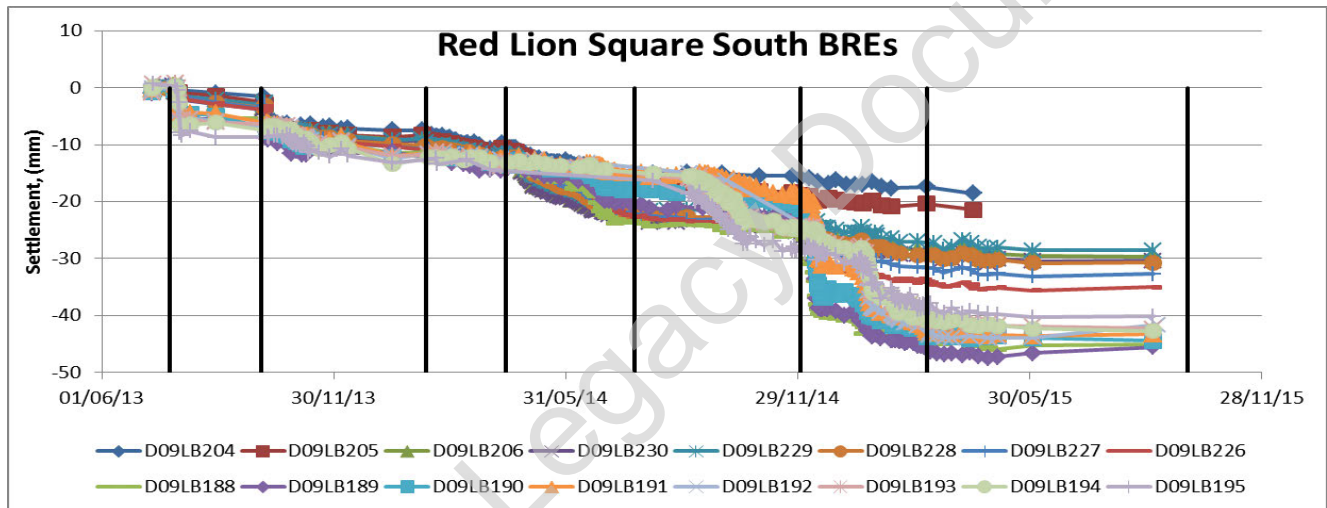
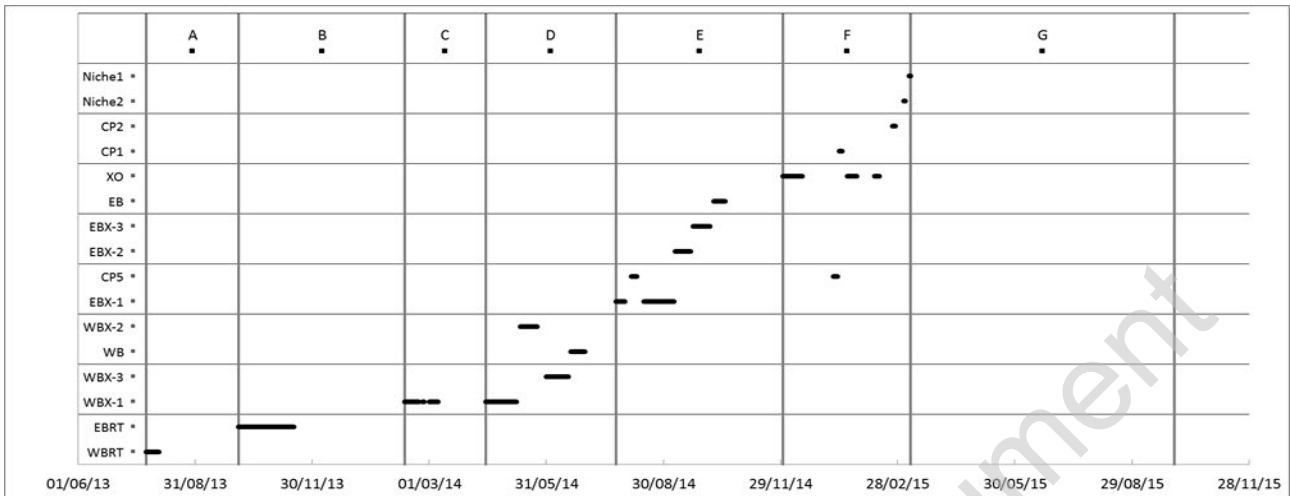


Figure 4.7: Location

Table 4.3 Triggers

Point Code	Point type	Achieved Trigger
D09LB188	BRE	Amber
D09LB189	BRE	Amber
D09LB190	BRE	Green
D09LB191	BRE	Green
D09LB173	BRE	Green
D09LB174	BRE	Green
D09LB192	BRE	Green
D09LB193	BRE	Green
D09LB194	BRE	Green
D09LB195	BRE	Green
D09LB175	BRE	Green
D09LP329	PLP	Green
D09LP331	PLP	Green
D09LP332	PLP	Green
D09LP333	PLP	Green
D09LP334	PLP	Green
D09LP335	PLP	Green
D09LP336	PLP	Green



4.7.2. Comments

The maximum settlement measured on Red Lion Square South BREs and PLPs is about 48mm. Significant effects can be attributed to both running tunnels (Periods A and B) and both WB and EB enlargements in Periods D as well as the crossover tunnel in Period F. The readings stabilized during Period G, with either no increase or a small decrease in settlement over a 6 month period. The residual risk is considered to be negligible.

