



C300/410



Western Tunnels & Caverns Project

# Final Monitoring Report

TBM DRIVES ~ Fisher Street to Farringdon

CRL Document No. **C300-BFK-C4-RGN-CRT00\_ST005-51130**

Contract MDL reference: C14.022

## 1. Contractor Document Submittal History

Revision	Date	Prepared by	Checked by	Approved by	Reason for Issue
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		[Redacted]	[Redacted]	[Redacted]	

## 2a. Stakeholder Review Required? YES NO

Stakeholder submission required: LU  RfL  Purpose of submission: For no objection   
 NR  LO  For information   
 DLR  Other: \_\_\_\_\_

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:

	<b>Crossrail Review and Acceptance Decal</b> 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. Receipt is confirmed	
Reviewed/Accepted by: (signature)	[Redacted]	Date:	18/12/15
Acceptance by Crossrail does not constitute approval of design, details, calculations, analyses, test methods or materials developed or selected by the designer/supplier.			

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## 1. Purpose and Scope

The purpose of this document is to provide a summary of the observed movements relative to the TBM works between Fisher Street Shaft and Farringdon Station in accordance with the requirements of the Instrumentation and Monitoring Specification KX10, Clauses KX10.2113 and KX10.2114.

### 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.

This report is one of a series of 5 which cover the TBM drives between Royal Oak Portal and Farringdon Station as listed in Table 1.

Report title: <i>Final and Close Out Monitoring</i>	Report Number: C300-BFK-C4 RGN CRT00_ST005-	Eastbound Tunnel		Westbound Tunnel	
		Start Chainage	End Chainage	Start Chainage	End Chainage
Royal Oak Portal to Paddington Station (ROP to PAD)	51232	510	1312	510	1300
Paddington Station to Bond Street Station (PAD to BOS)	51015	1670	3561	1660	3568
Bond Street Station to Tottenham Court Road Station (BOS to TCR)	51016	4187	4672	4159	4679
Tottenham Court Road Station to Fisher Street Shaft & Crossover (TCR to FIS)	51129	5147	5792	5108	5856
Fisher Street Shaft & Crossover to Farringdon Station (FIS to FAR)	51130	6097	6860	6162	6945

Table 1 List of Final / Close Out Reports for TBM drives Royal Oak Portal to Farringdon.

### 1.1. Executive summary

This document includes settlement data from instruments on assets (BRE) and from general ground transects (PLP) for the TBM drives between Fisher Street Shaft and Farringdon Station. A summary of the monitoring data is provided, with the influence of the two TBM drives identified. The rate of post-construction settlement is compared to the specified limit of 2mm/year and the absolute magnitude of settlement is compared to the trigger values given in the C122 I&M plan. Points where trigger levels have been exceeded are listed. Monitoring data from Cross Passage 5 is also presented.

Information about Thames Water assets is provided, both within the report and in Appendix 3 (summary table). In general, no deflection amber trigger (average of 3 values) has been breached on Thames Water assets.

The transects from which data is presented are listed in Table 2. The locations of the instruments are plotted in Appendix 7 and those from which data is presented are identified. A summary of the

final settlements recorded on all BRE and PLP is also given in Appendix 7. The maximum recorded settlement between Fisher Street Shaft and Farringdon Station is **20mm**.

The transects marked with “\*” in Table 2 were de-scoped less than 1 year after the passage of the TBMs. This was agreed during dedicated meetings with CRL and C122 based on analysis of the monitoring data (trends and settlement values).

TBM progress information, supporting documents references, and a summary of claims for building damage (provided by CRL) are provided in Appendices 1, 2 and 4 respectively.

It should be noted that the data from all instruments is available on the UCIMS platform

Table 2: Transects presented

Sections
Princeton Street*
Bedford Row*
Jockey’s Fields*
Raymond Buildings ad Atkin Building *
Gray’s Inn Gardens*
Gray’s Inn Square*
Baldwin’s Gardens*
Gray’s Inn Road
Baldwin’s Gardens*
Brooke’s*
St. Alban’s Church
Brooke Street & Dorrington Street*
Beauchamp Street & Brooke’s Market*
Leather Lane*
Greville Street*
Hatton Garden*
Kirby Street and Bleeding Heart Yard*
Saffron Hill*
Post Office Tunnel*

It should be noted that some transects include a large number of measuring points. In these cases, for the sake of clarity, only the points within the zone of influence of the TBMs were included in the charts.

## 2. Summary of the observed settlements

### 2.1. Princeton Street PLPs

#### 2.1.1. Data

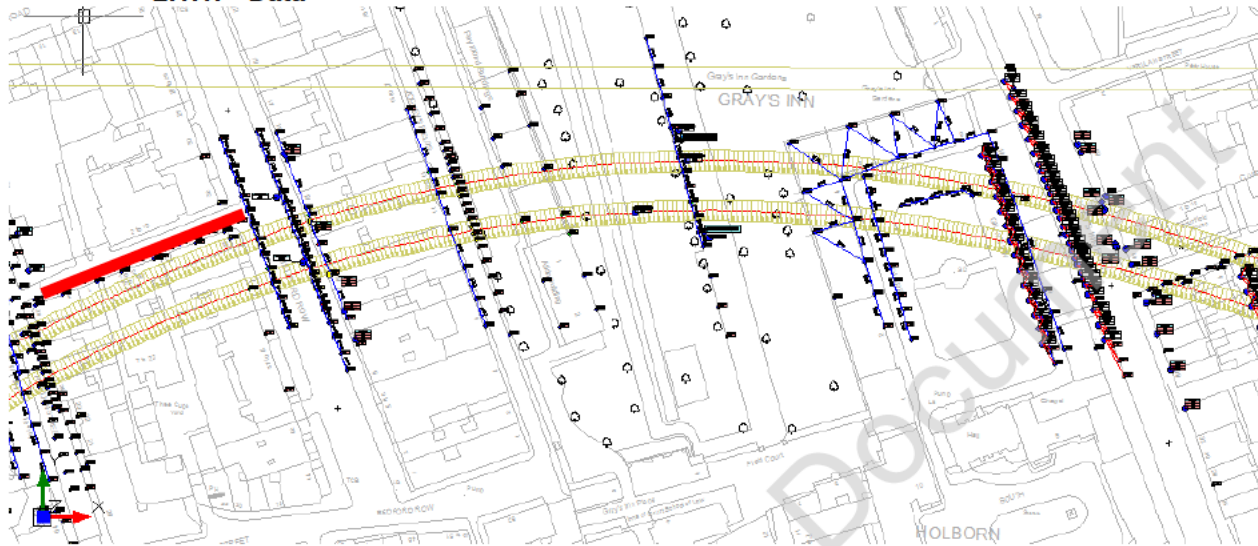


Figure 1: Location

#### PLPs Princeton Street

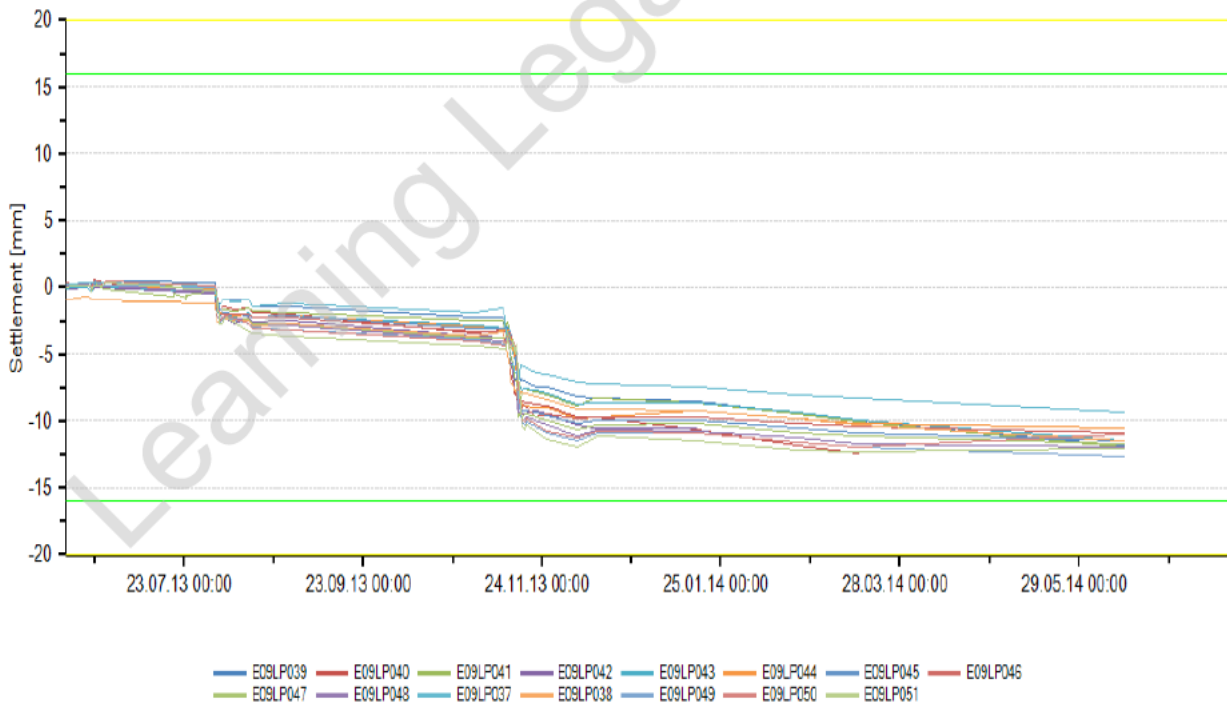


Figure 2 - data time-plots: comparison against settlement triggers

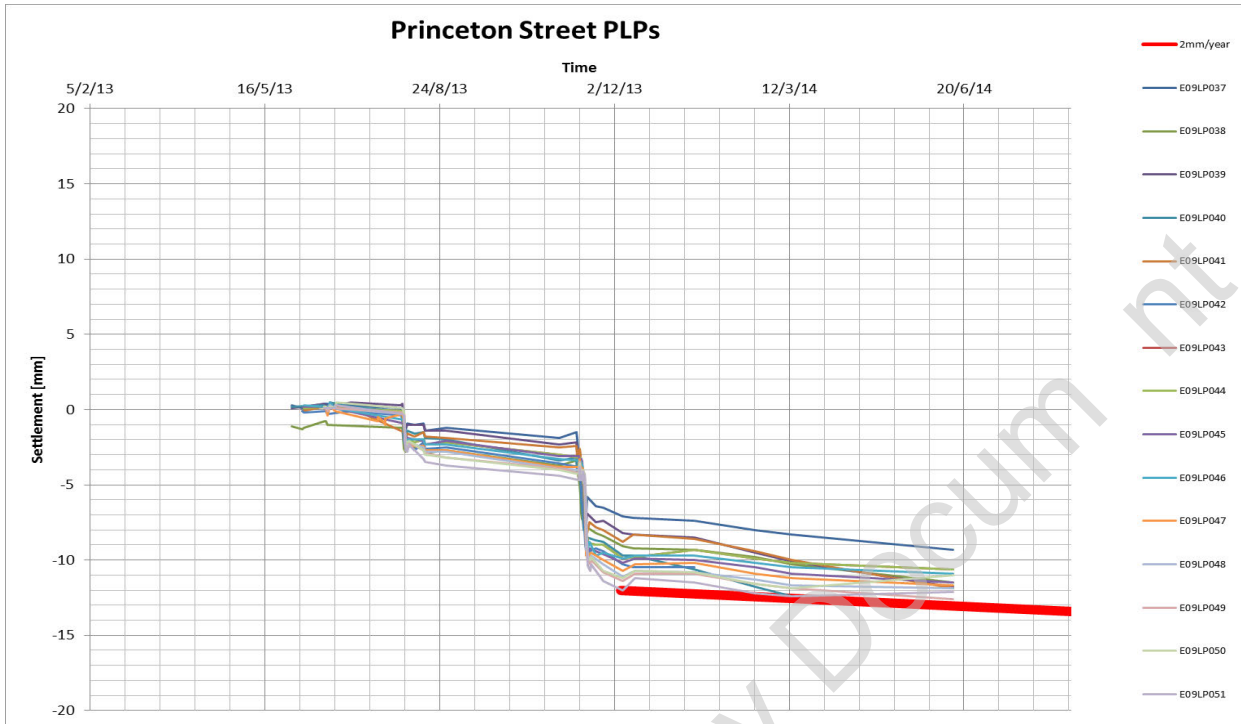


Figure 3: data time-plots - comparison against 2mm/year settlement rate (long-term)

Table 3: Achieved Triggers – deflection ratio

Worst case deflection ratio (average of 3 values) [1/-]	Trigger
13,200	no

### 2.1.2. Comments

The points in Princeton Street settled up to approx. 13mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots.

The time plots are showing stabilising settlement trend, and the long term behaviour appears to be less than 2mm/year.

## 2.2. Bedford Row PLPs and BREs

### 2.2.1. Data

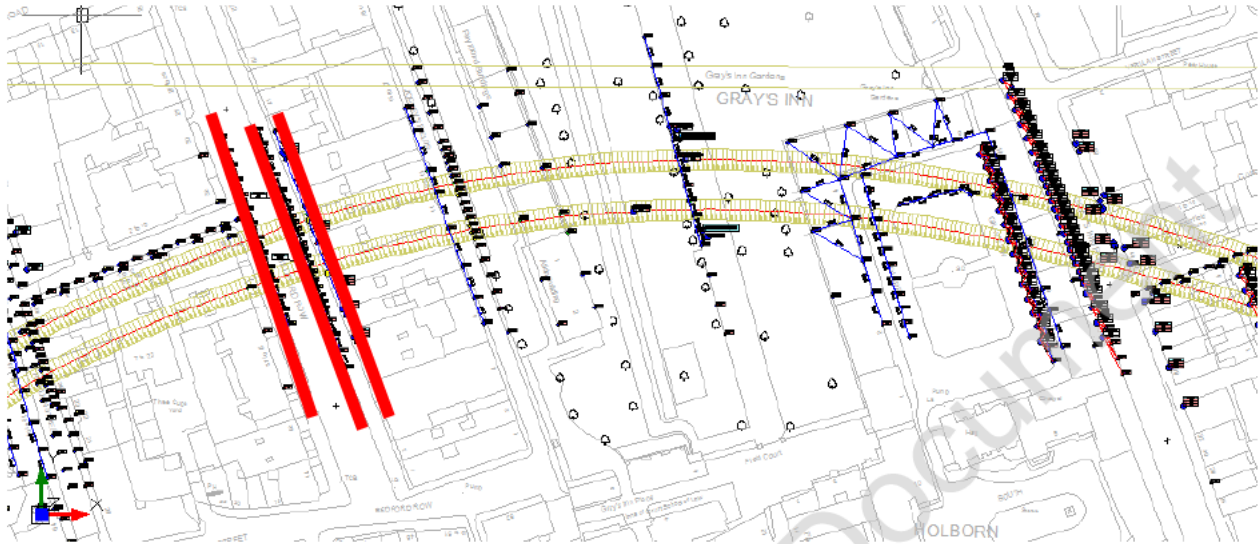
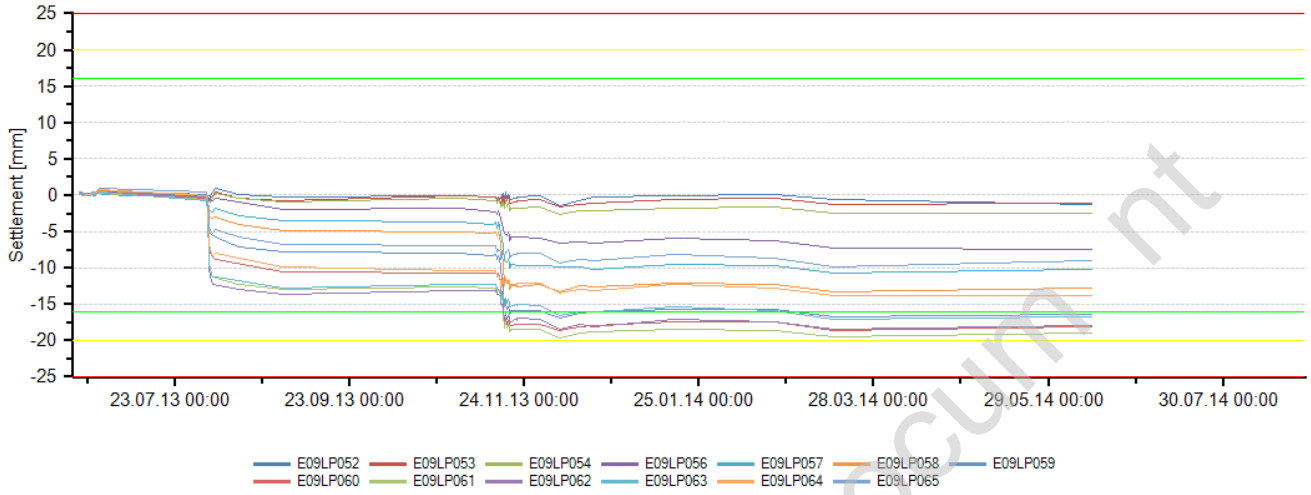
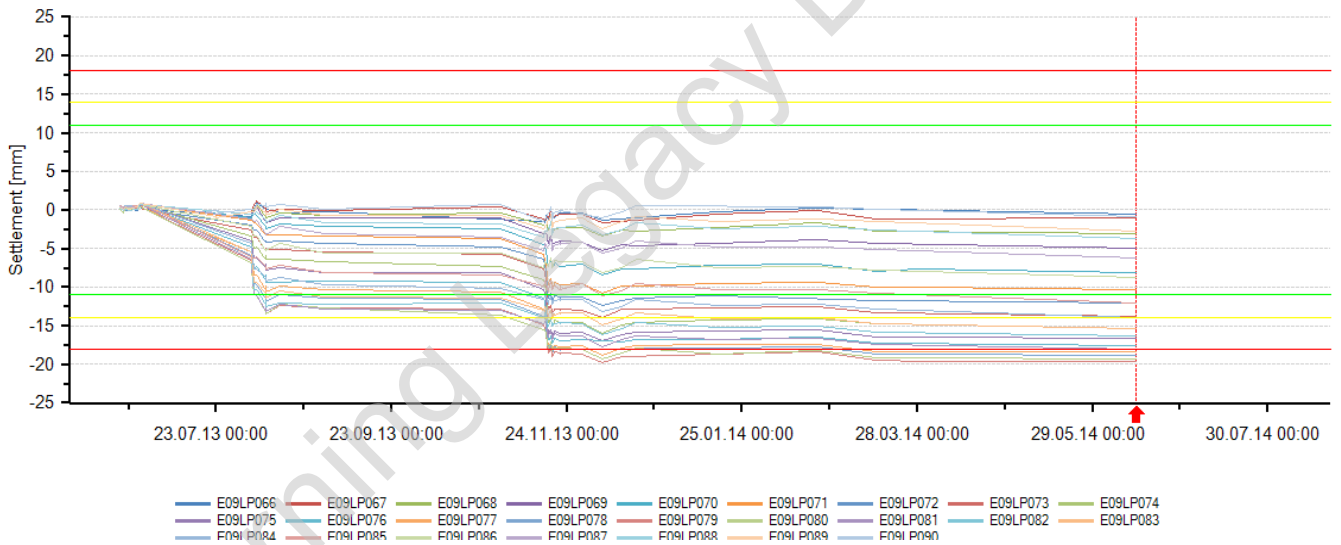