4.8. Red Lion Square East

4.8.1. Data

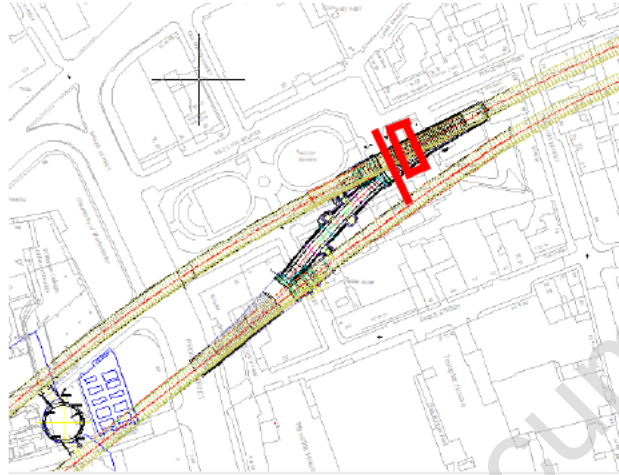
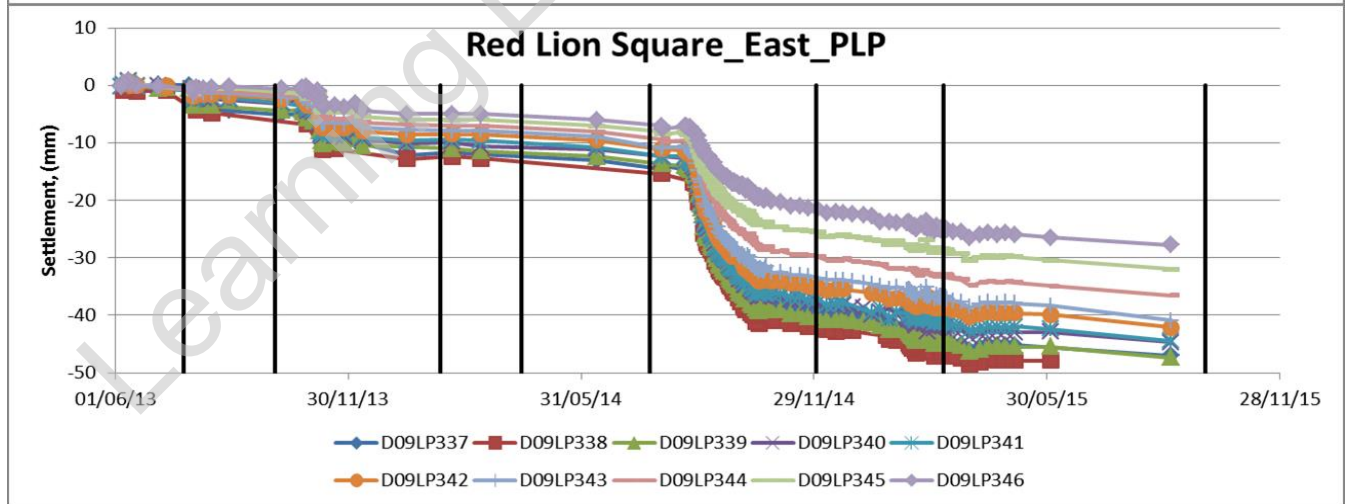
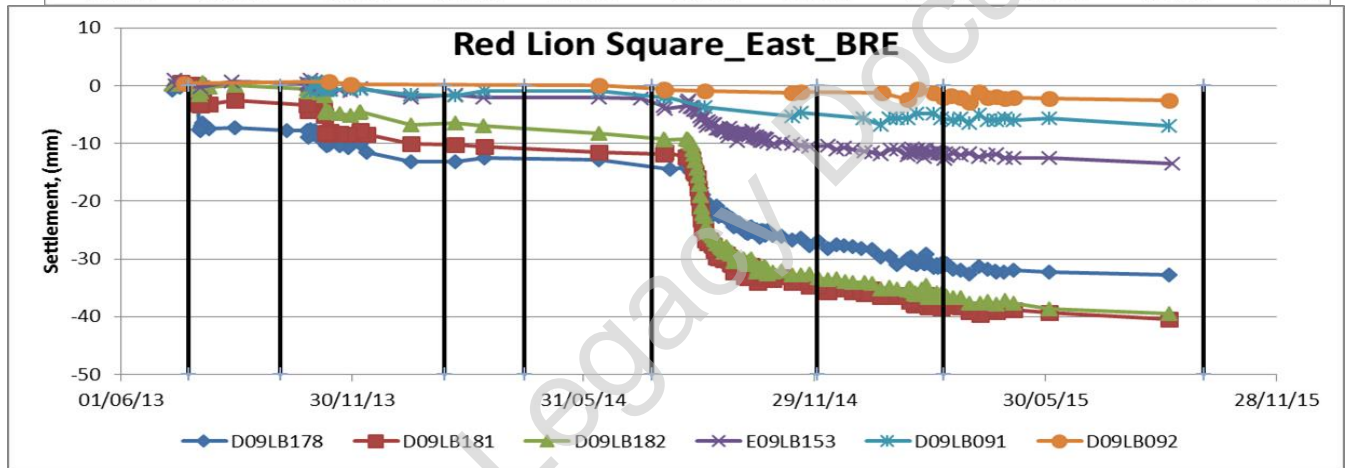
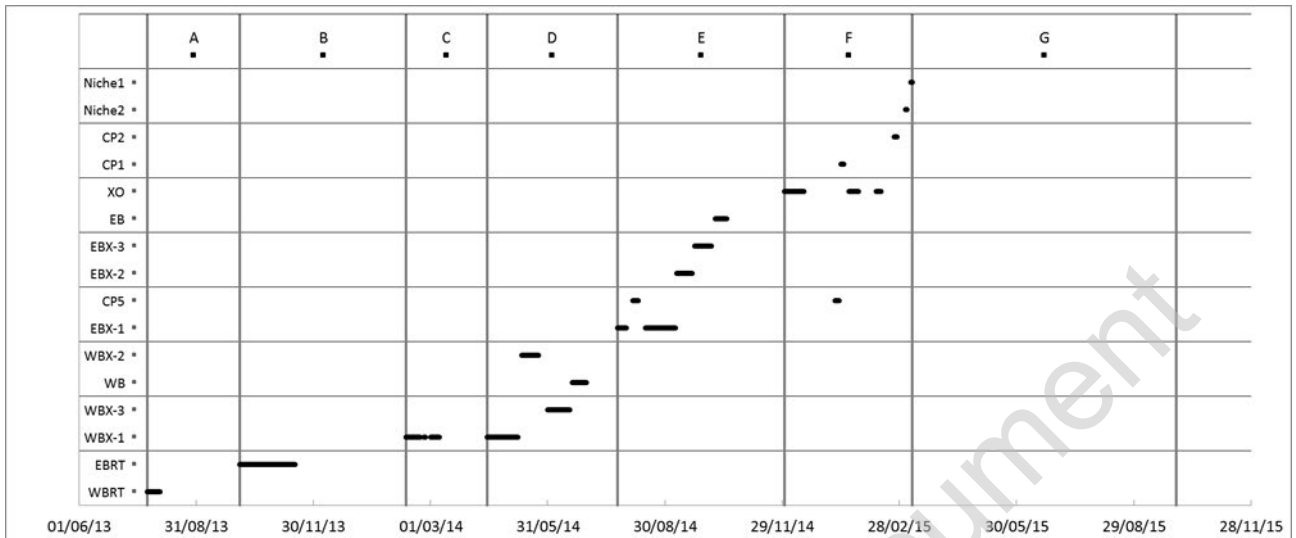


Figure 4.8: Location

Table 4.4 Triggers

Point Code	Point type	Achieved Trigger
D09LB181	BRE	Green
D09LB182	BRE	Green
D09LB183	BRE	Green
D09LP337	PLP	Amber
D09LP338	PLP	Amber
D09LP339	PLP	Amber
D09LP340	PLP	Green
D09LP341	PLP	Green
D09LP342	PLP	Green
D09LP343	PLP	Green
D09LP344	PLP	Green



4.8.2. Comments

The maximum settlement measured on Red Lion Square East PLPs is about 50mm whereas a maximum of 40mm was recorded on BREs. The major impact was due to the EB enlargements in Period E. Direct effects can also be attributed to both running tunnels (Periods A and B) and the crossover tunnel in Period F. The readings stabilized during Period G, with a 2 to 3mm increase in settlement over a 6 month period. The residual risk is considered to be negligible.

4.9. Princeton Street

4.9.1. Data

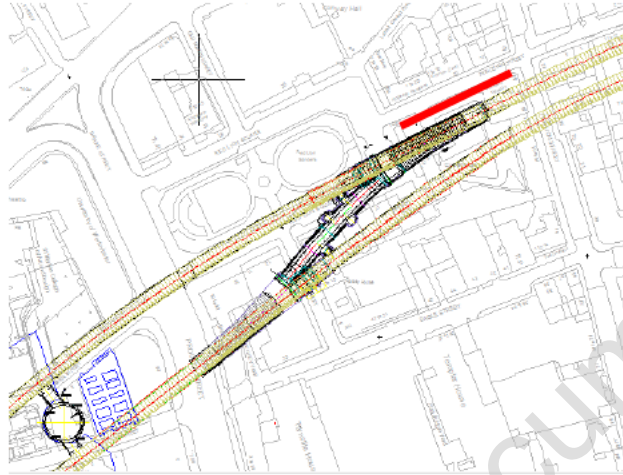
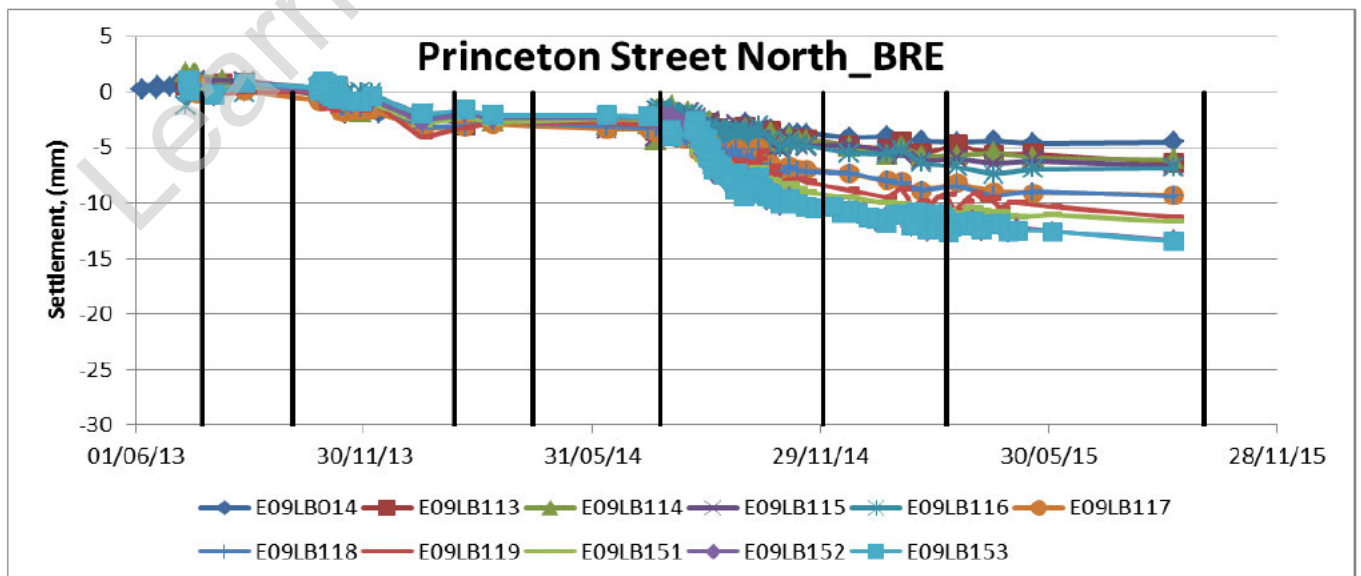
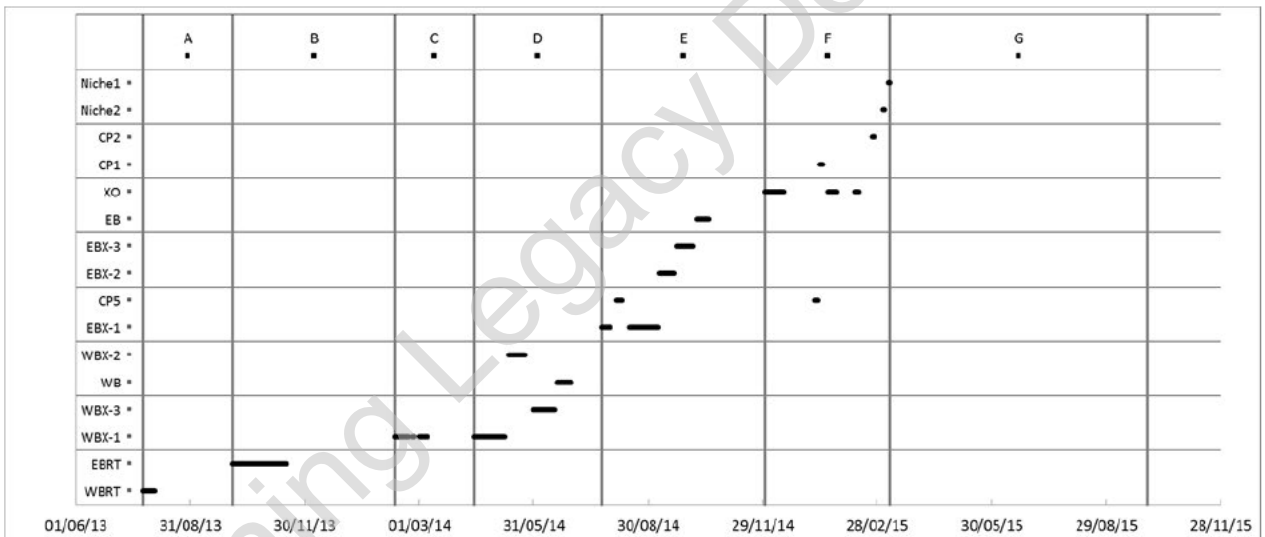
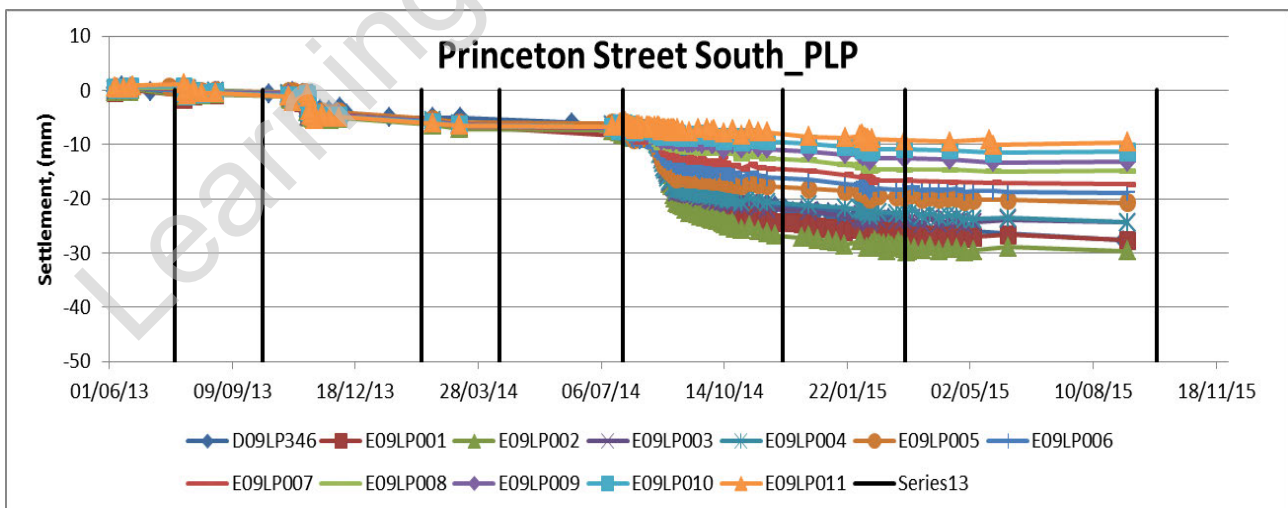
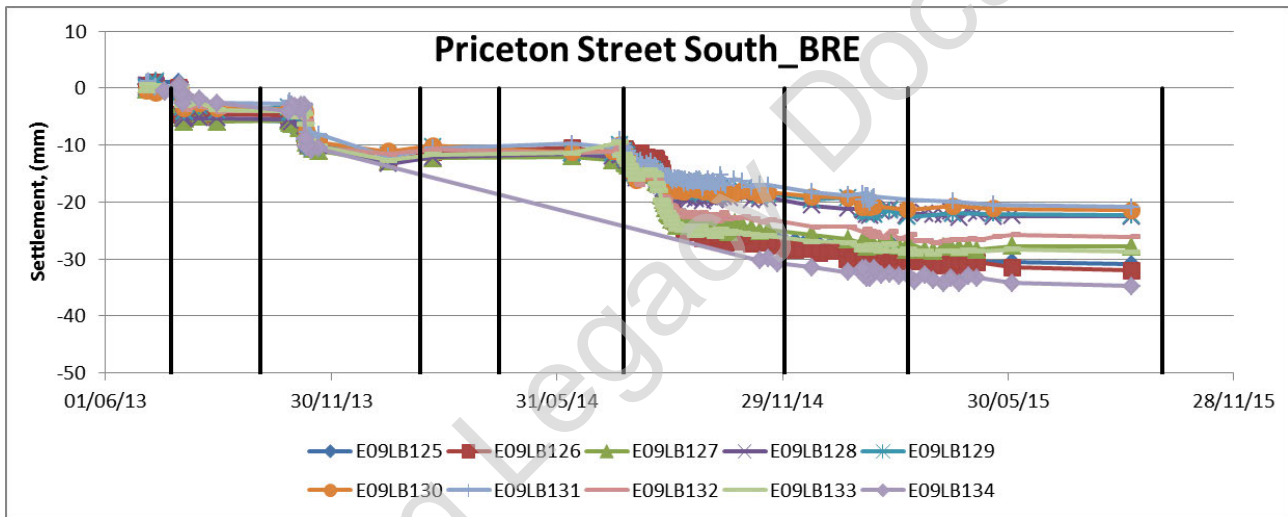
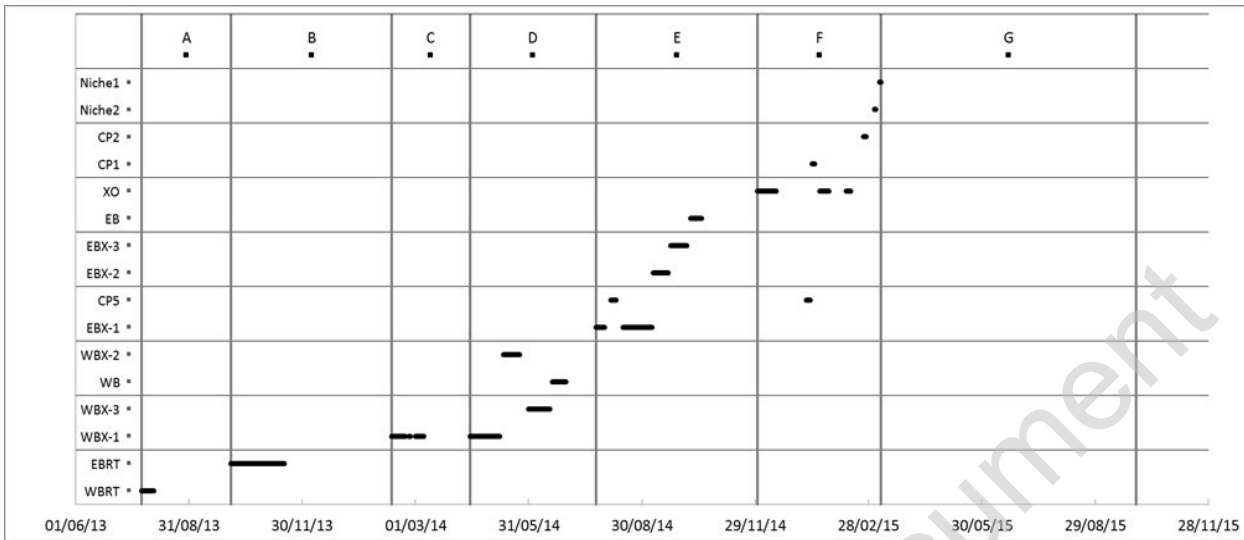


Figure 4.9: Location





4.9.2. Comments

The maximum settlement measured on Princeton Street PLPs is about 30mm. The major impact was due to the EB enlargements in Period E. Direct effects can also be attributed to both running tunnels (Periods A and B). The readings stabilized during Period G, with a 2 to 3mm increase in settlement over a 6 month period. The residual risk is considered to be negligible.