Figure 4: Location

**PLPs Bedford Row West**



**PLPs Bedford Row East**



**BRE Bedford Row East**

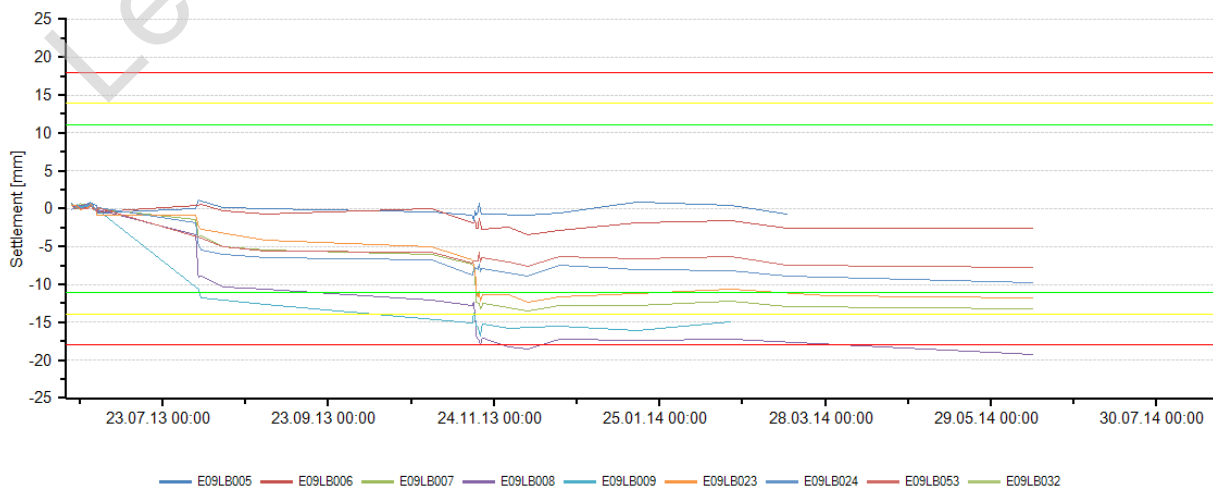


Figure 5a, b, c: data time-plots: comparison against settlement triggers



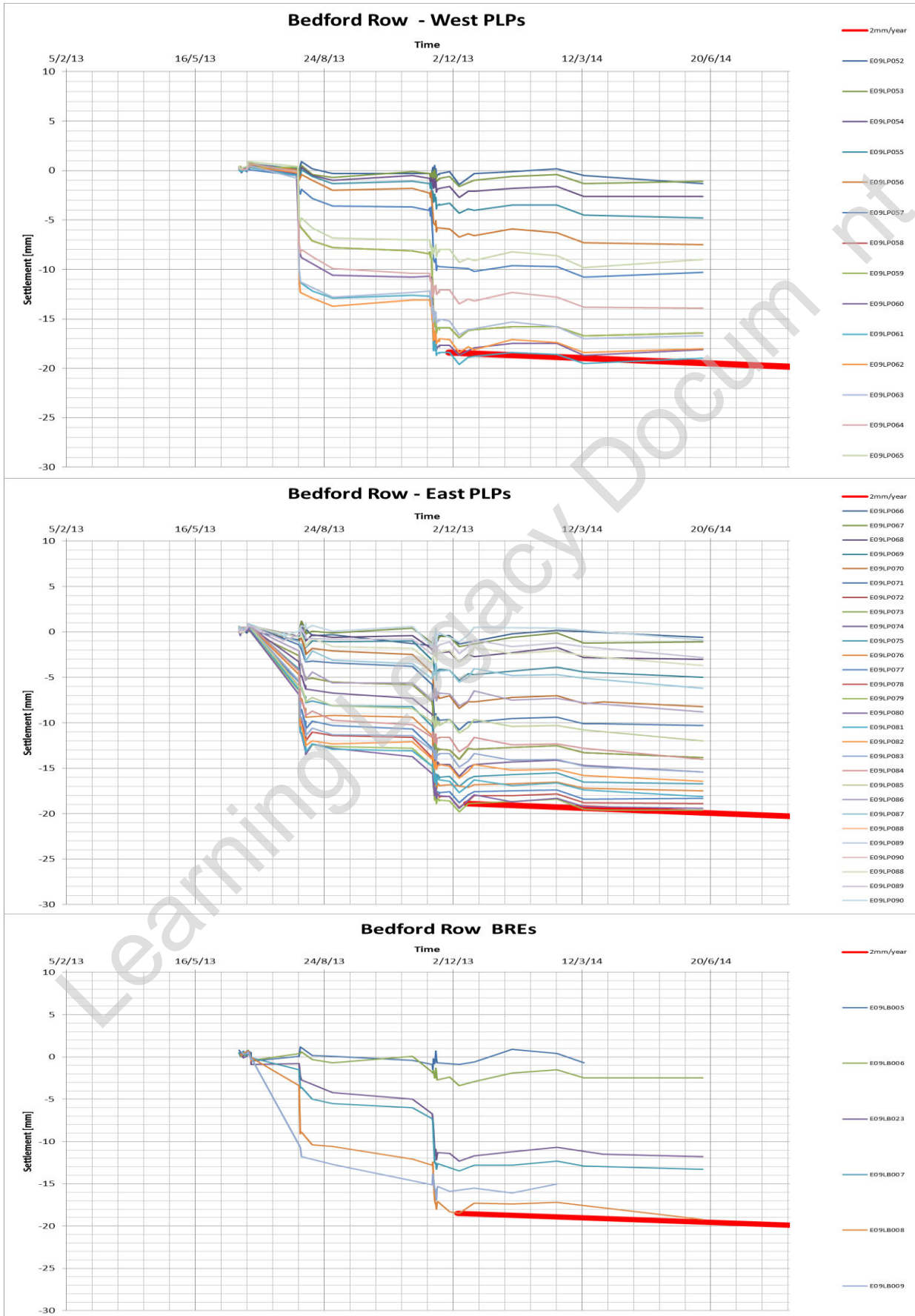


Figure 6: data time-plots - comparison against 2mm/year settlement rate (long-term)

Table 4: Achieved Triggers – settlement, deflection ratio and slope

Point Code	Point type	Achieved Trigger
E09LP072	PLP	Green
E09LP073	PLP	Green
E09LP074	PLP	Amber
E09LP075	PLP	Amber
E09LP076	PLP	Amber
E09LP077	PLP	Red
E09LP078	PLP	Red
E09LP079	PLP	Red
E09LP080	PLP	Red
E09LP081	PLP	Red
E09LP082	PLP	Amber
E09LP083	PLP	Amber
E09LP084	PLP	Green
E09LP085	PLP	Green
E09LP086	PLP	Green
E09LP023	BRE	Green
E09LP007	BRE	Green
E09LP008	BRE	Red
E09LP009	BRE	Amber

Worst case PLPs deflection ratio (average of 3 values) [1/-]	Trigger
8,600	no

Worst case BREs slope [1/-]	Trigger
1,600	no

### 2.2.2. Comments

The points in Bedford Row settled up to approx. 20mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have been breached as per Table 4.

The time-plots are generally showing stabilising settlement trends, and the long term behaviour appears to be about 2mm/year.

## 2.3. Jockey's Fields PLPs and BREs

### 2.3.1. Data

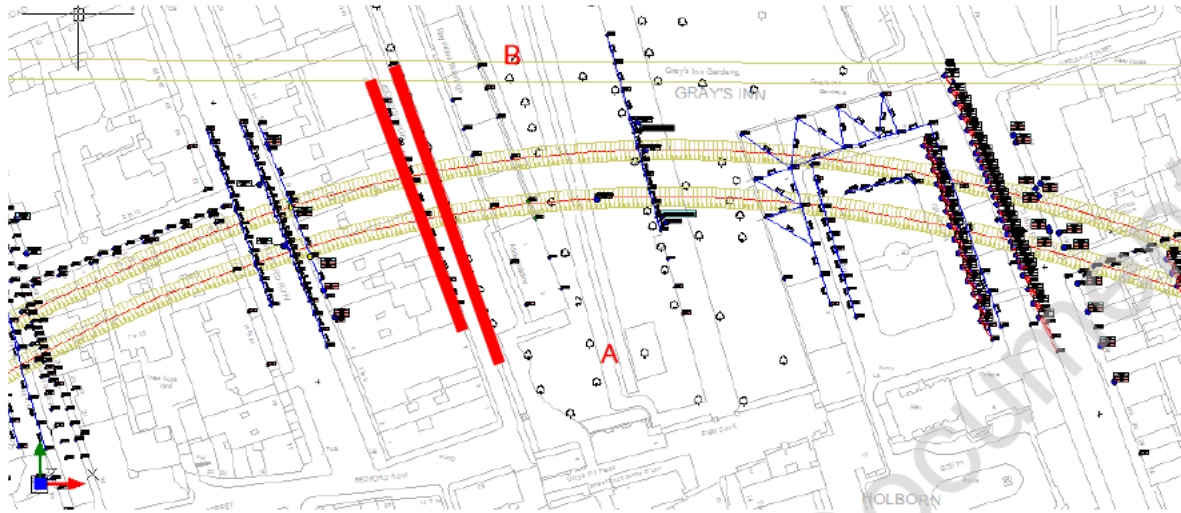
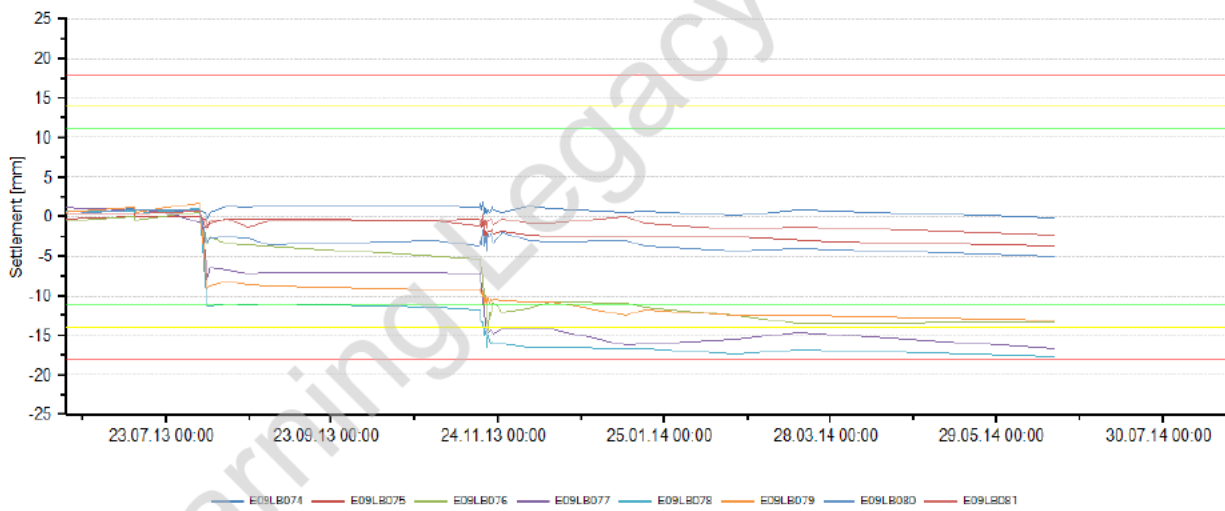


Figure 7: Location

#### BRE Jockeys Field West



#### PLPs Jockeys Fields East

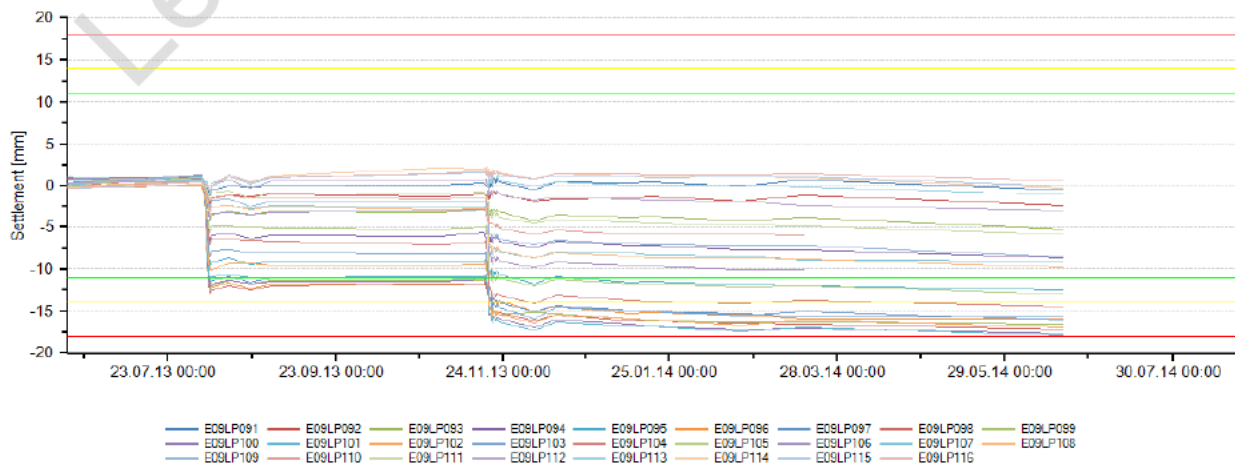


Figure 8a, b: data time-plots - comparison against settlement triggers

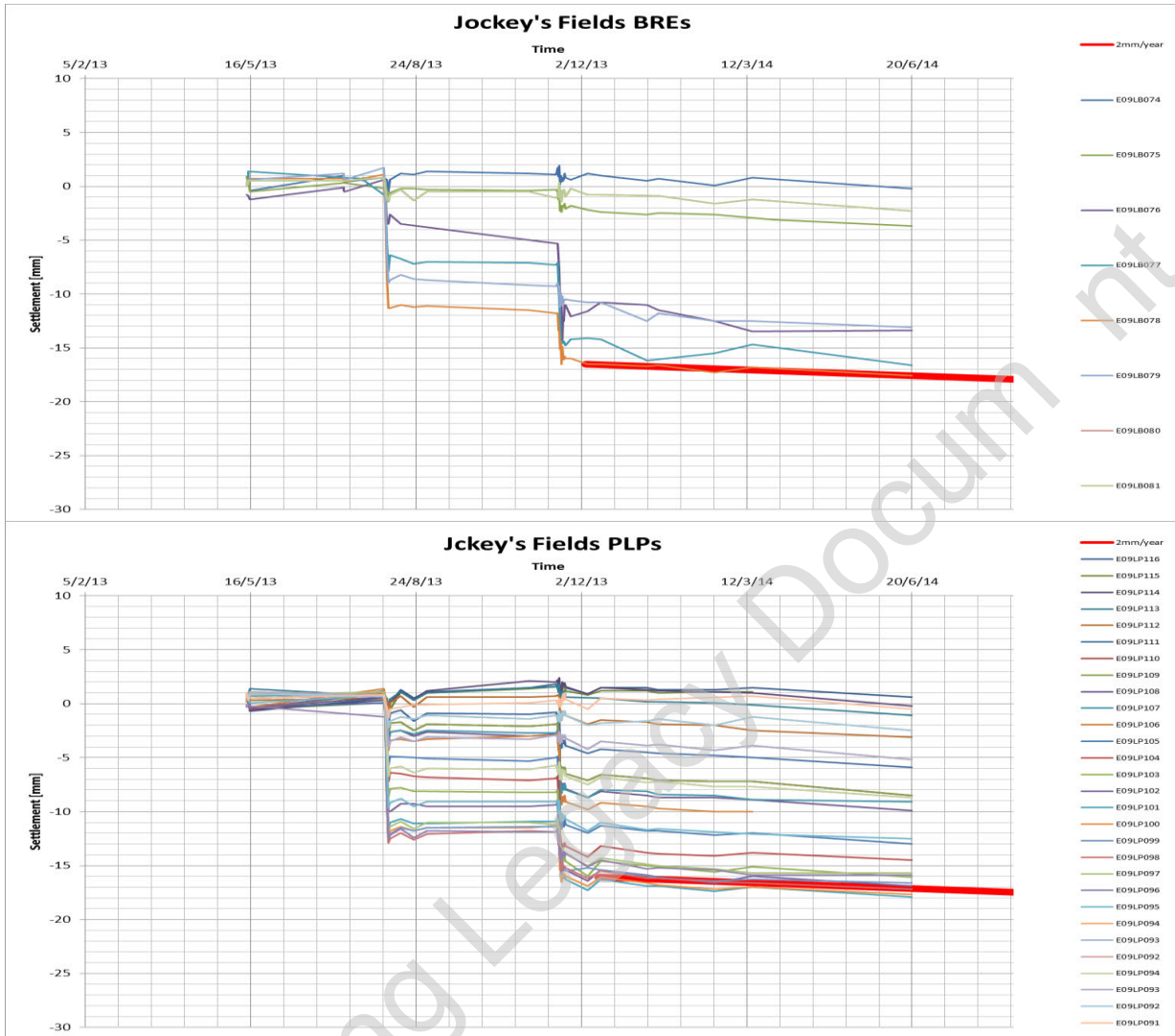


Figure 9: data time-plots - comparison against 2mm/year settlement rate (long-term)

Jockeys Fields East PLPs transect

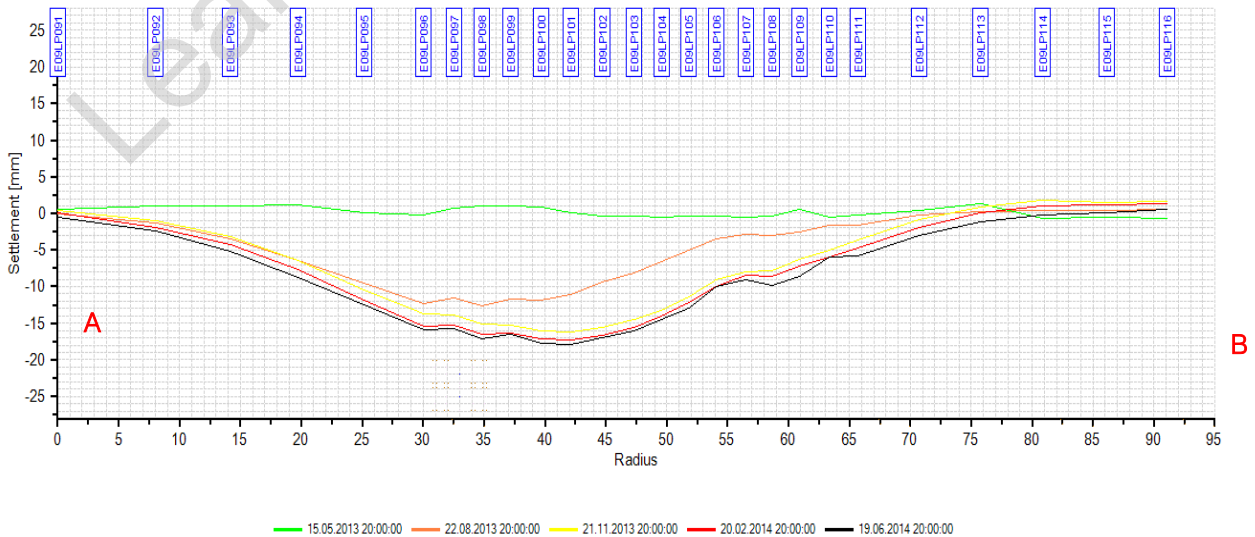


Figure 10: cut

Table 5 : Achieved Triggers – settlements, deflections, slopes

Point Code	Point type	Achieved Trigger
E09LB076	BRE	Green
E09LB 077	BRE	Amber
E09LB078	BRE	Amber
E09LB079	BRE	Green
E09LP105	PLP	Green
E09LP104	PLP	Amber
E09LP103	PLP	Amber
E09LP102	PLP	Amber
E09LP101	PLP	Amber
E09LP100	PLP	Amber
E09LP099	PLP	Amber
E09LP098	PLP	Amber
E09LP097	PLP	Amber
E09LP096	PLP	Amber
E09LP095	PLP	Green

Worst case PLPs deflection ratio (average of 3 values) [1/-]	Trigger
4,540	no

Worst case BREs slope ratio [1/-]	Trigger
1,340	no

### 2.3.2. Comments

The points in Jockey's Fields settled up to approx. 18mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have been breached as per Table 5.