4.10. Red Lion Street

4.10.1. Data

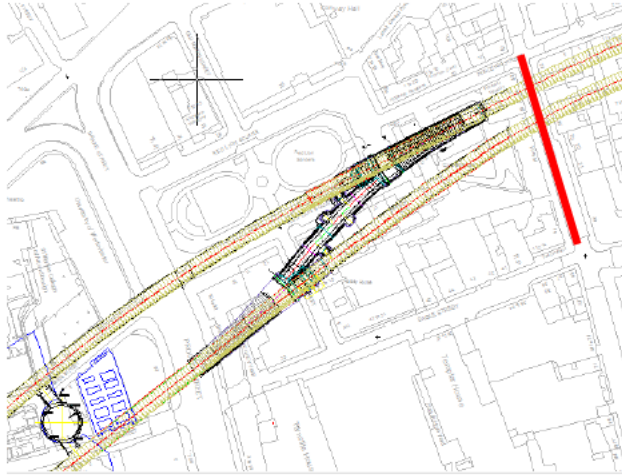
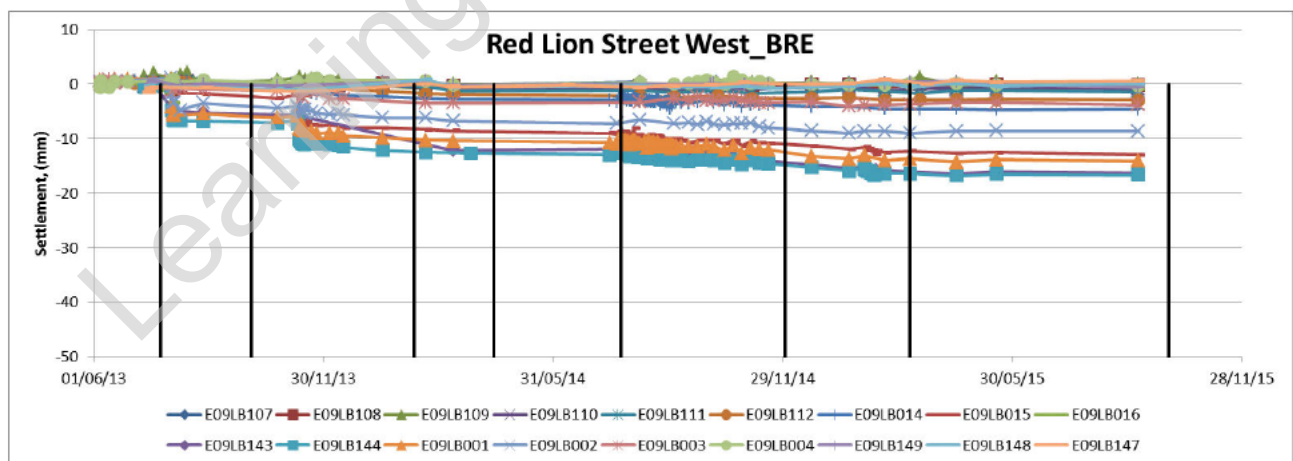
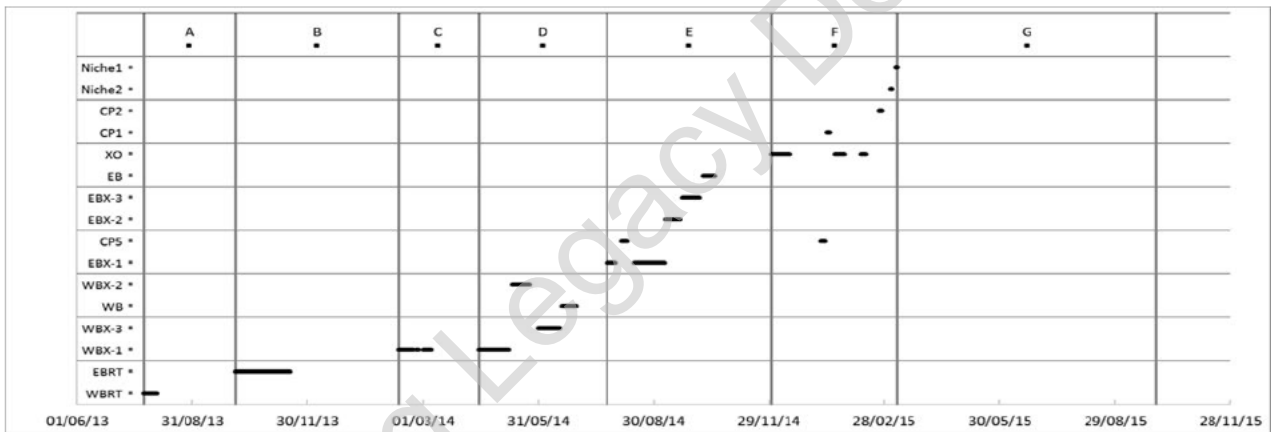
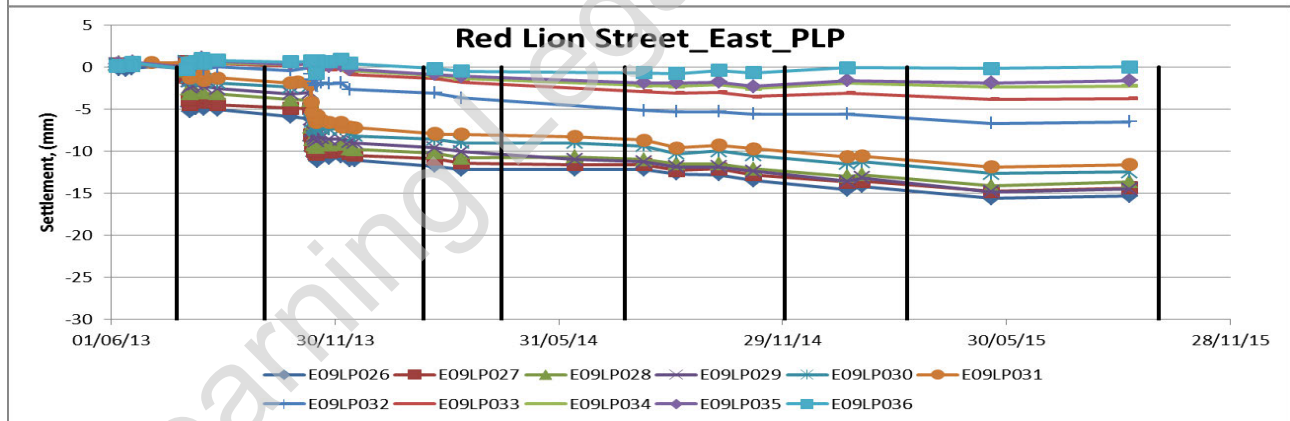
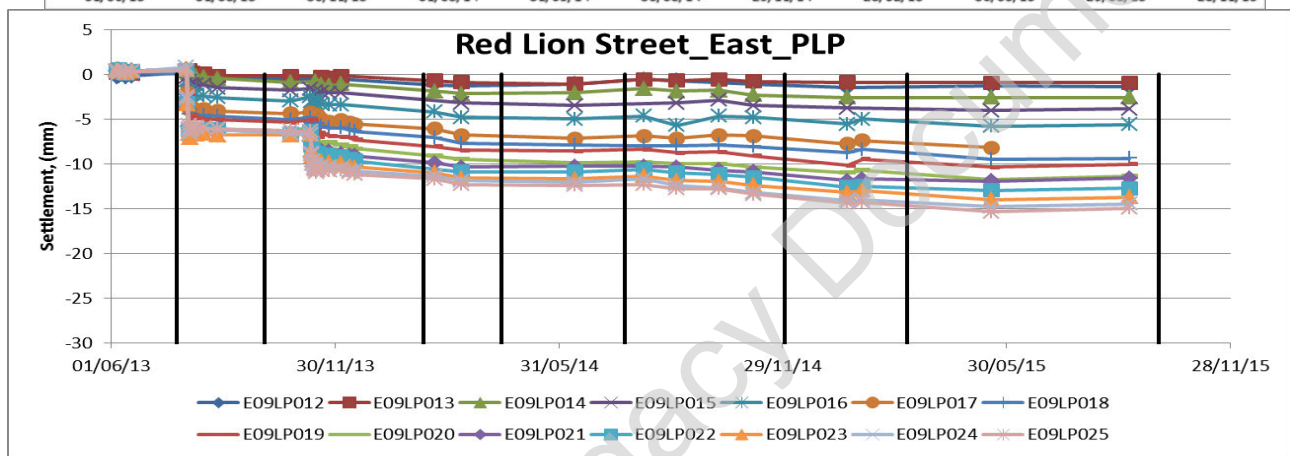
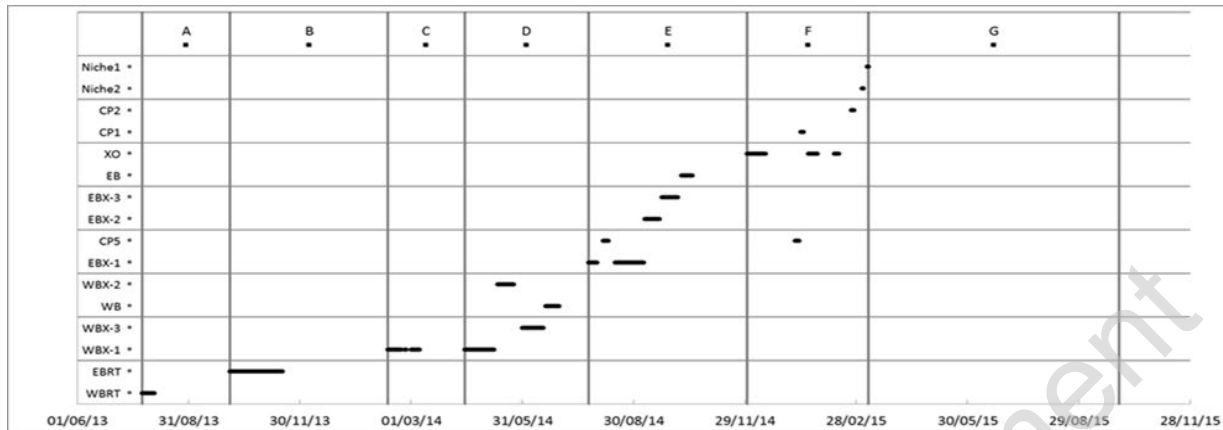