The time-plots are generally showing stabilising settlement trend, and the long term behaviour appears to be at or below 2mm/year.

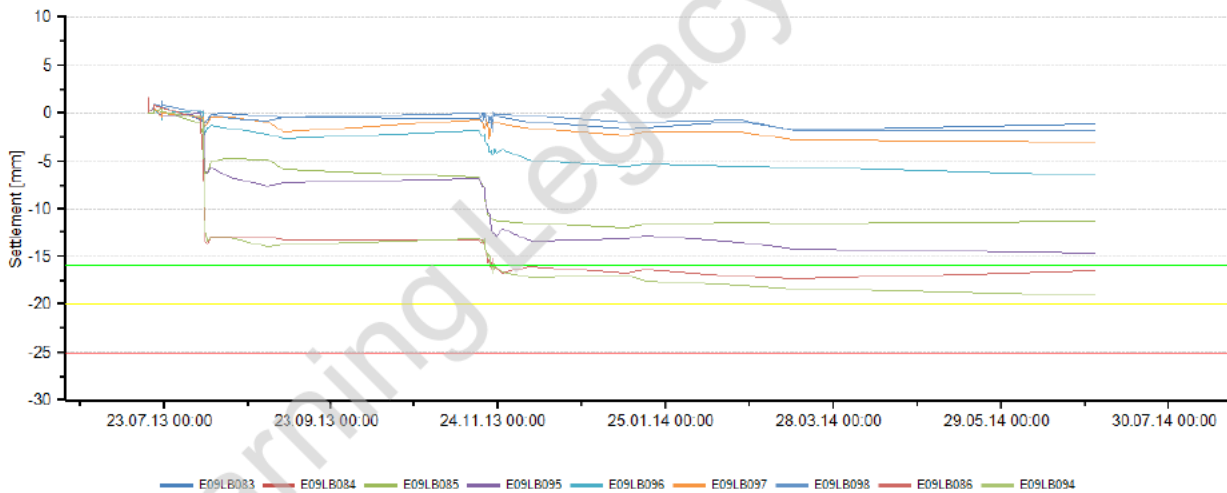
## 2.4. Raymond Buildings and Atkin Building BREs

### 2.4.1. Data



Figure 11: Location

#### BRE Raymond Buildings



#### BRE Atkin Building

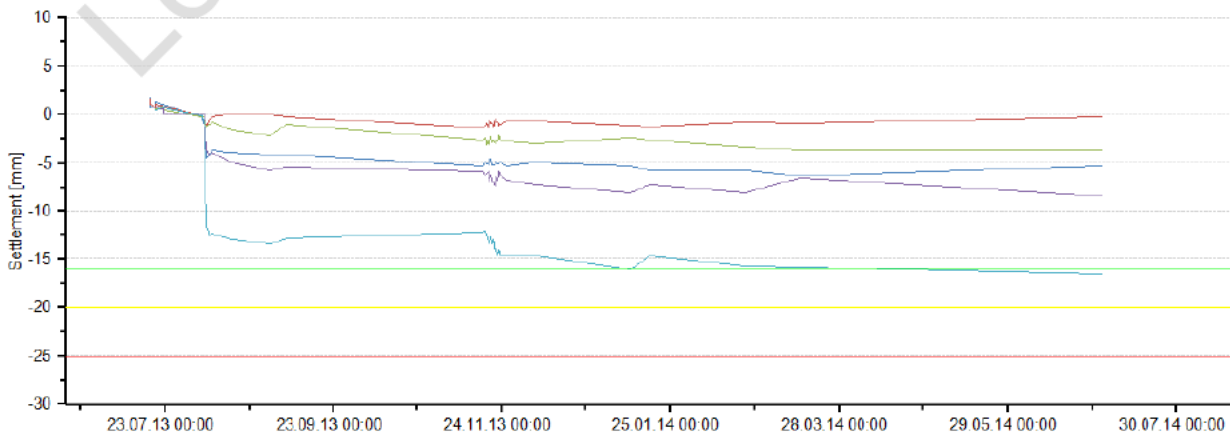


Figure 12a, b: data time-plots - comparison against settlement triggers

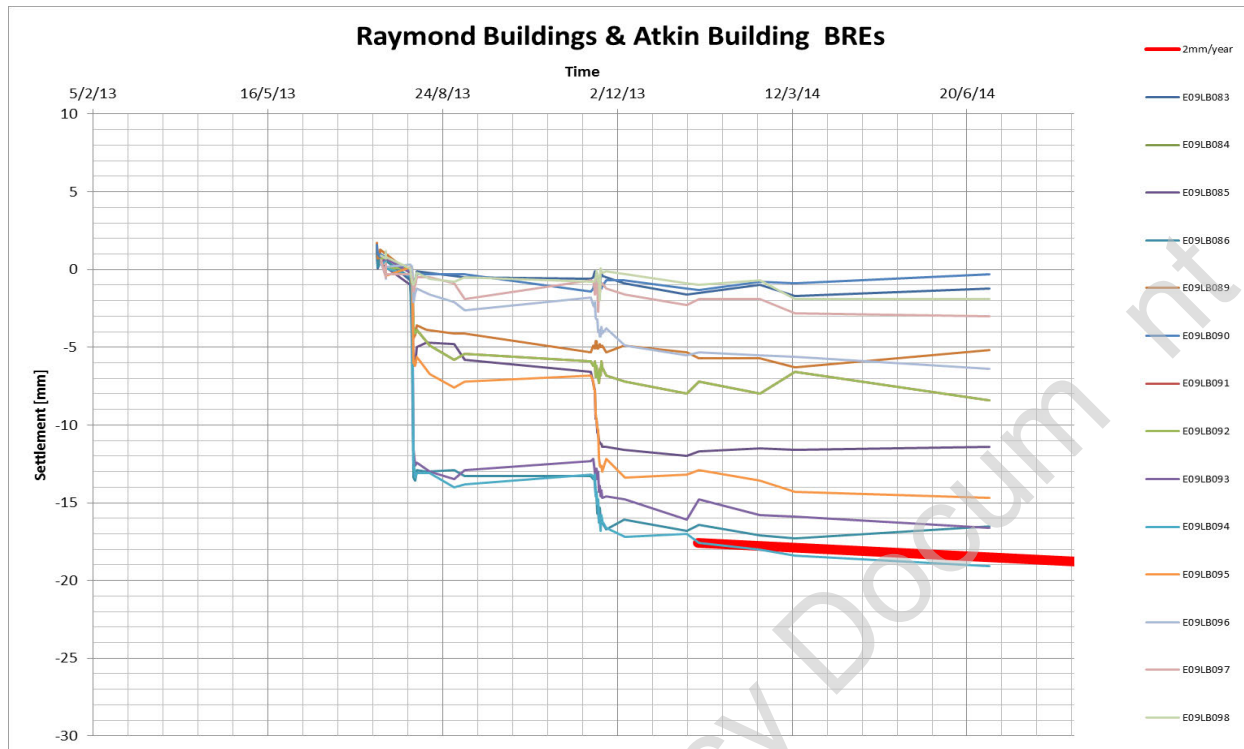


Figure 13: data time-plots - comparison against 2mm/year settlement rate (ong-term)

Table 6: Achieved Triggers – settlement and slope

Point Code	Point type	Achieved Trigger
E09LB086	BRE	Green
E09LB093	BRE	Green
E09LB094	BRE	Green

Worst case slope ratio [1/-]	Trigger
1,500	no

#### 2.4.2. Comments

The points in Raymond Buildings and Atkin Building settled up to approx. 19mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have been breached as per Table 6.

The time-plots are generally showing stabilising settlement trend, and the long term behaviour appears to be slightly over 2mm/year.

## 2.5. Gray's Inn Gardens PLPs

### 2.5.1. Data

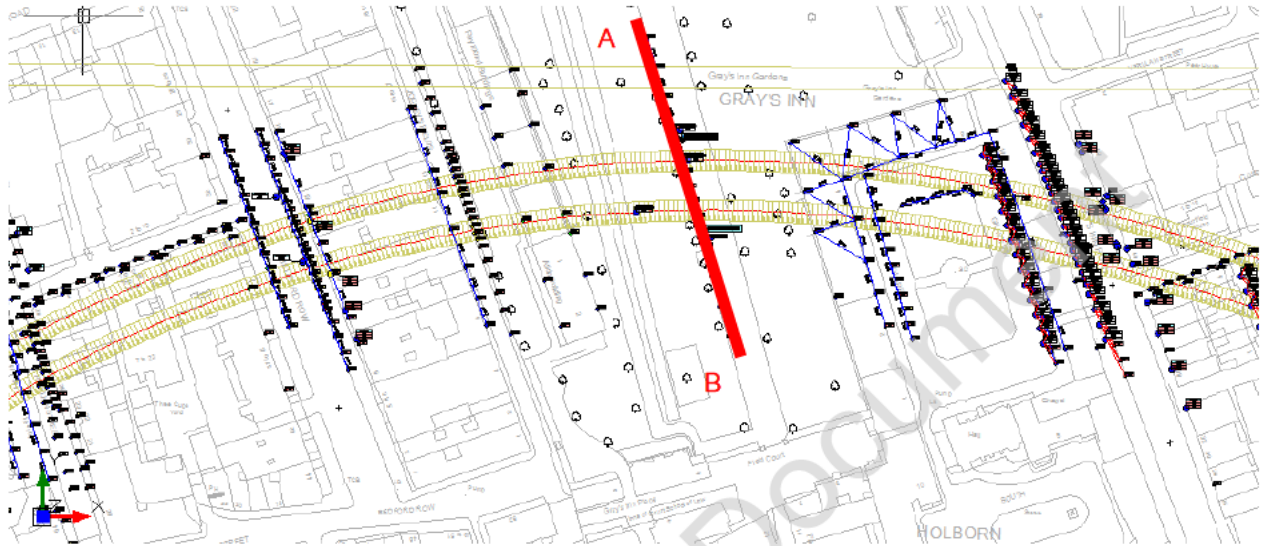


Figure 14: Location

### PLP's Grays Inn Gardens

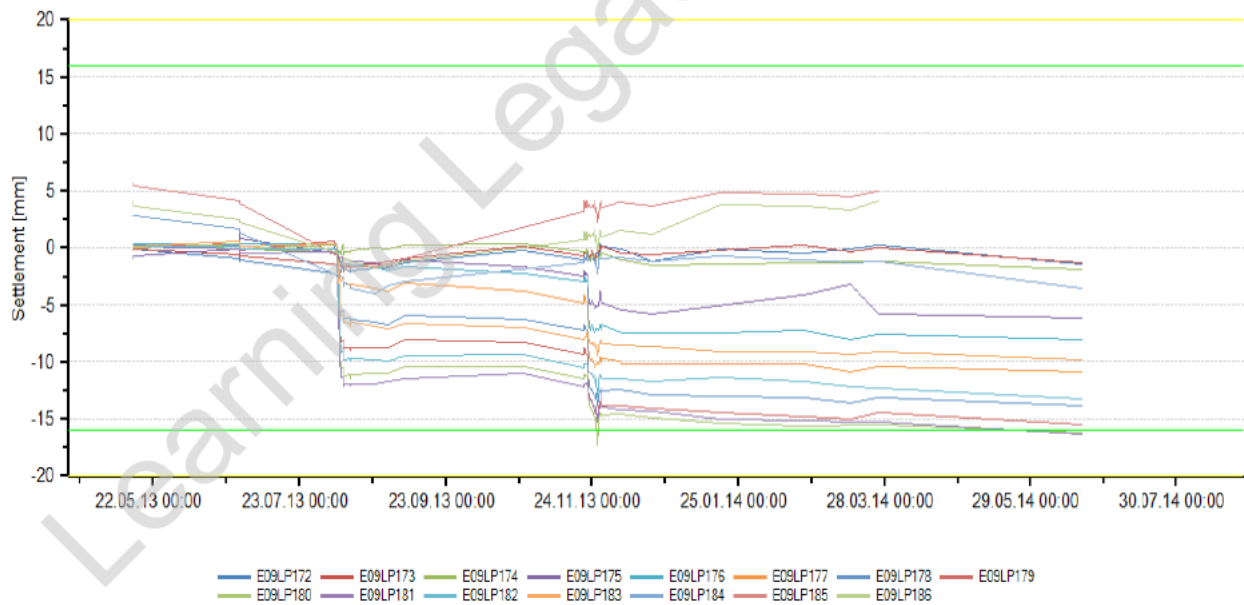


Figure 15: data time-plots - comparison against settlement triggers



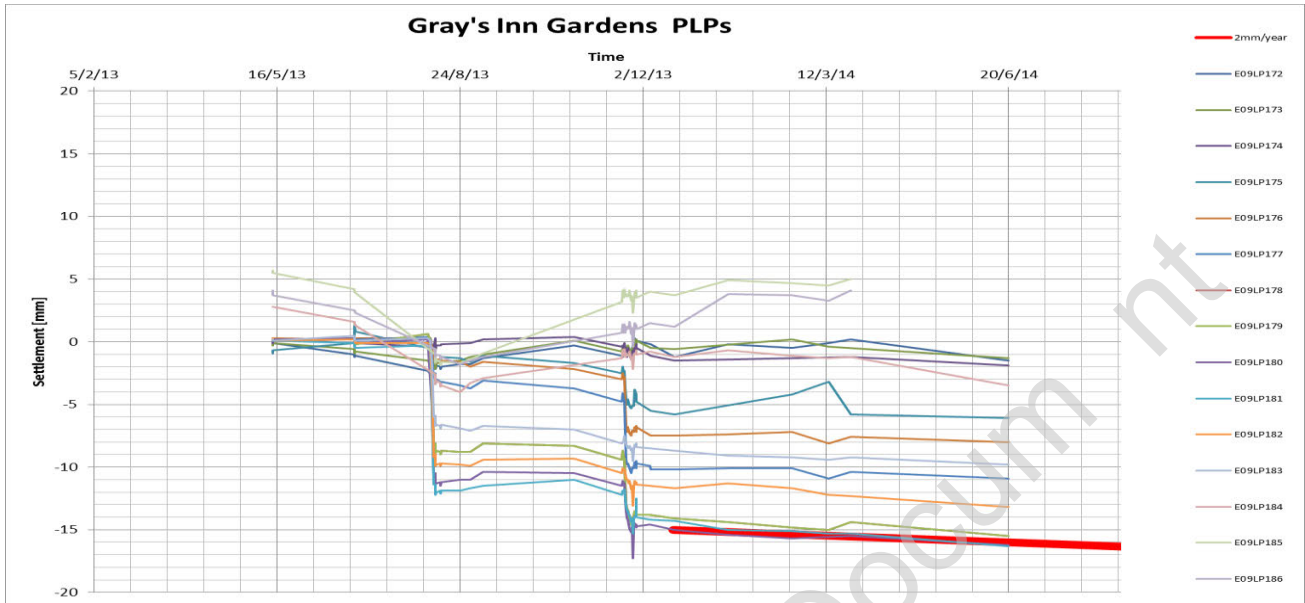


Figure 16: data time-plots - comparison against 2mm/year settlement rate (long-term)

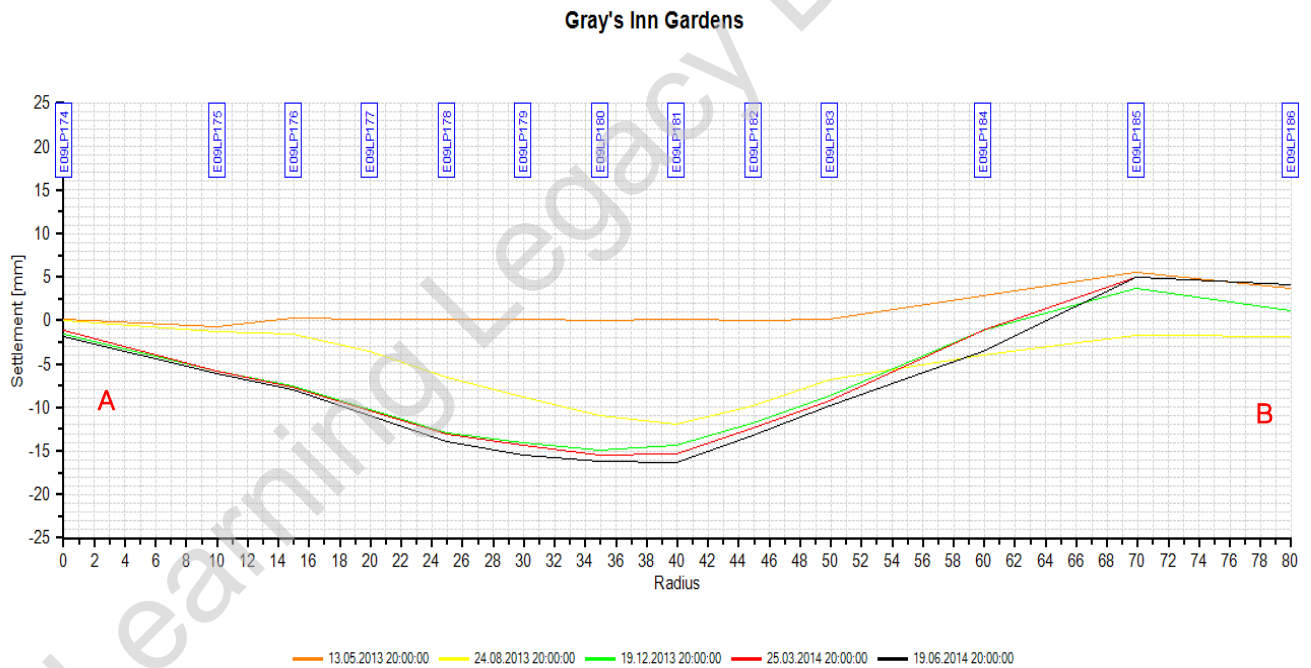


Figure 17: cut

Table 7: Achieved Triggers – settlement and deflection ratio

Point Code	Point type	Achieved Trigger
E09LP180	PLP	Green
E09LP181	PLP	Green

Worst case PLPs deflection ratio (average of 3 values) [1/-]	Trigger
20,500	no



### 2.5.2. Comments

The points in Gray's Inn Gardens settled up to approx. 16mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have been breached as per Table 7.

The time-plots are generally showing stabilising settlement trend, and the long term behaviour appears to be about or below 2mm/year.

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## 2.6. Gray's Inn Square PLPs and BREs

### 2.6.1. Data

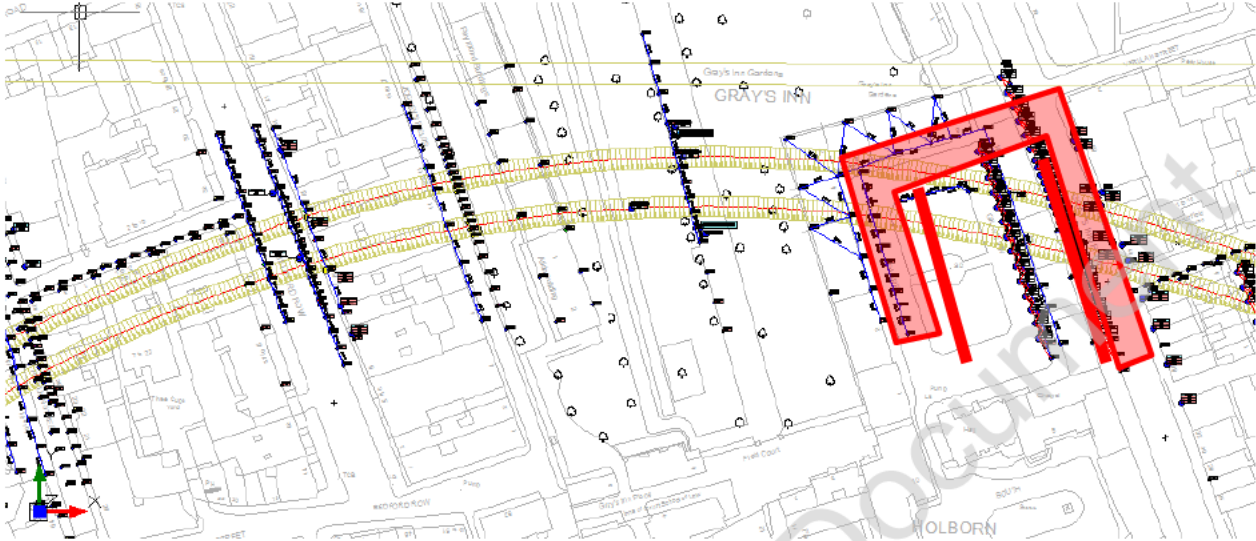
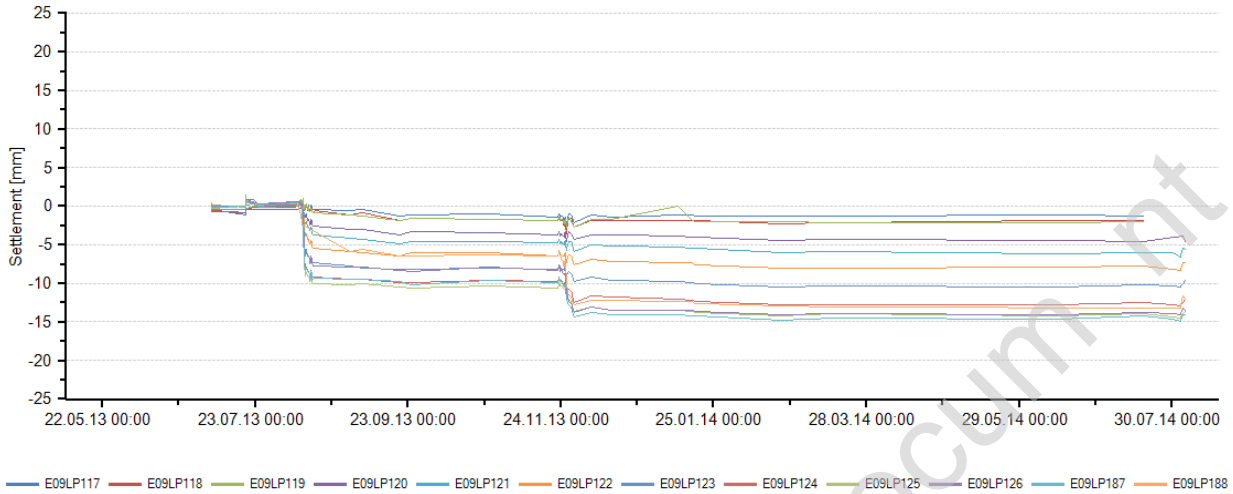
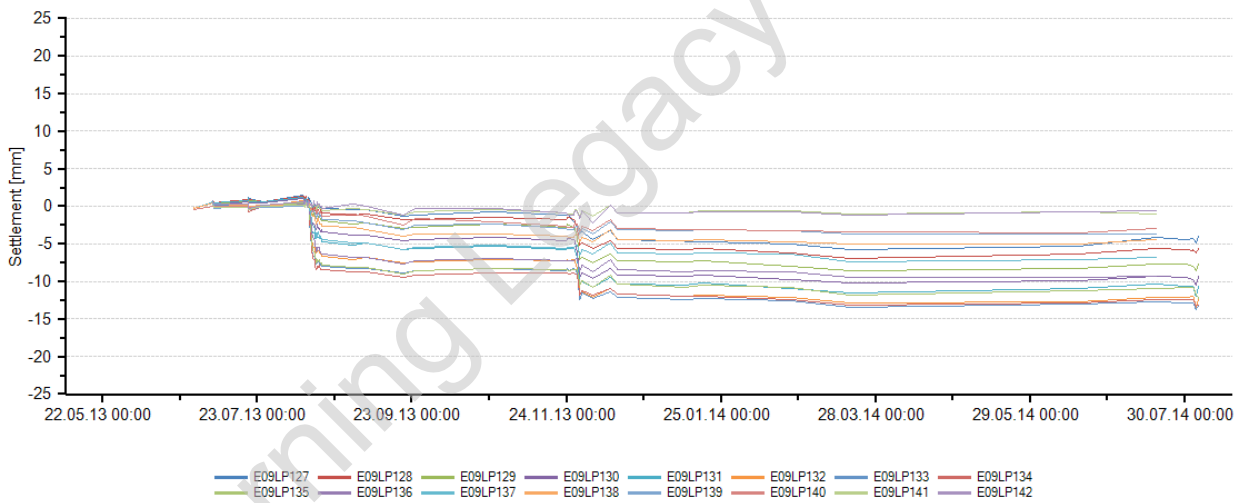


Figure 18: Location

**PLPs Gray's Inn Square West**



**PLPs Gray's Inn Square East**



**BRE Grays Inn Square West**

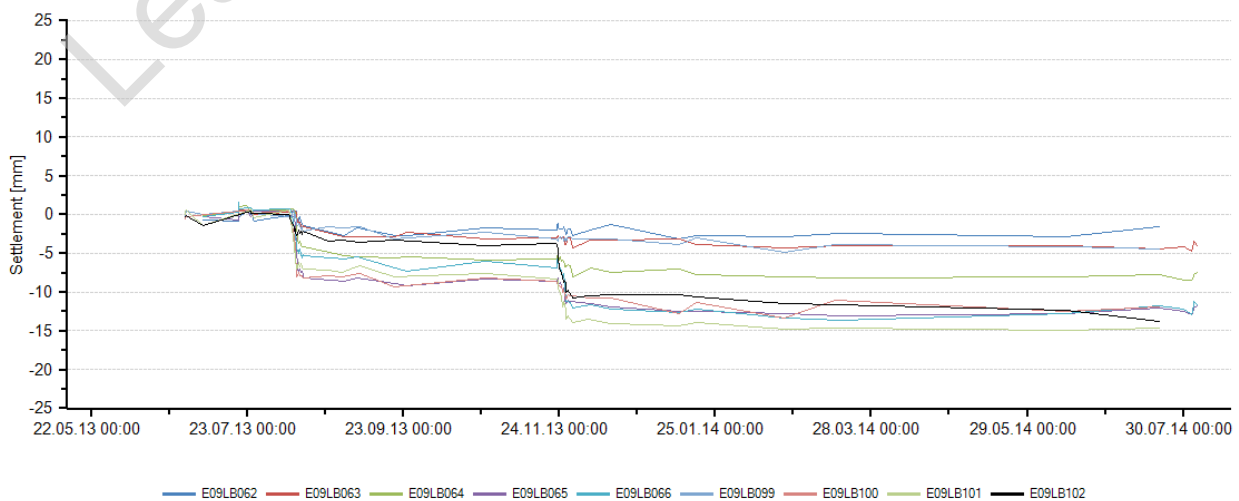


Figure 19: data time-plots - comparison against settlement triggers

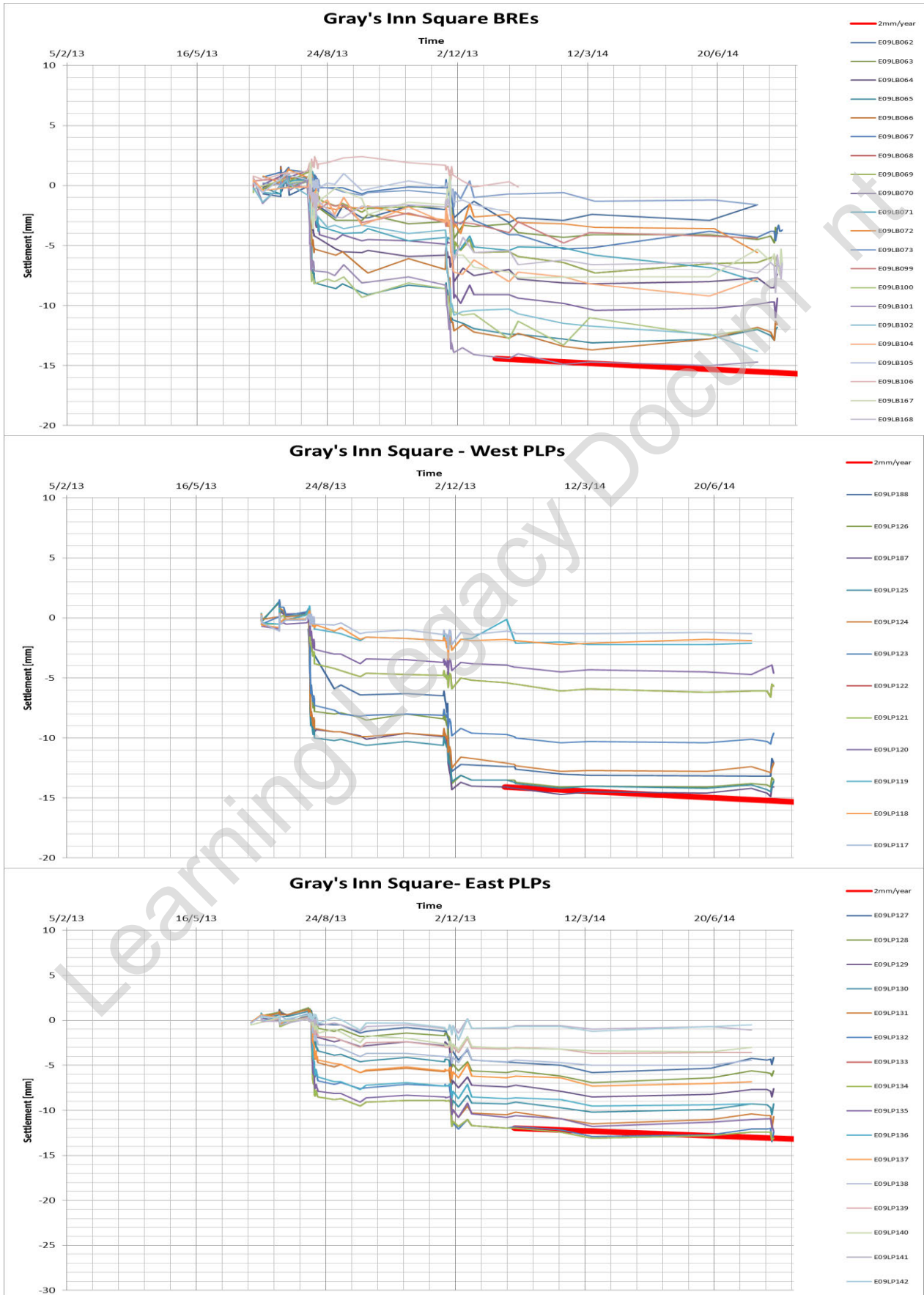


Figure 20a, b, c: data time-plots - comparison against 2mm/year settlement rate (long-term)

### 2.6.2. Comments

The points in Gray's Inn Square settled up to approx. 15mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have not been breached.

The time-plots are generally showing stabilising settlement trend, and the long term behaviour appears to be less than 2mm/year.

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## 2.7. Gray's Inn Road PLPs