Figure 4.10 Location





4.10.2. Comments

The maximum settlement recorded on Red Lion Street is 17mm. Direct effects are only visible for the WBRT and EBRT in Period A and B. The maximum post-construction increase in settlement is about 5 to 6mm over a period of nearly 2 years (average rate ~3mm/year). The residual risk is considered to be negligible.

4.11. Eagle Street

4.11.1. Data

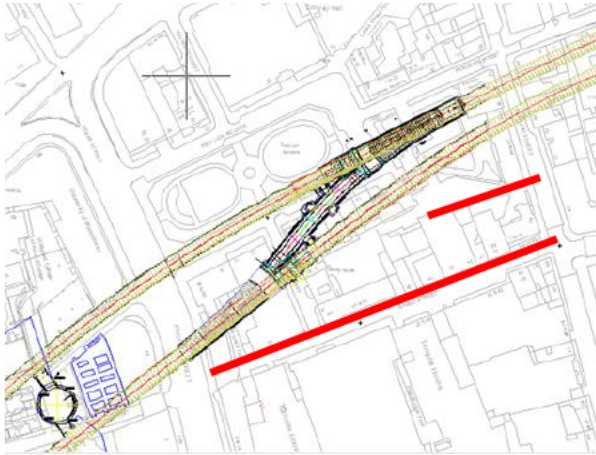
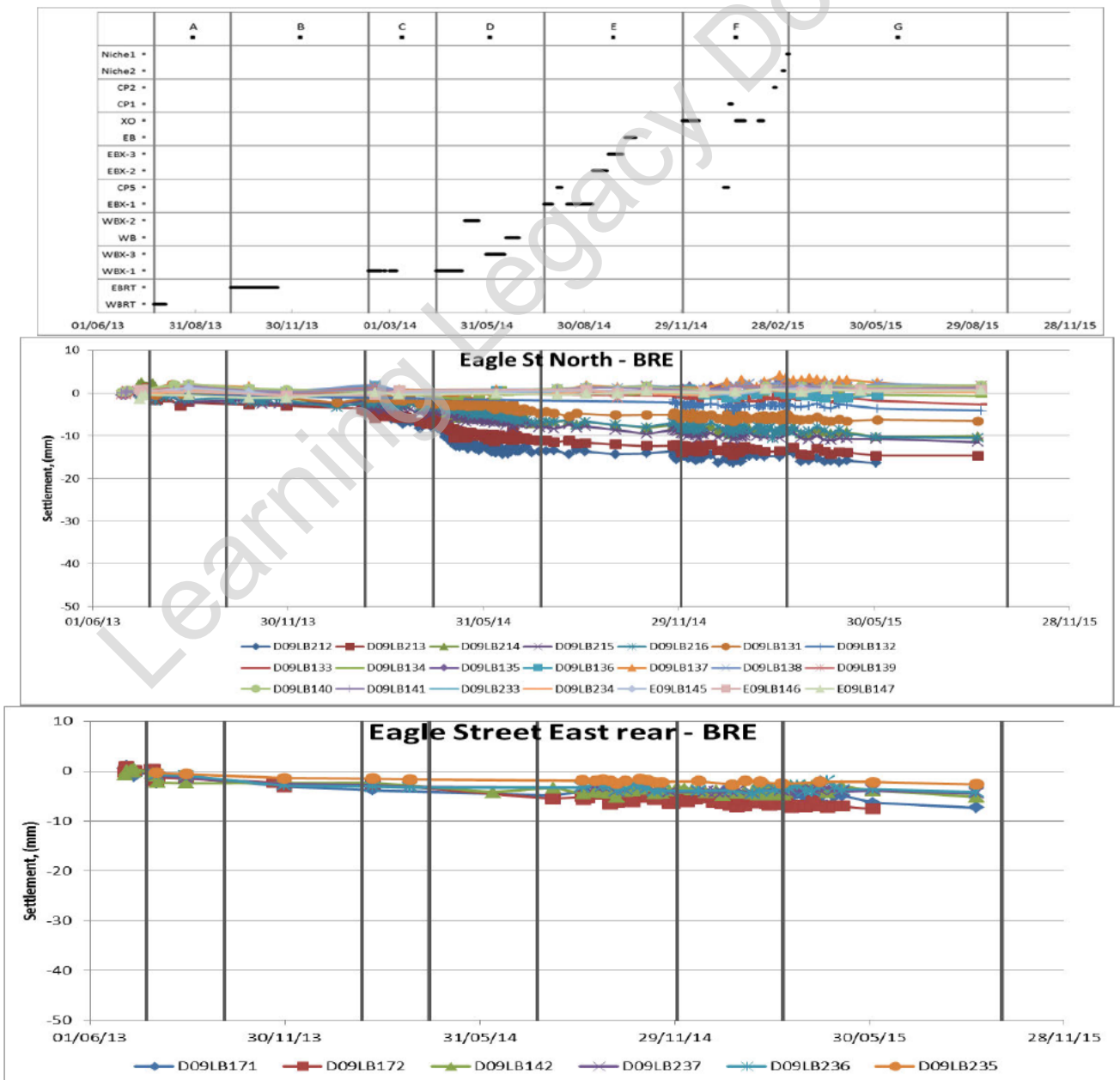


Figure 4.11: Location





4.11.2. Comments

The maximum settlement recorded on Eagle Street is 13mm. Direct effects are only visible for the WB enlargement in Period D. The post-construction data shows no significant change in settlement. The residual risk is considered to be negligible.