### 2.7.1. Data

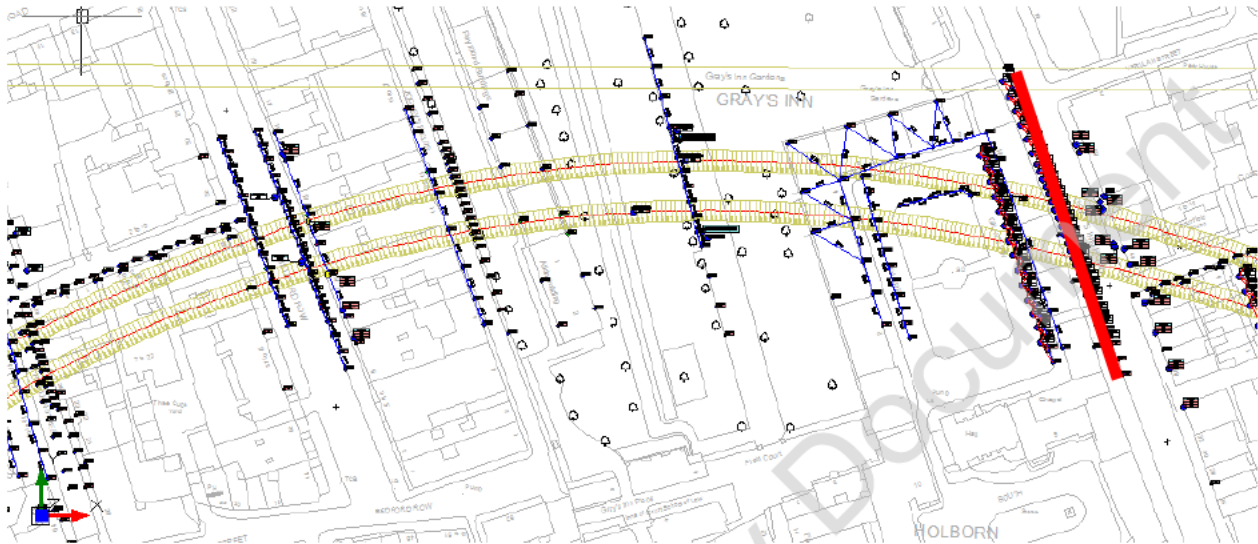


Figure 21: location

### PLPs Grays Inn Road West

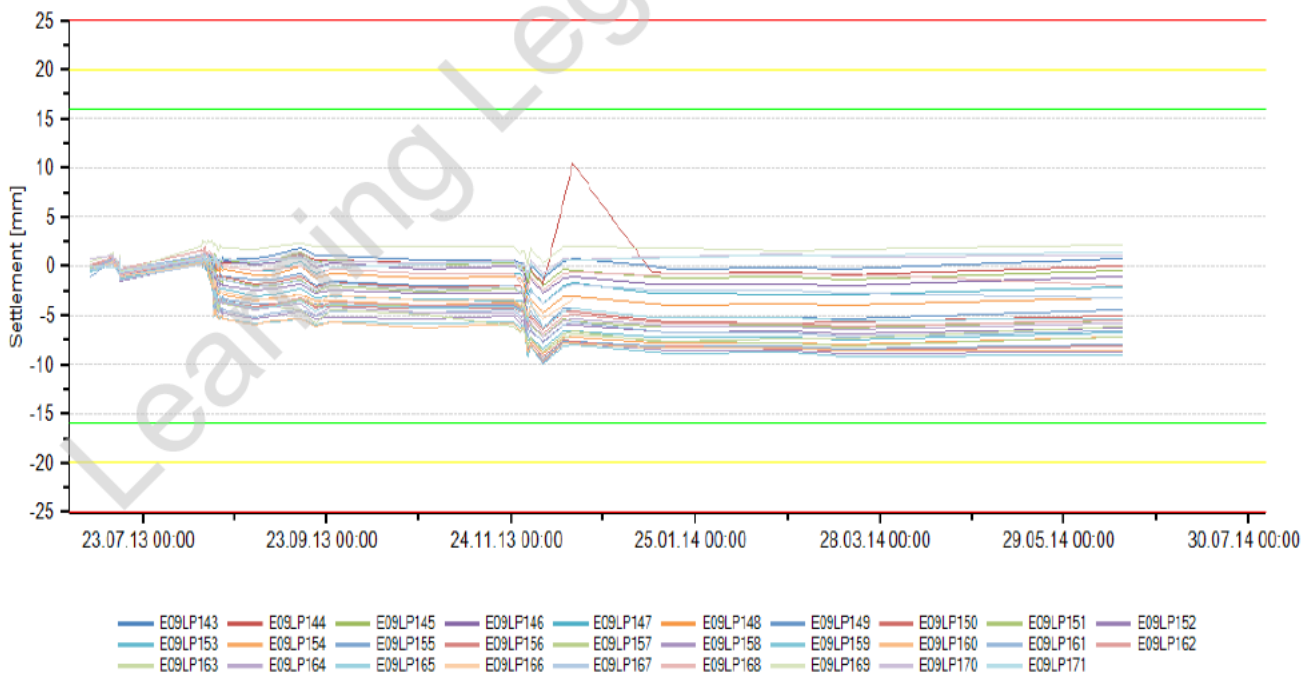


Figure 22: data time-plots - comparison against settlement triggers

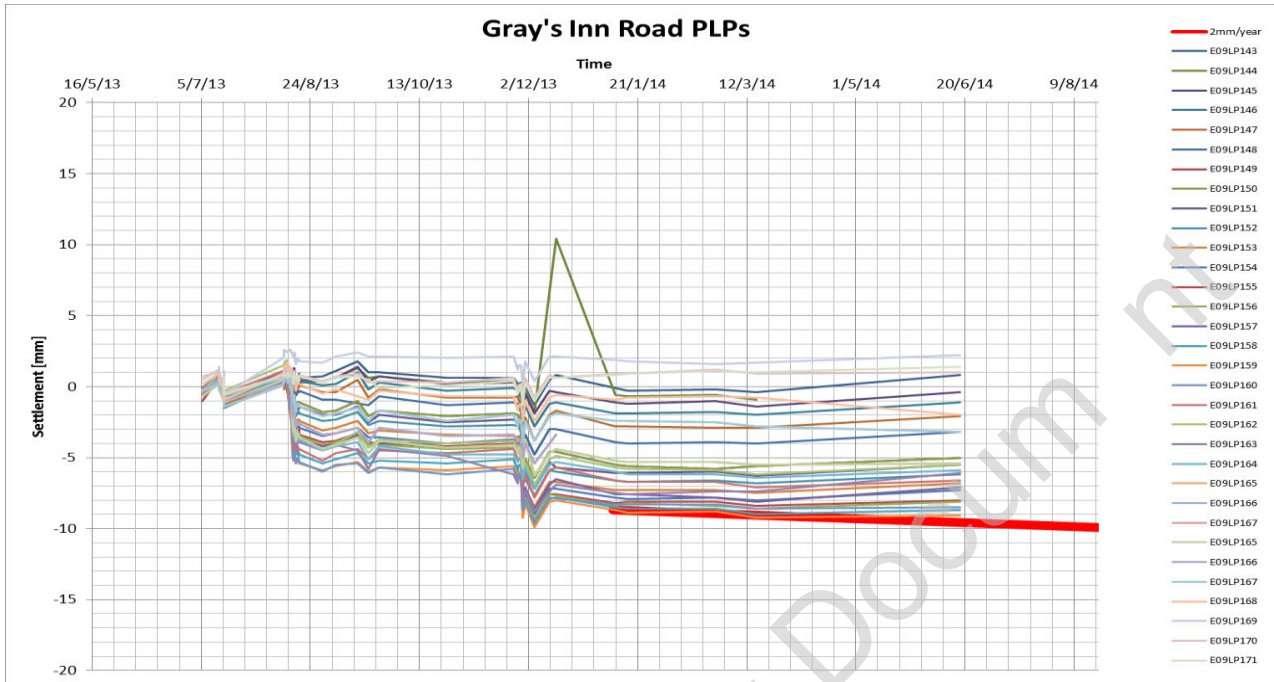


Figure 23: data time-plots - comparison against 2mm/year settlement rate (long-term)

### 2.7.2. Comments

The points in Gray's Inn Road settled up to approx. 10mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have not been breached.

The time-plots are generally showing stabilising settlement trend, and the long term behaviour appears to be less than 2mm/year.



## 2.8. Baldwin's Gardens PLPs and BREs

### 2.8.1. Data

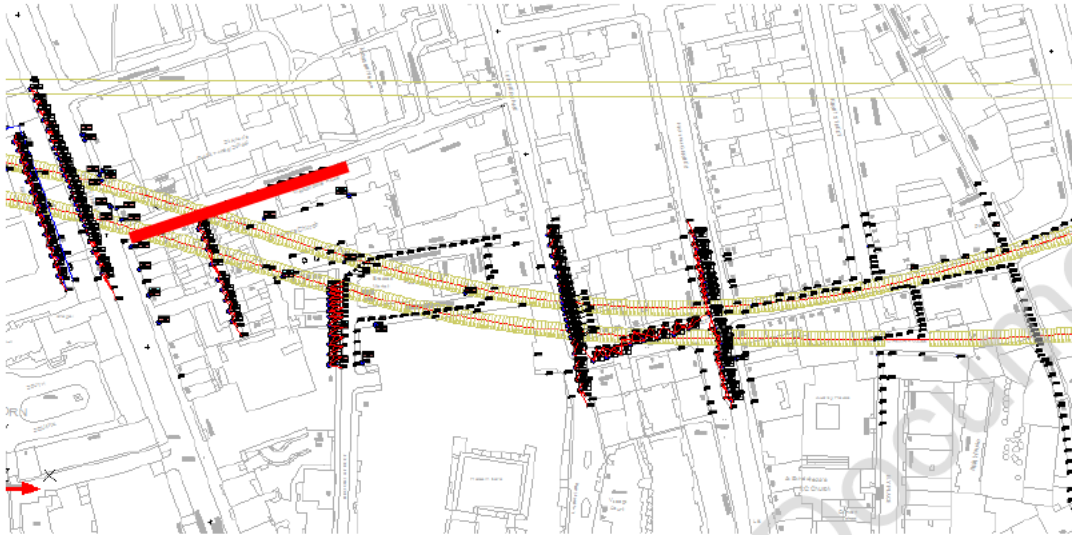


Figure 24: location

#### PLPs Baldwins Gardens South

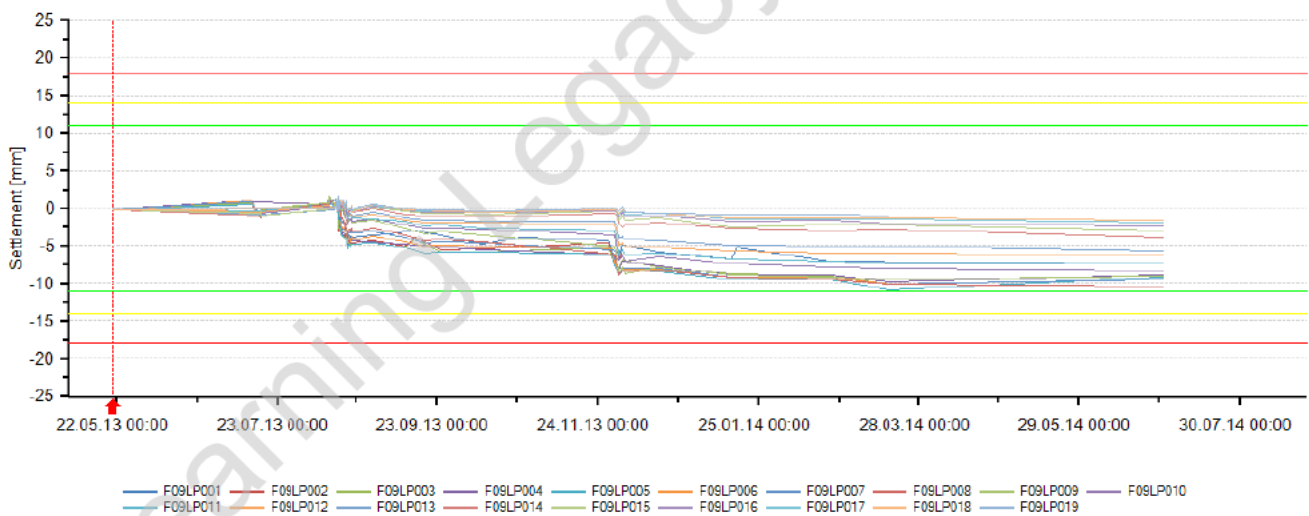


Figure 25: data time plots - comparison against settlement triggers



Figure 26: data time-plots - comparison against 2mm/year settlement rate (long-term)

**BRE Baldwins Gardens 6 - 46**

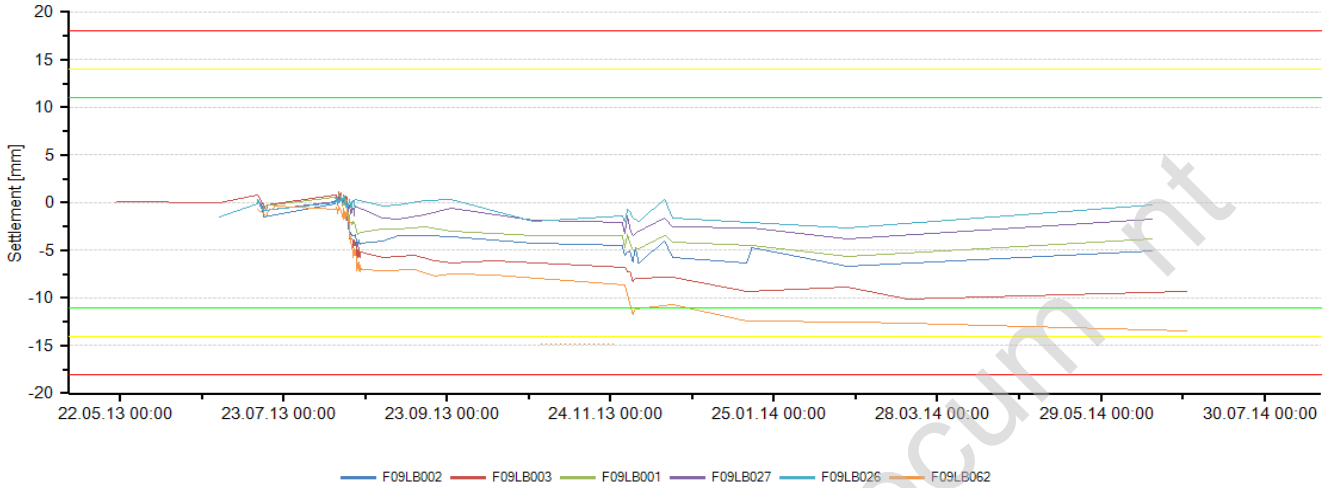


Figure 27: data time-plots - comparison against settlement triggers

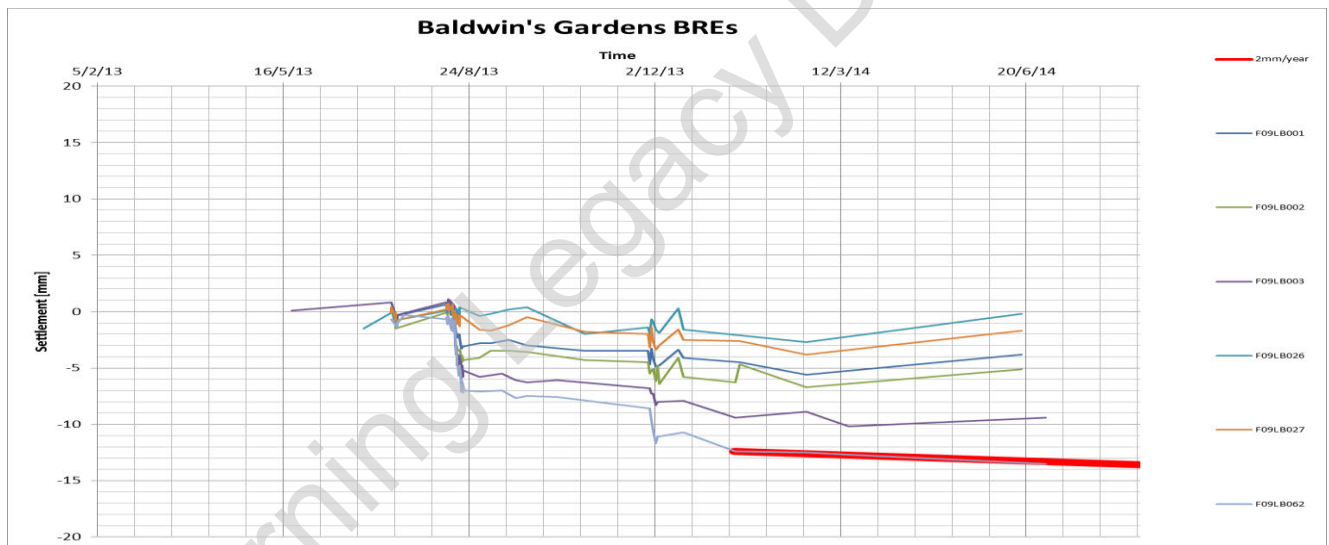


Figure 28: data time-plots - comparison against 2mm/year settlement rate (long-term)

Table 8: Achieved Triggers – settlements, deflections, slopes

Point Code	Point type	Achieved Trigger
F09LB062	BRE	Green
Worst case slope ratio [1/-]		Trigger
2,400		no

**2.8.2. Comments**

The points in Baldwin’s Gardens settled up to approx. 14mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have been breached as per Table 8.

The time-plots are generally showing stabilising settlement trend, and the long term behaviour appears to be less than 2mm/year.

## 2.9. Brooke's Court

### 2.9.1. Data



Figure 29: location

PLP Brooks Court

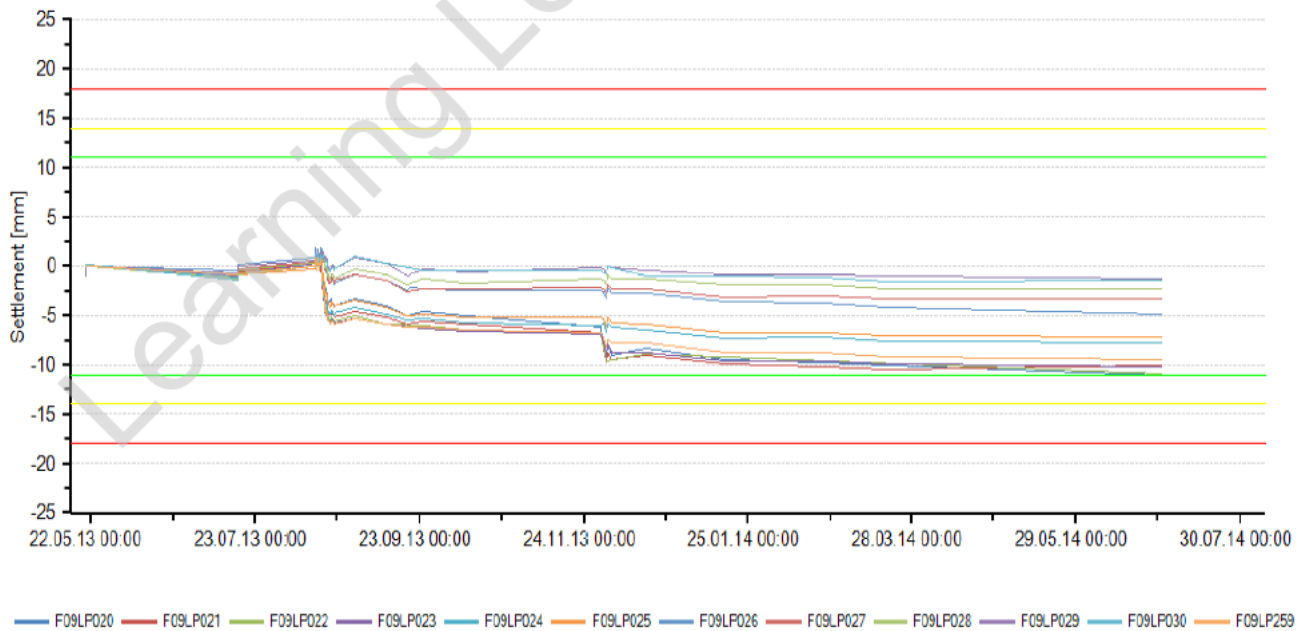


Figure 30: data time-plots - comparison against settlement triggers

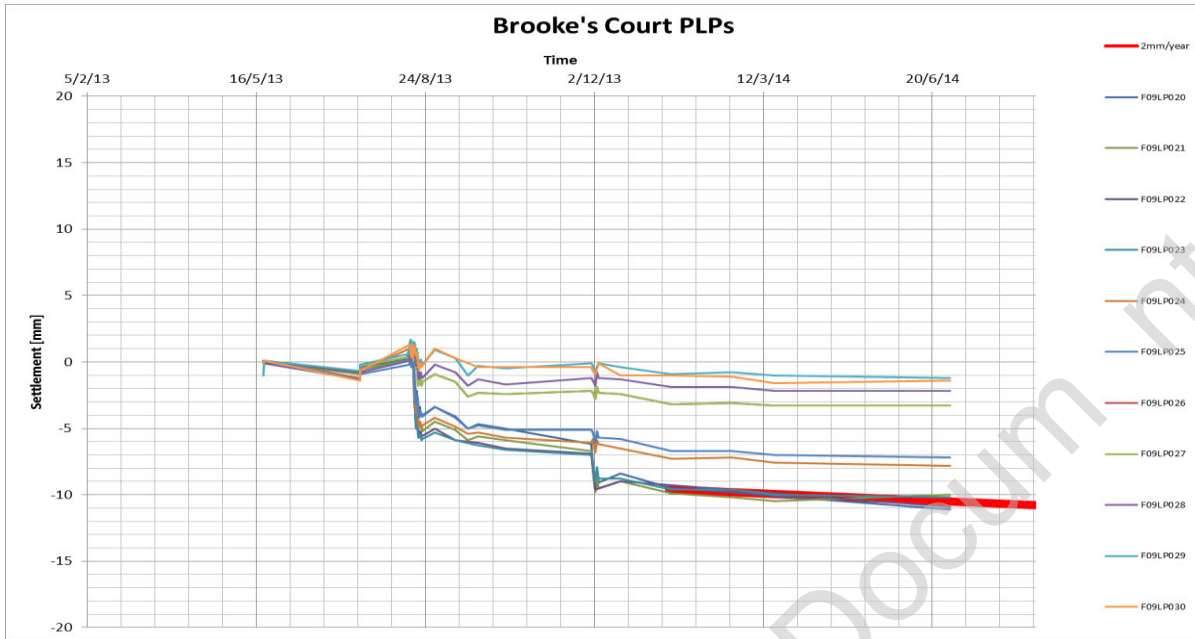


Figure 31: data time-plots - comparison against 2mm/year settlement rate (long-term)