Learning Legacy Document

4.12. Ground Instruments

4.12.1. Data

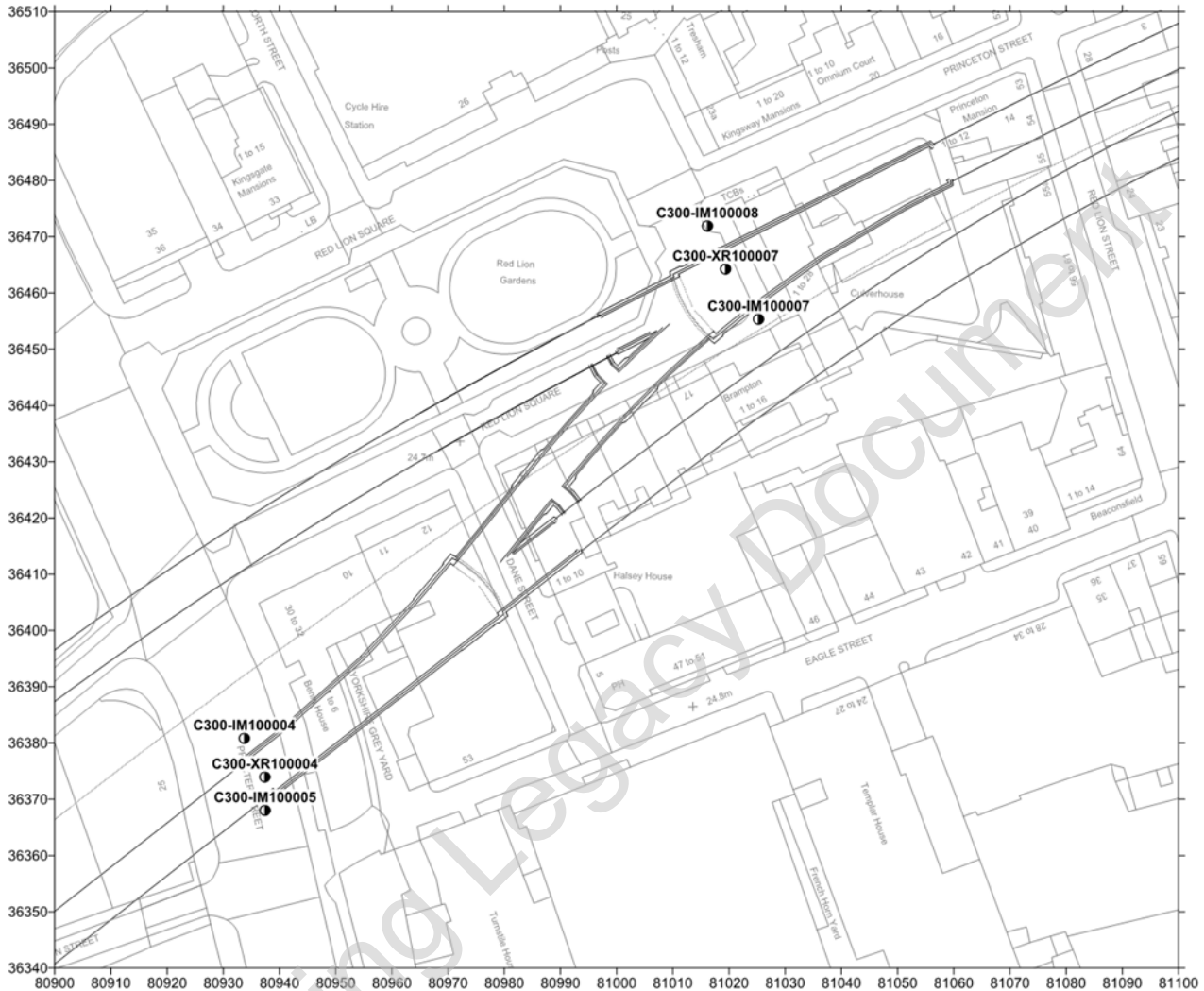
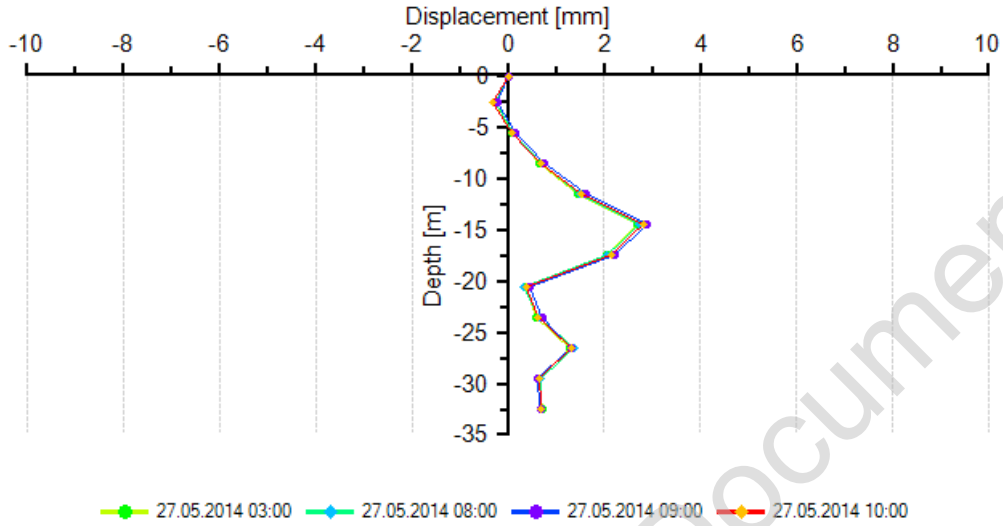


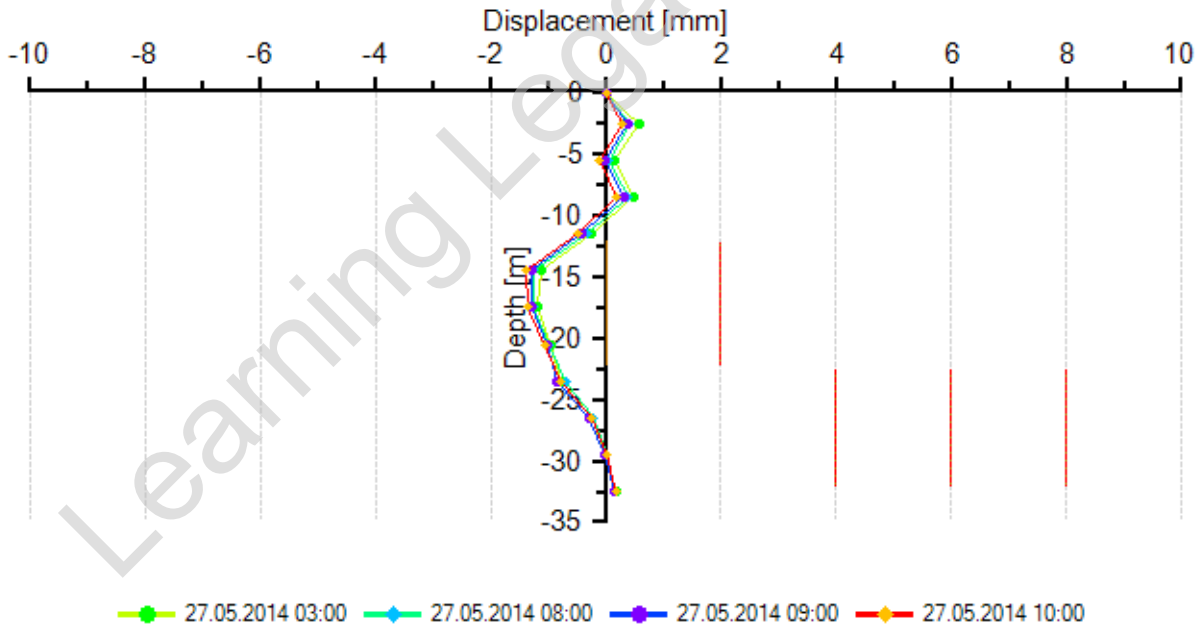
Figure 4.12: location

The positive X direction is towards the closest tunnel for all inclinometers (referred to as "A" direction in the installation report). The positive Y (or B) direction is 90° anti-clockwise from the positive X (or A) direction.