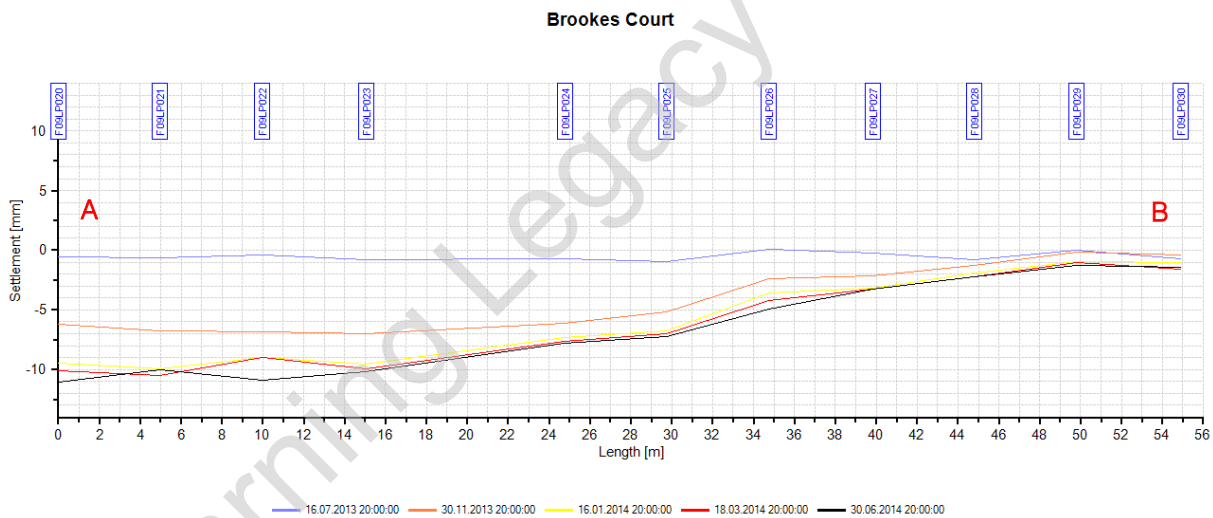


Figure 32: cut

Table 9: Achieved Triggers – settlements, deflections, slopes

Point Code	Point type	Achieved Trigger
F09LP020	PLP	Green

### 2.9.2. Comments

The points in Baldwin’s Gardens settled up to approx. 11mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have been breached as per Table 9.

The time-plots are generally showing stabilising settlement trend, and the long term behaviour appears to be approximately 2mm/year.

## 2.10. St. Alban's Church BREs

### 2.10.1. Data



Figure 33: location

### BRE St. Albans Church

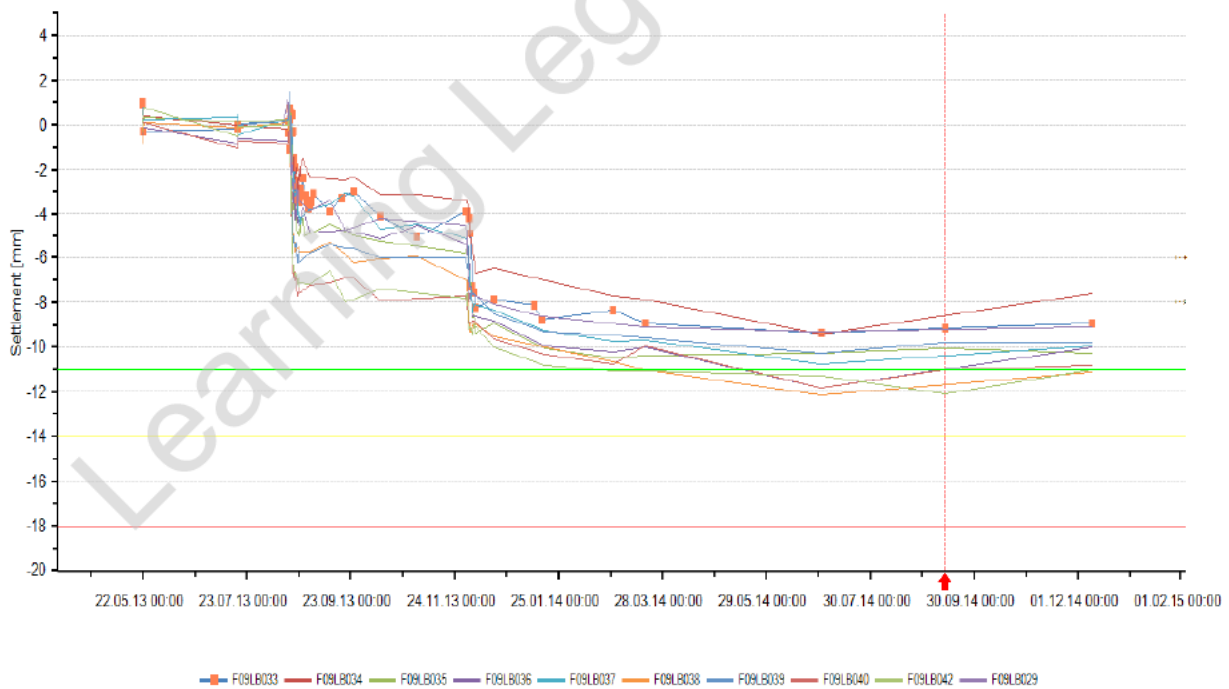


Figure 34: data time-plots - comparison against settlement triggers

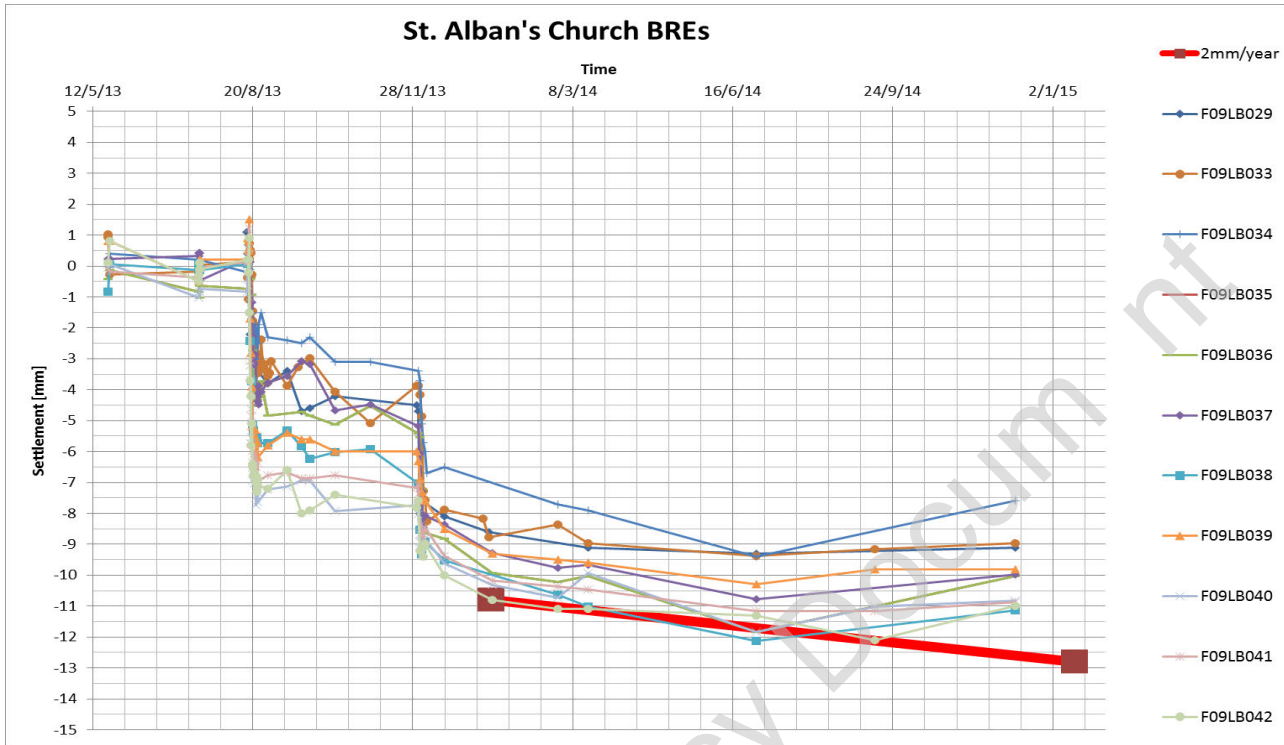


Figure 35: data time-plots - comparison against 2mm/year settlement rate (ong-term)

Table 10: Achieved Triggers – settlements, deflections, slopes

Point Code	Point type	Achieved Trigger
F09LB038	BRE	Green
F09LB042	BRE	Green

### 2.10.2. Comments

The points in St. Alban's Church settled up to approx. 12mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have been breached as per Table 10.

The time-plots are generally showing a settlement trend of less than 2mm/year.

## 2.11. Brooke Street & Dorrington Street

### 2.11.1. Data

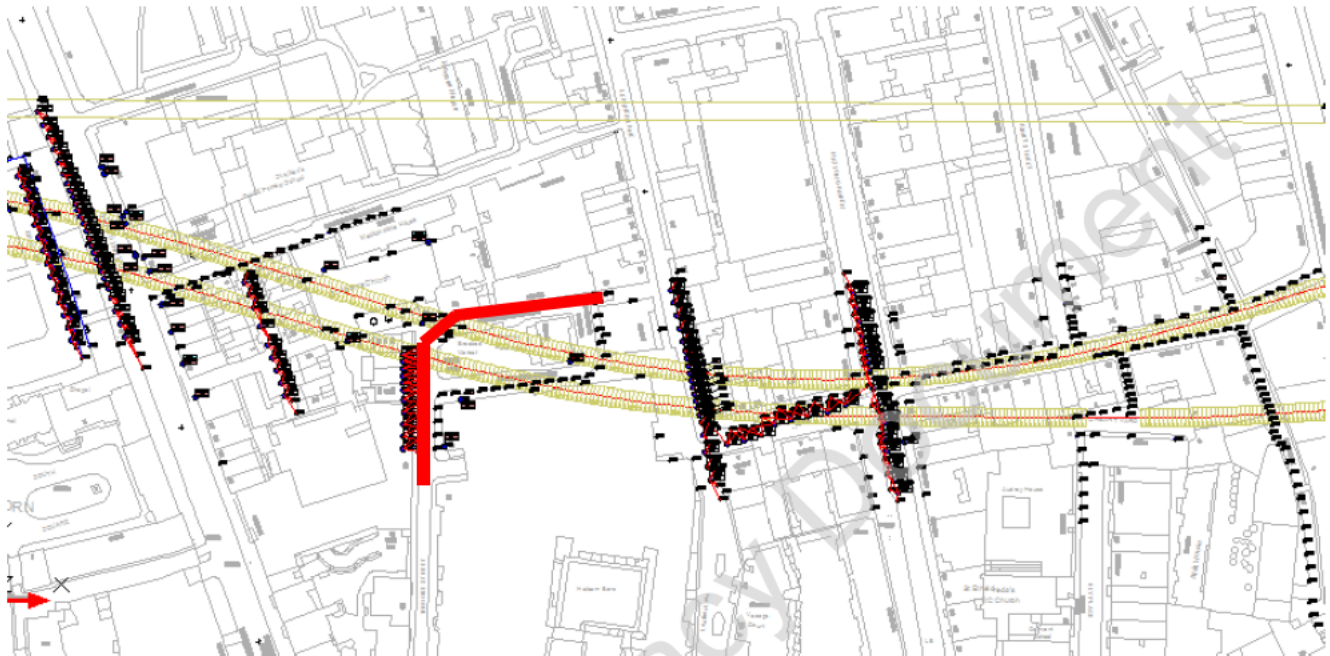


Figure 36: location

### PLP Brookes Market West

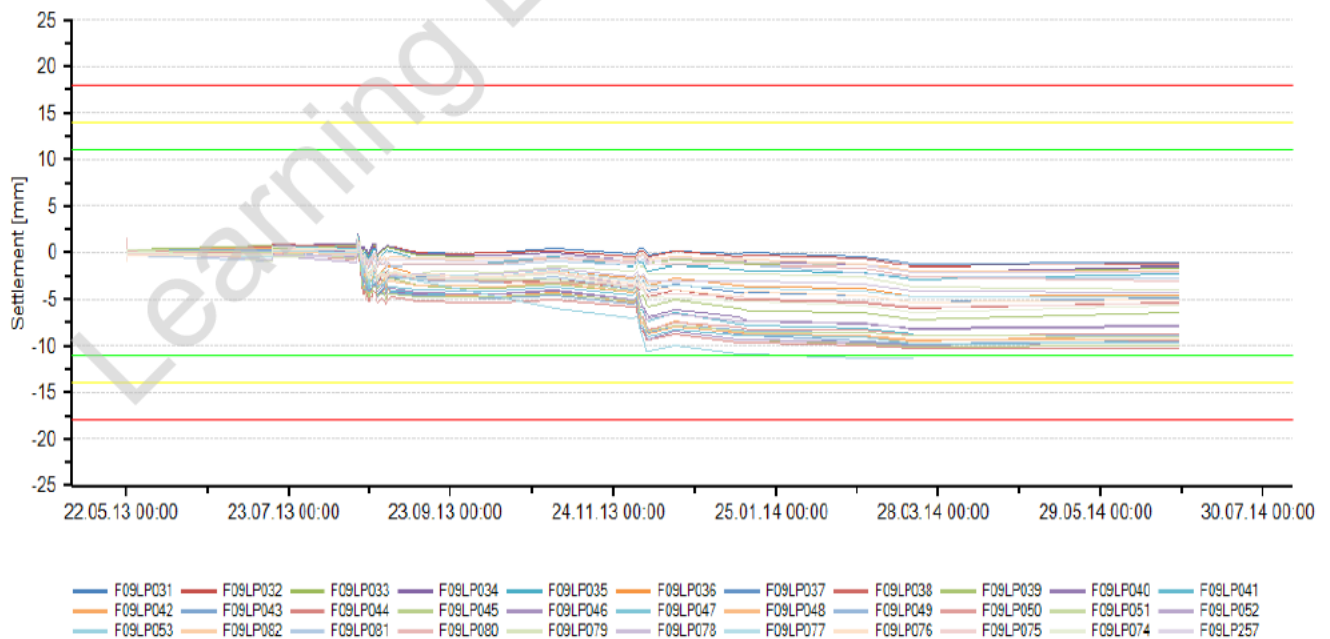


Figure 37: data time-plots - comparison against settlement triggers

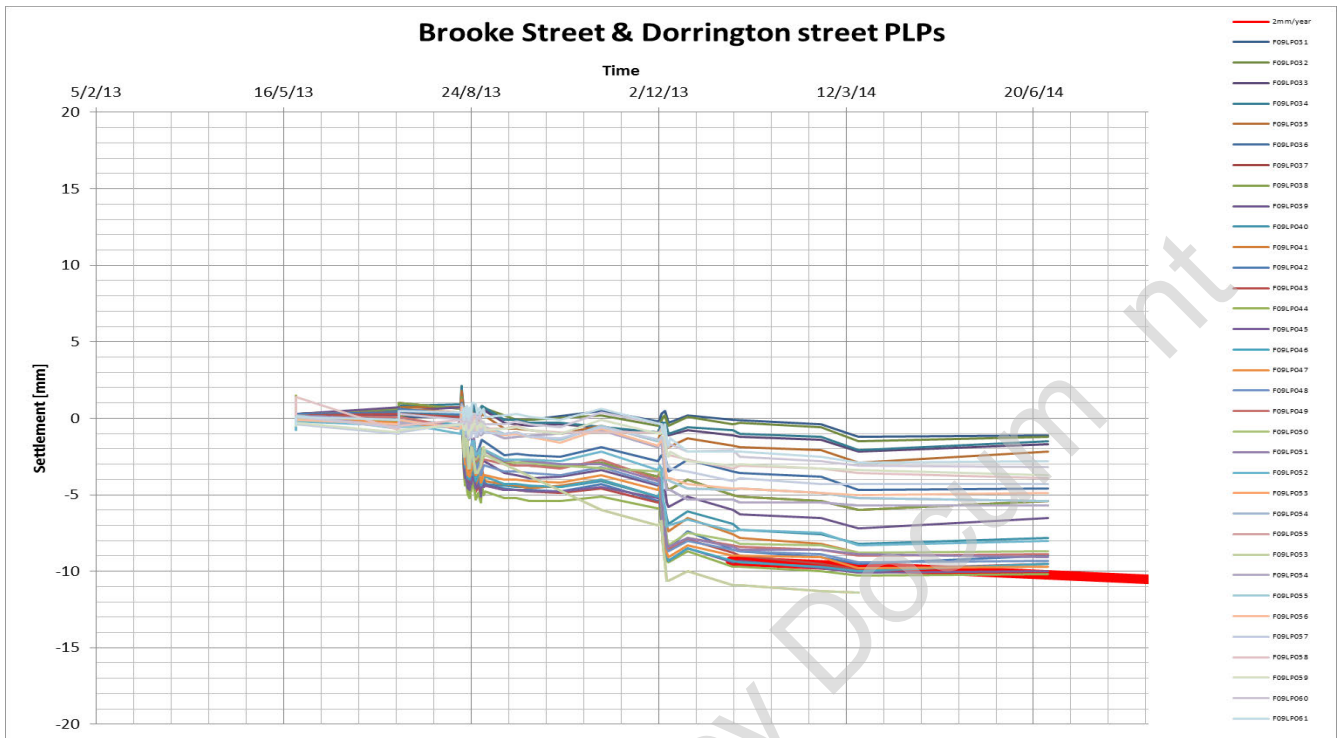


Figure 38: data time-plots - comparison against 2mm/year settlement rate (long-term)

Table 11: Achieved Triggers – settlement

Point Code	Point type	Achieved Trigger
F09 P053	PLP	Green

### 2.11.2. Comments

The points in Brooke Street & Dorrington Street settled up to approx. 12mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have been breached as per Table 11.

The time plots are generally showing a settlement trend of less than 2mm/year.



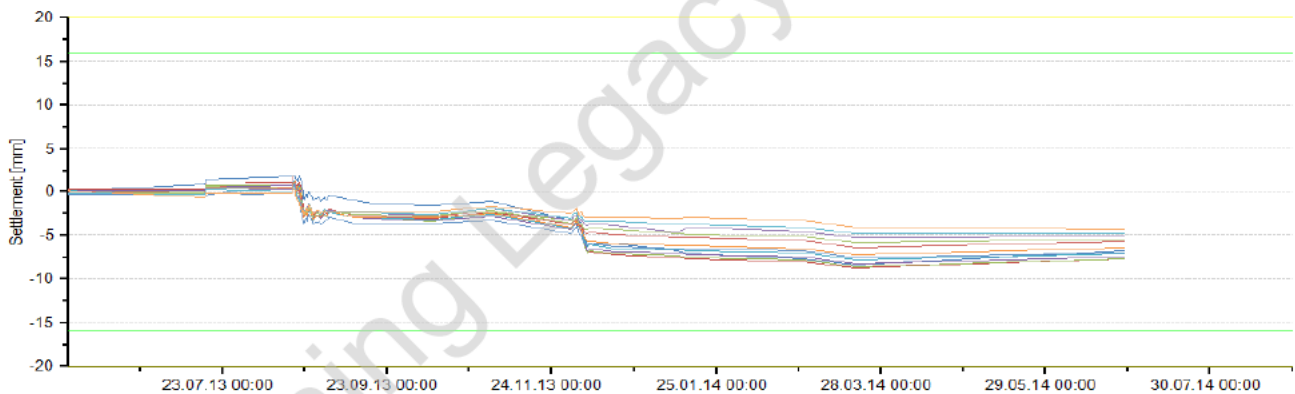
## 2.12. Beauchamp Street & Brooke's Market

### 2.12.1. Data



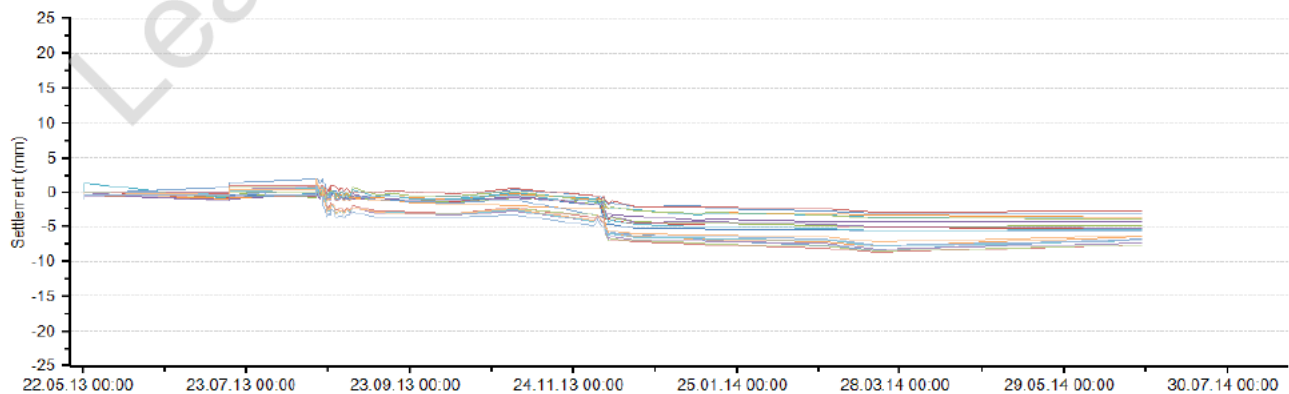
Figure 39: location

#### PLPs Brookes Market South/Beauchamp Street



F09LP067 F09LP068 F09LP069 F09LP070 F09LP071 F09LP072 F09LP073 F09LP074 F09LP075 F09LP076 F09LP077 F09LP078

#### PLPs - Brookes Market West



F09LP054 F09LP055 F09LP056 F09LP057 F09LP058 F09LP059 F09LP060 F09LP061 F09LP062 F09LP063  
F09LP064 F09LP066 F09LP067 F09LP068 F09LP069 F09LP070 F09LP071 F09LP072 F09LP073

Figure 40a,b: data time-plots - comparison against settlement triggers

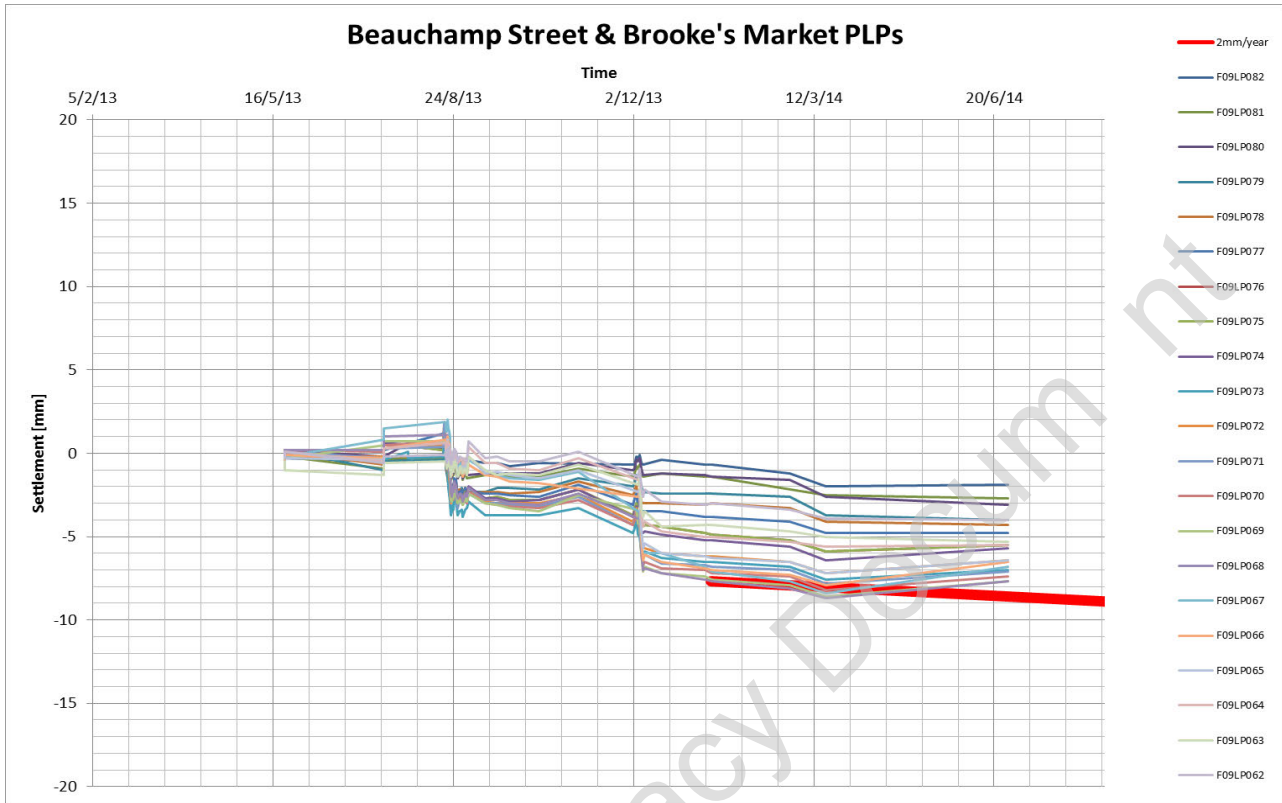


Figure 41: data time-plots - comparison against 2mm/year settlement rate (long-term)

### 2.12.2. Comments

The points in Beauchamp Street and Brooke's Market settled up to approx. 8mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have not been breached.

The long-term settlement trends are less than 2mm/year.

## 2.13. Leather Lane

### 2.13.1. Data



Figure 42: location

### PLP Leather Lane

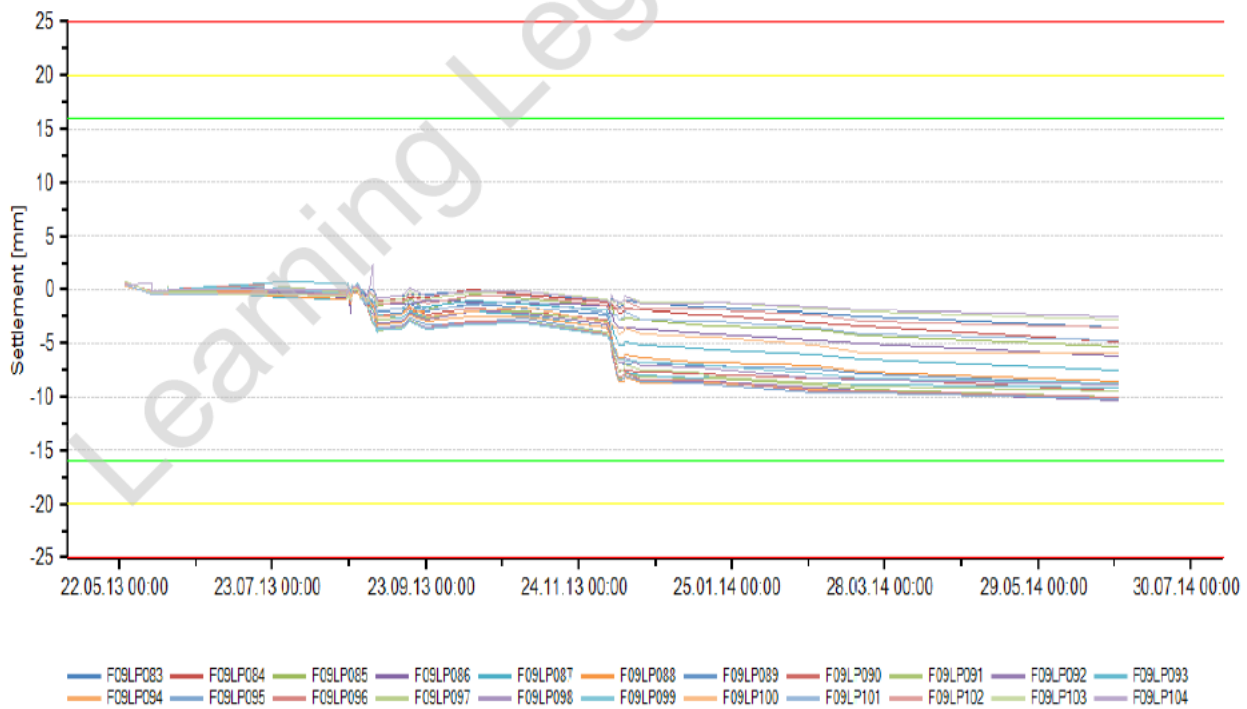


Figure 43: data time-plots - comparison against settlement triggers

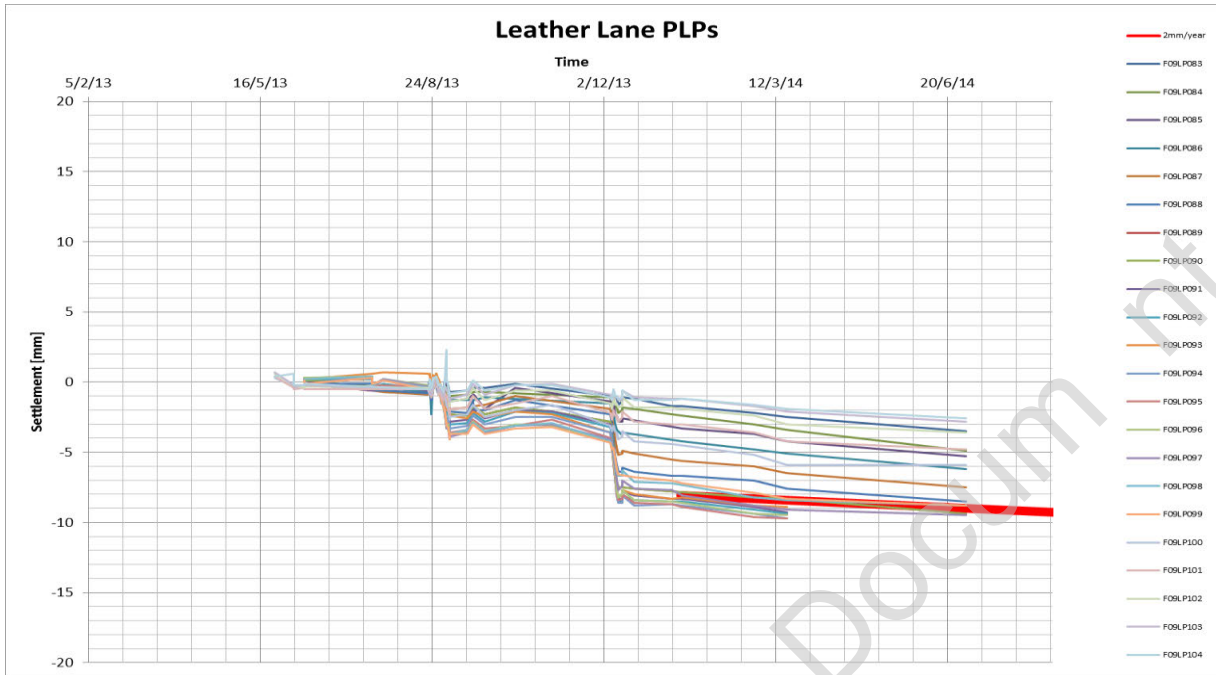


Figure 44: data time-plots - comparison against 2mm/year settlement rate (long-term)

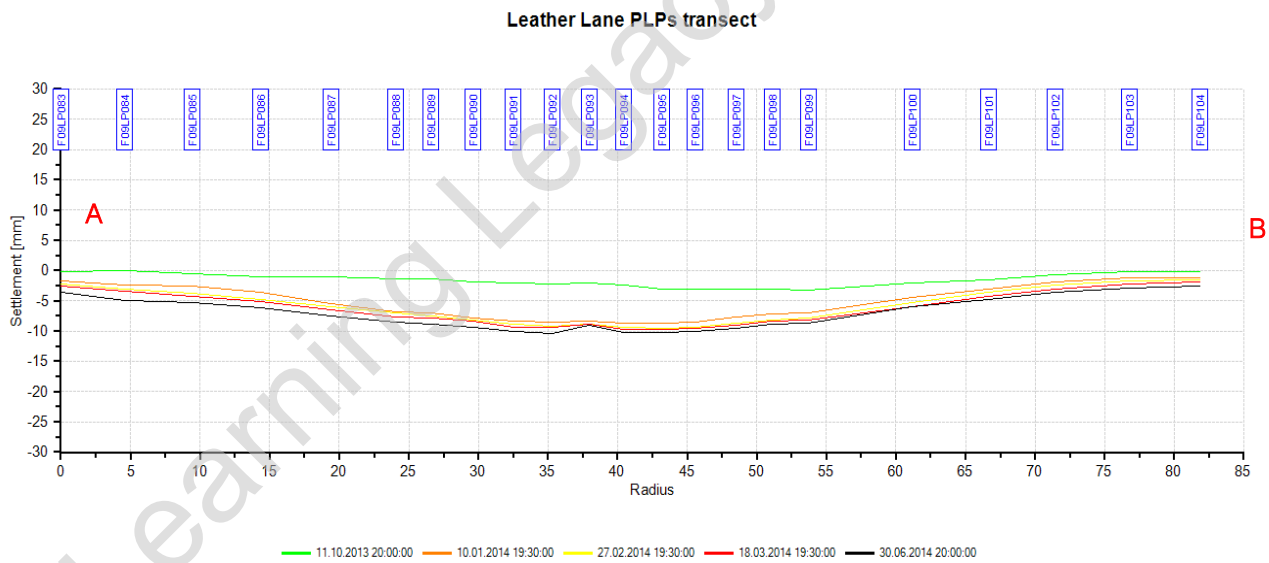


Figure 45: cut

**2.13.2. Comment**

The points in Leather Lane settled up to approx. 8mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have not been breached.

The long-term settlement trends are about 2mm/year.