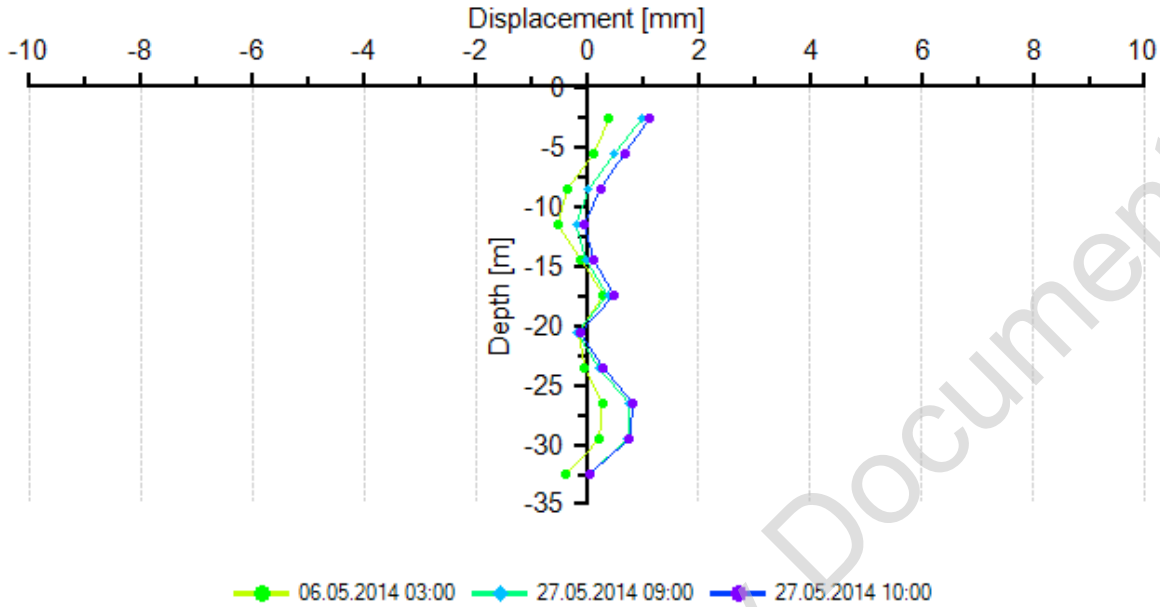
Inclinometer: IM1000004 Dir. X 100.0 Grad



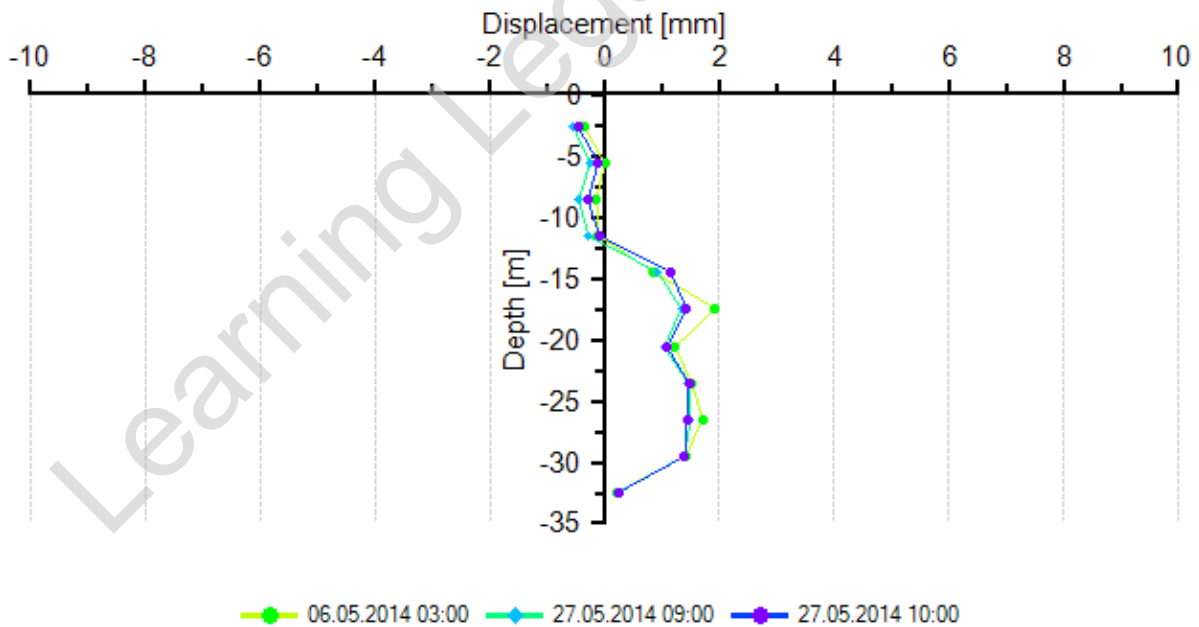
Inclinometer: IM1000004 Dir. Y 0.0 Grad



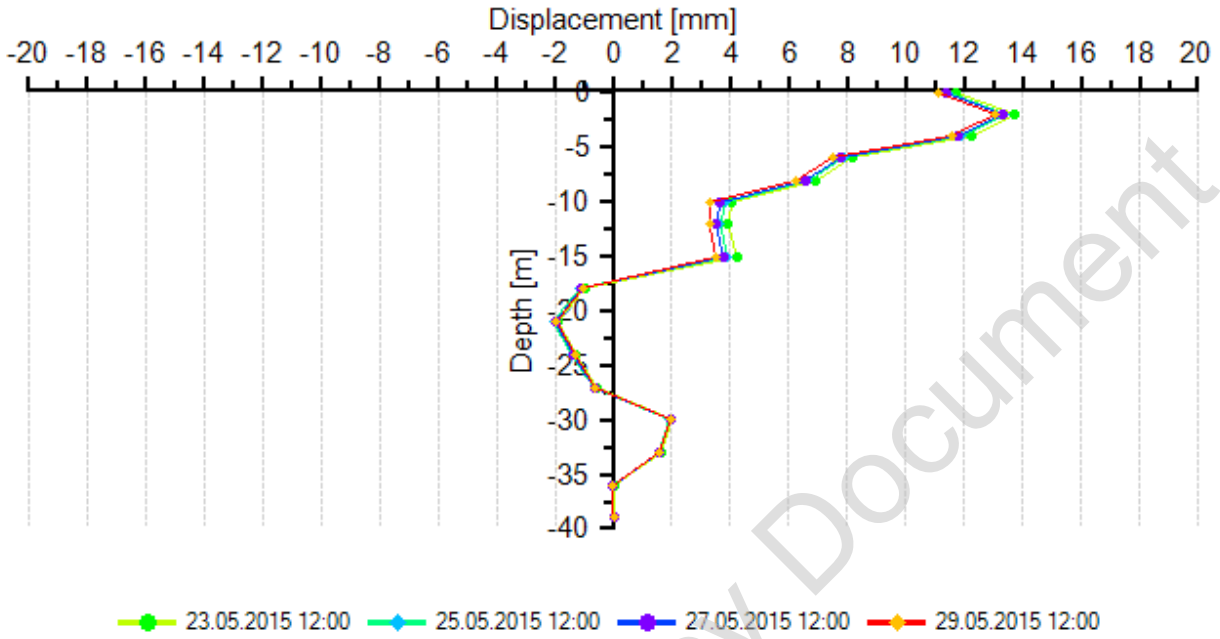
Inclinometer: IM1000005 Dir. X 100.0 Grad



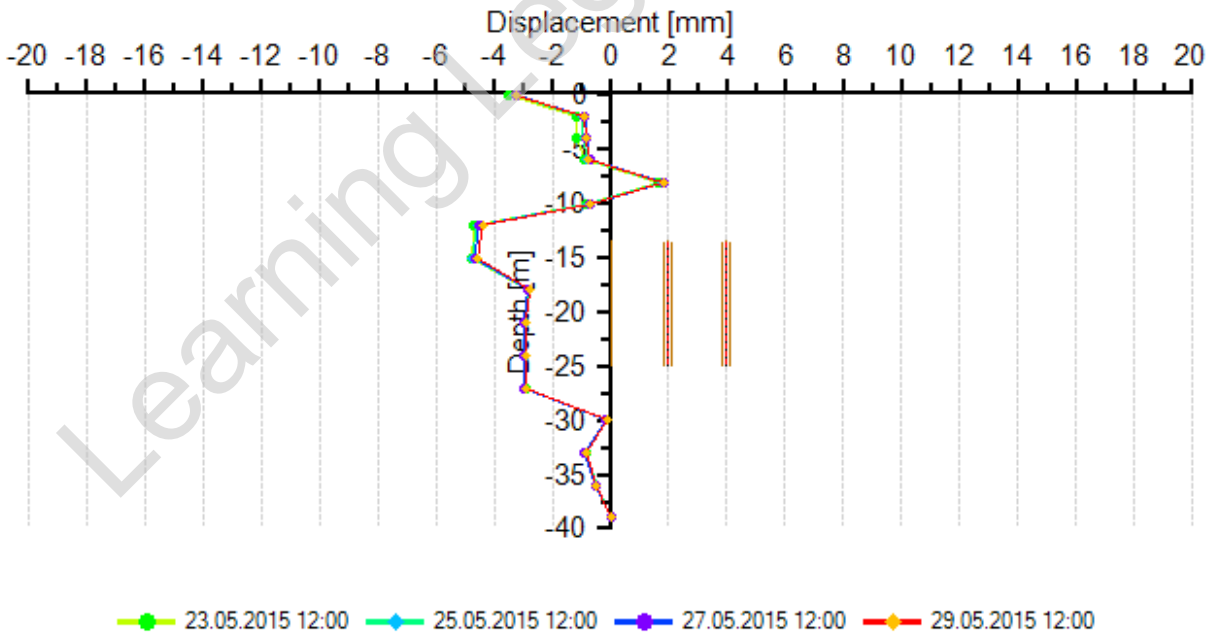
Inclinometer: IM1000005 Dir. Y 0.0 Grad

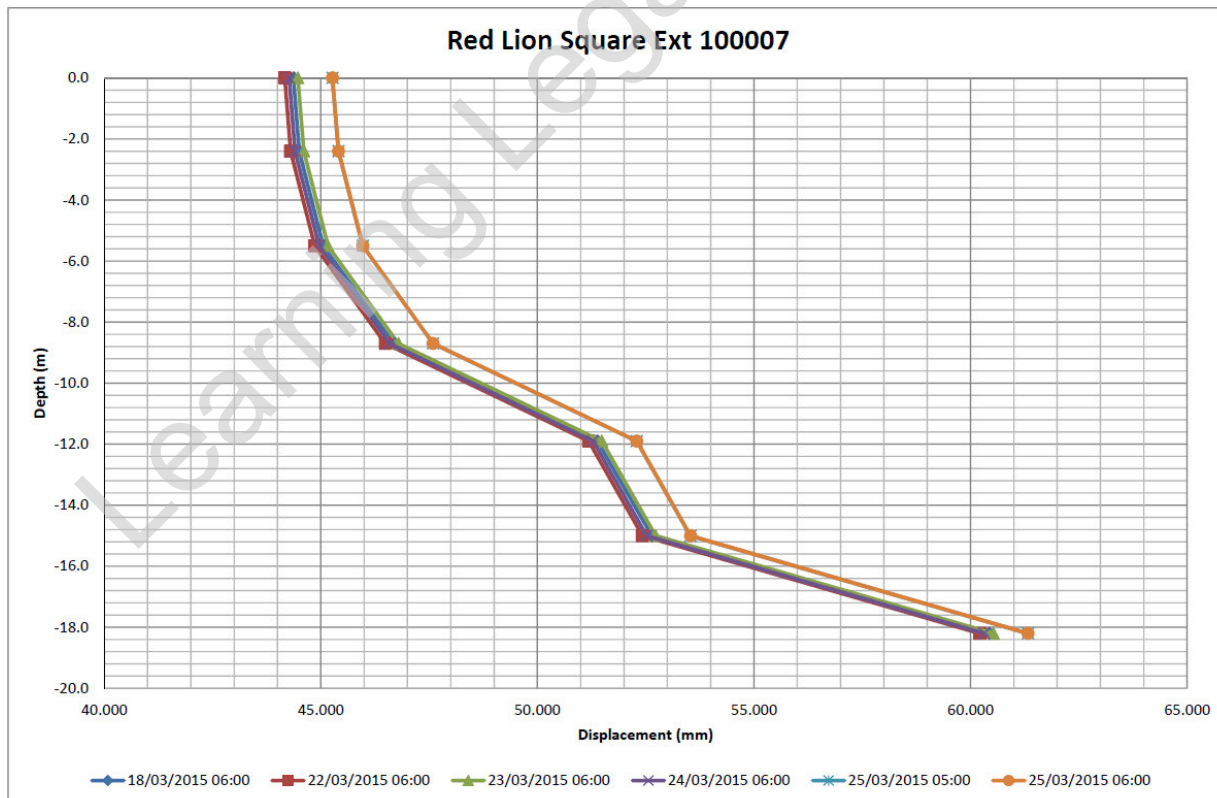
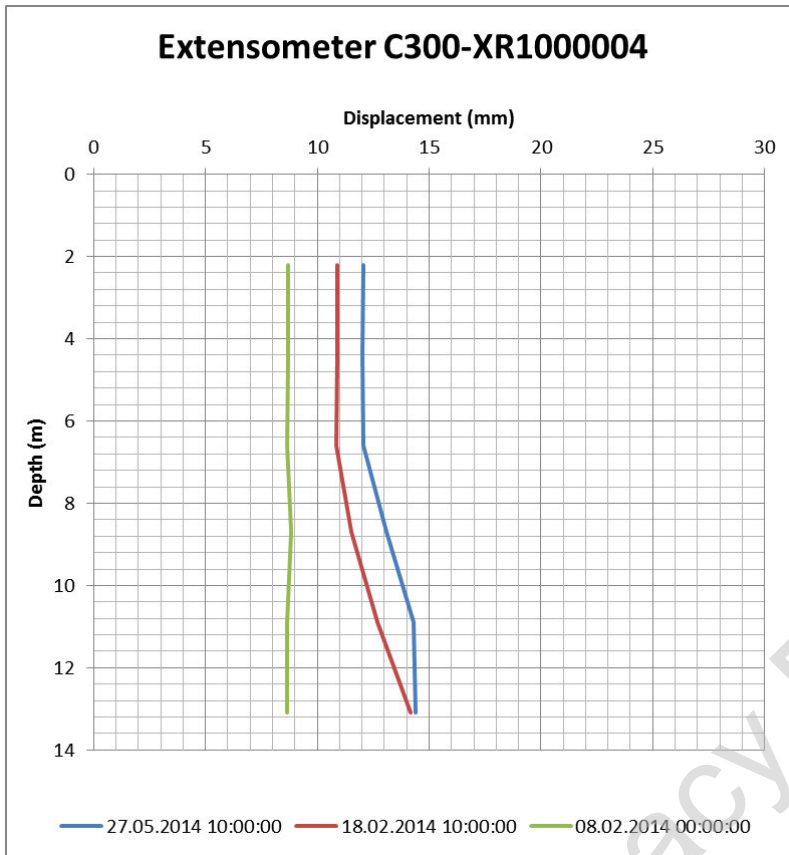


Inclinometer: C300-IM100007 Dir. X 100.0 Grad



Inclinometer: C300-IM100007 Dir. Y 0.0 Grad





4.12.2. Comments

The in-ground instruments in the Red Lion Square area, were subject to a number of issues (refer C300-NCR-001115 and C300-NCR-001120). In particular, no reliable information was obtained from inclinometer C300-IM100008. In general, all the monitoring data from the deep instruments are showing stable behavior or very slow movement trends after the works.

Appendix 1. Reference Documents

Code	Document
C300-BFK-C4-STP-CRT00_ST005-51812	MANAGEMENT PLAN FOR THE CONTROL OF GROUND MOVEMENTS: ADDENDUM 44 CROSSOVER SCL WORKS
C300-BFK-C4-STP-CRT00_ST005-50166	MANAGEMENT PLAN FOR THE CONTROL OF GROUND MOVEMENTS: ADDENDUM 37 TBM DRIVE 9 – FISHER STREET
C122-OVE-C2-RGN-CR086_SH003-50011	Instrumentation & Monitoring Plan C300 Fisher Street Shaft and Crossover Ground Movement And Asset Protection
C122-OVE-C2-RGN-CRG01-50076	Instrumentation & Monitoring Plan C300 Running Tunnels Ground Movement And Asset Protection
C122-OVE-U-RGN-CRG01-50003	Instrumentation and Monitoring Plans: Thames Water Assets: Drive X (C300) Instrumentation Plan for large or Deep Sewers
C300-BFK-C4-RGN-CRT00_ST005-50770	Installation report for PLPs FIS St
C300-BFK-C4-RGN-CRT00_ST005-50771	Installation Report for Precise Level point in FIS to FARR Area
C300-BFK-C4-RGN-CRT00_ST005-50891	Installation Report for Geodetic Prisms and BREs - FIS-FARR
C300-BFK-C4-RGN-CRT00_ST005-51137	Installation Report for Subsurface Instruments at Proctor Street
C300-BFK-C4-RGN-CRT00_ST005-51981	Installation Report for Subsurface Instruments at Red Lion Square
C300-NCR-001115	Red Lion Sq. IPIs
C300-NCR-001120	Red Lion Sq. IPIs

Appendix 2. Thames Water Assets summary table

Thames Water Assets summary tables included within C300-BFK-C4-RGN-CRT00_ST005-51129 and 51130.

Appendix 3. C300 Buildings Claims

Buildings Claims Sketched included within C300-BFK-C4-RGN-CRT00_ST005-51129 and 51130.



Appendix 4. BRE and PLP Location Plans

Learning Legacy Document