## 2.14. Greville Street

### 2.14.1. Data



Figure 46: location

### PLP Greville Street East

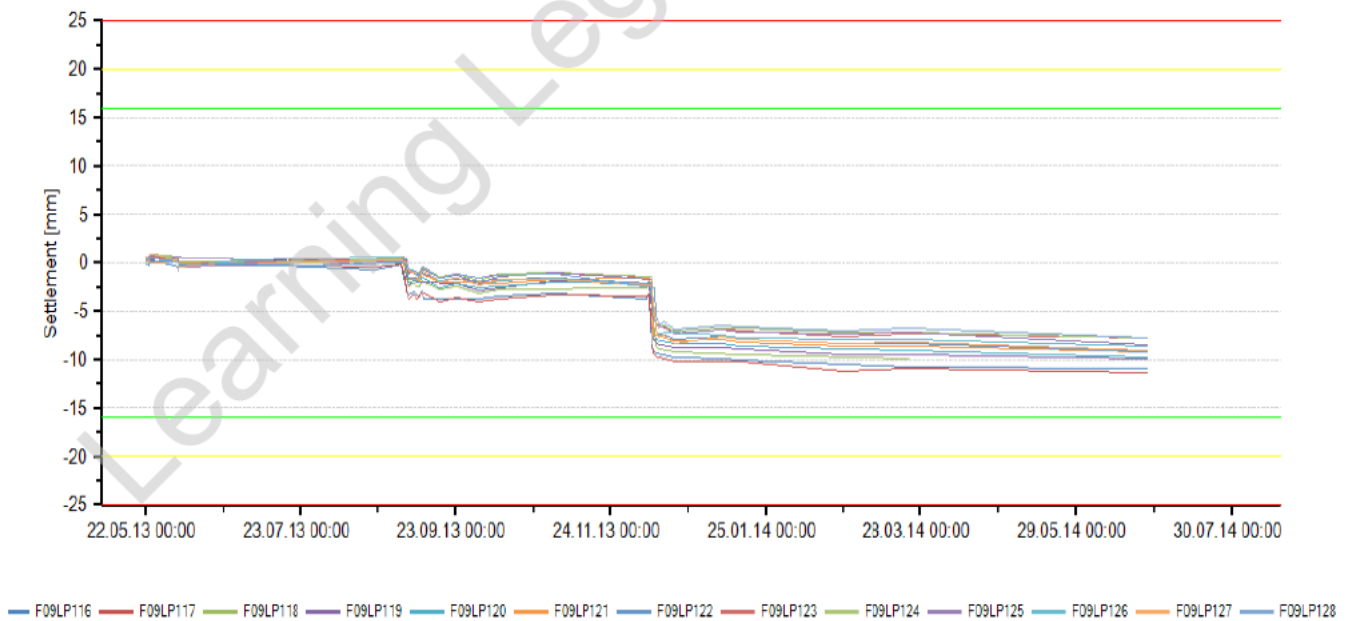


Figure 47: data time-plots - comparison against settlement triggers

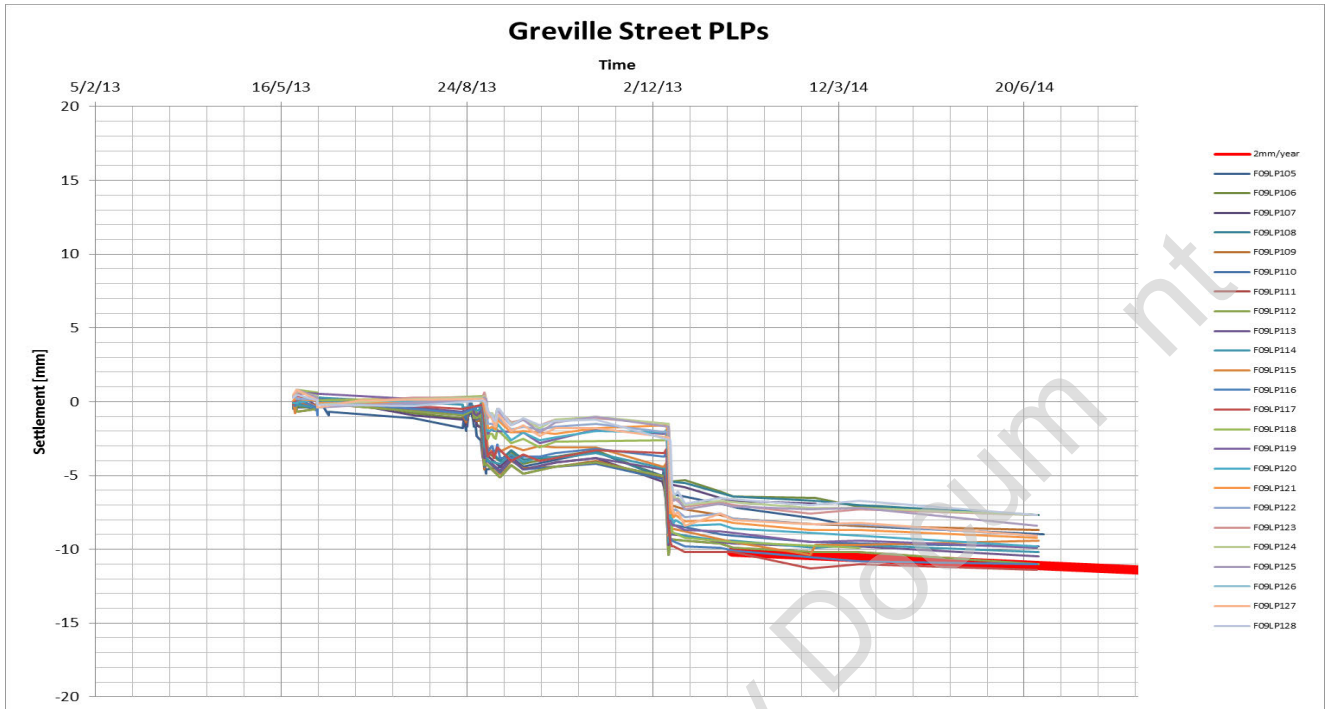


Figure 48: data time-plots - comparison against 2mm/year settlement rate (long-term)

**2.14.2. Comments**

The points in Greville Street settled up to approx. 12mm due to the C300 running tunnels excavation. The effect of the WB and EB BMs is visible from the settlement time-plots. Settlement triggers have not been breached.

The long-term settlement trends are about 2mm/year.

## 2.15. Hatton Garden PLPs and BRES

### 2.15.1. Data



Figure 49: location

#### PLP Hatton Gardens

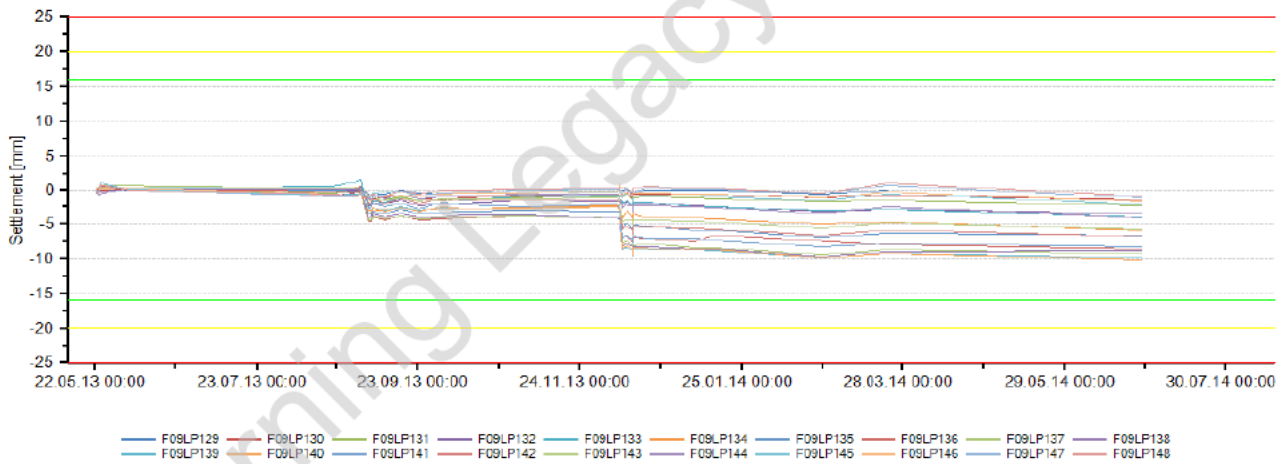


Figure 50: data time plots comparison against settlement triggers

#### PLP Hatton Gardens

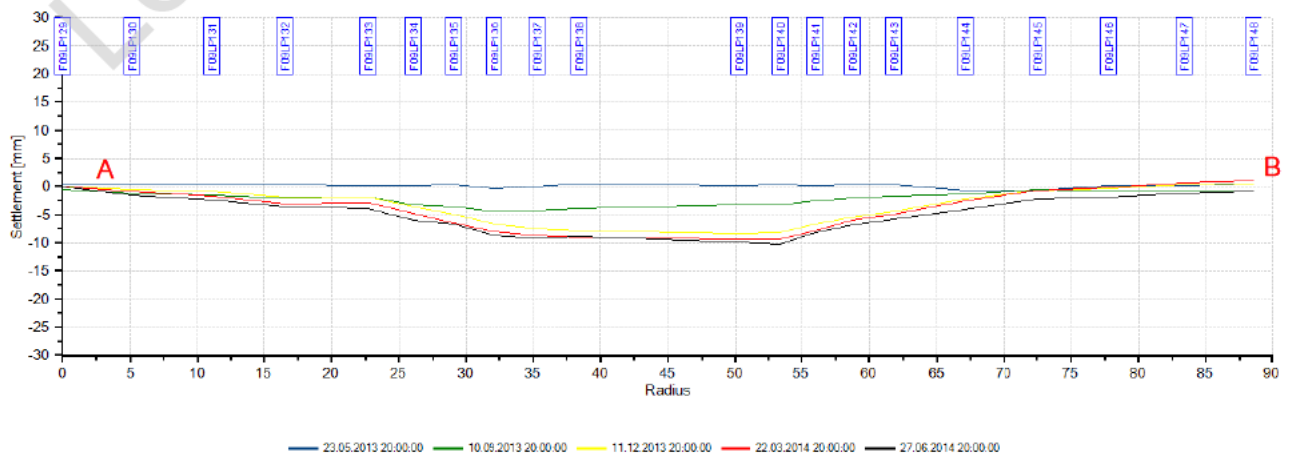


Figure 51: cut

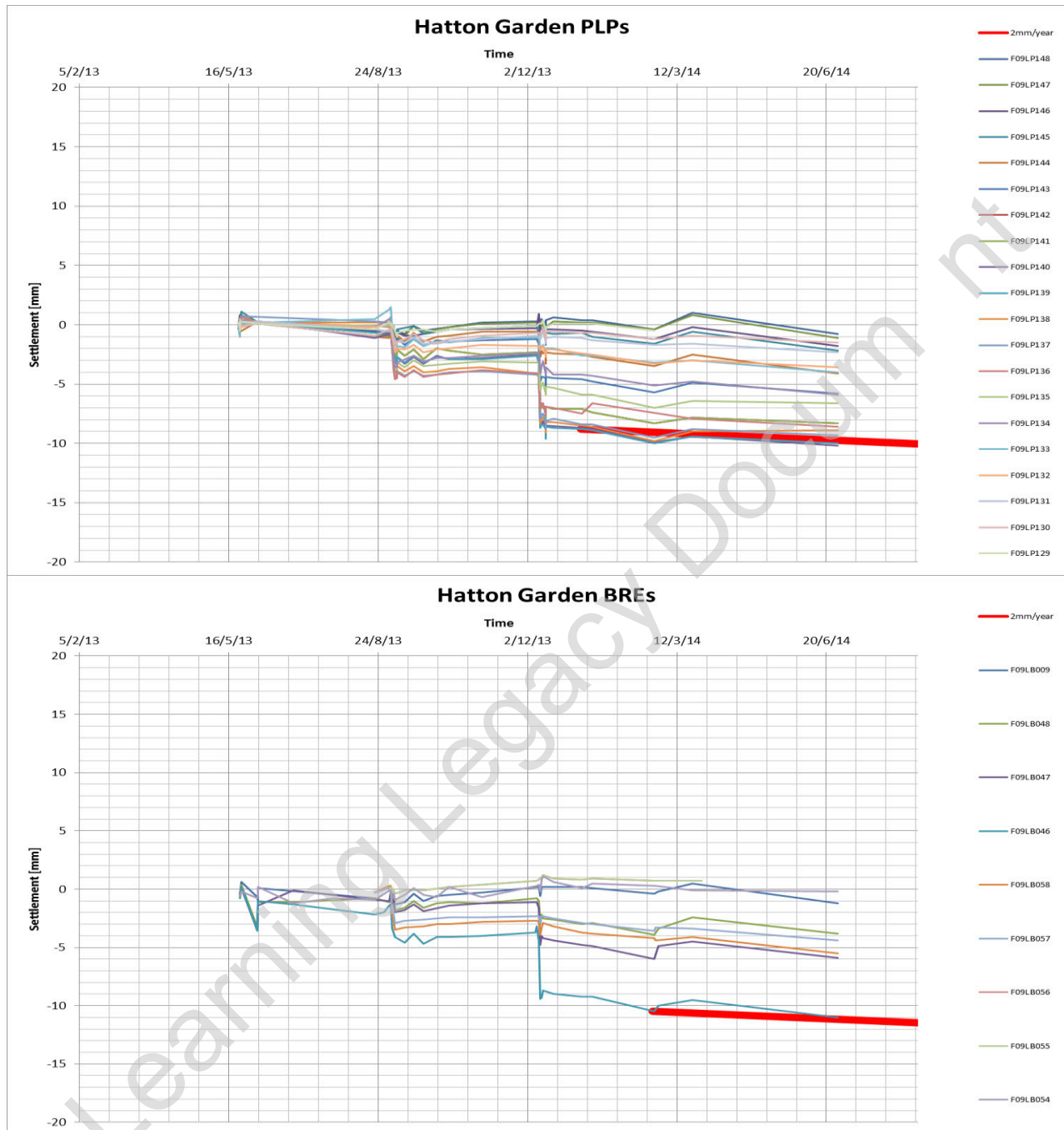


Figure 52a,b data time-plots - comparison against 2mm/year settlement rate (long-term)

**2.15.2. Comments**

The points in Hatton Garden settled up to approx. 11mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have not been breached.

The long-term settlement trends are about or below 2mm/year.



## 2.16. Kirby Street and Bleeding Heart Yard

### 2.16.1. Data



Figure 53: location

### PLP Bleeding Heart Yard & Kirby Street

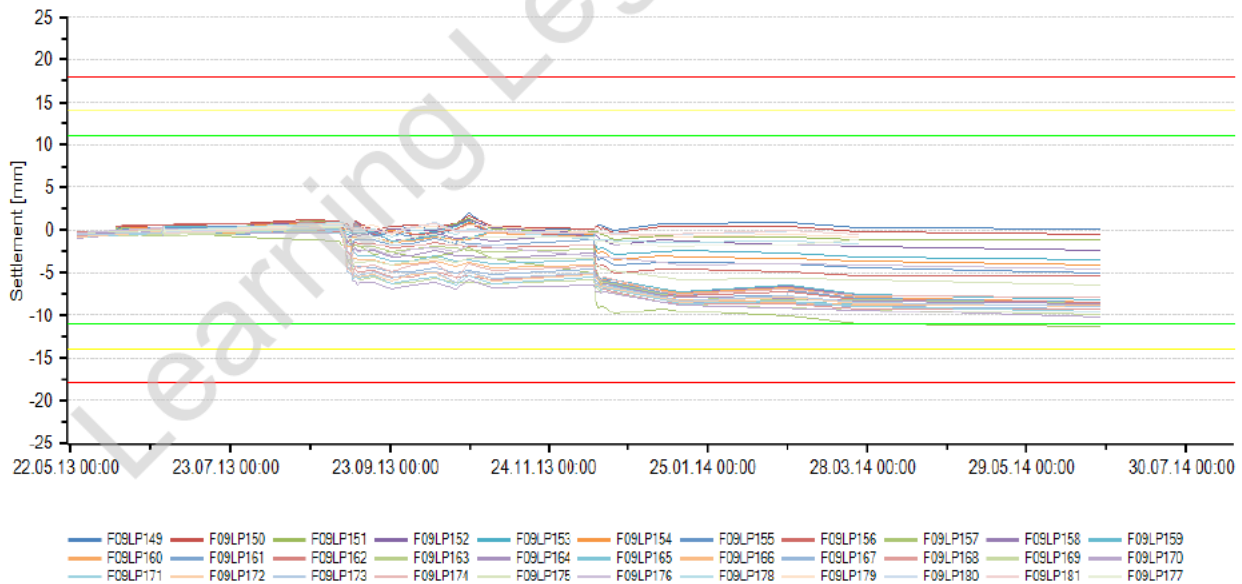


Figure 54: data time-plots - comparison against settlement triggers

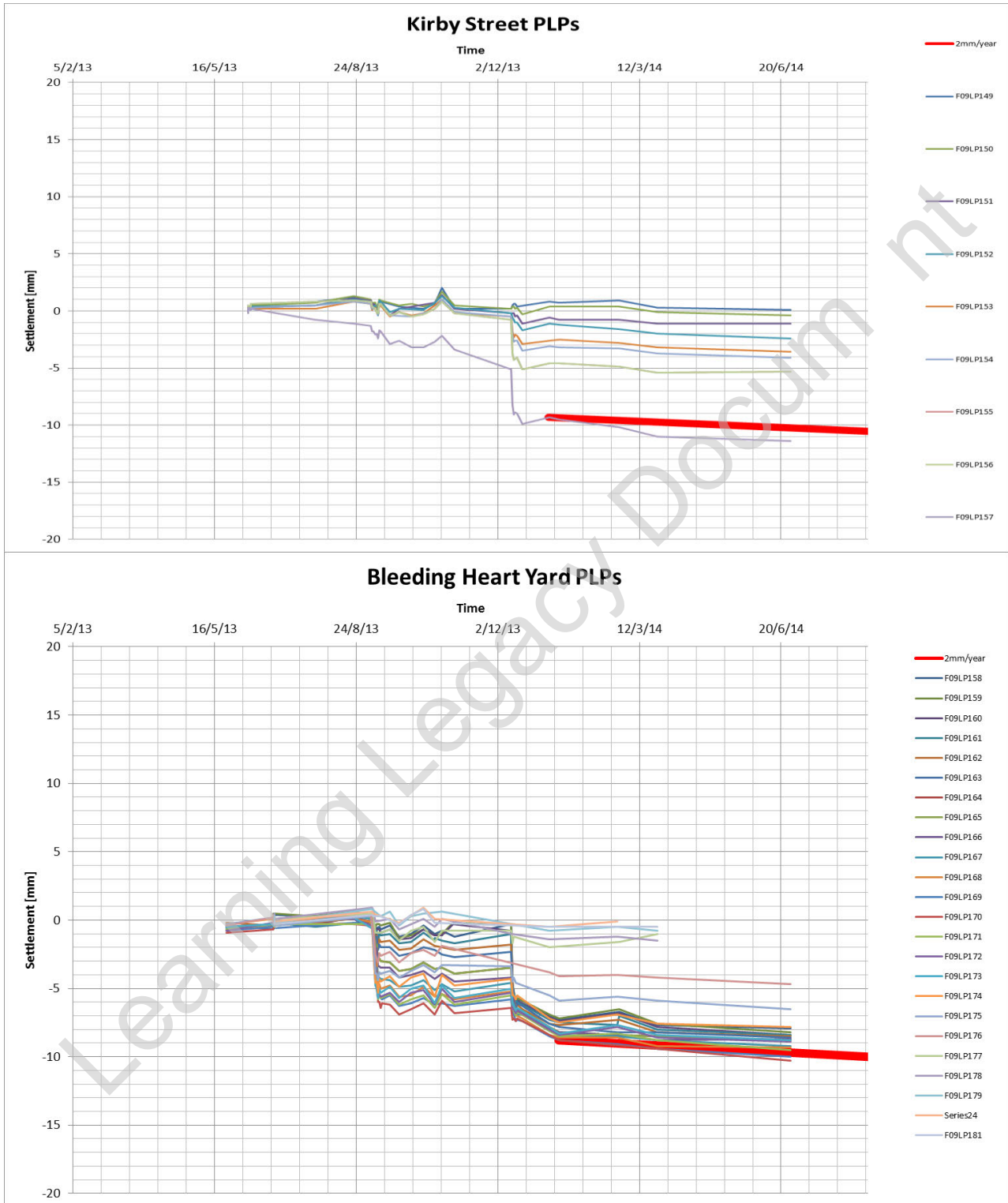


Figure 55a,b: data time-plots - comparison against 2mm/year settlement rate (long-term)



Figure 56: Kirby St. cut

Table 12: Achieved Triggers – settlements, deflections, slopes

Point Code	Point type	Achieved Trigger
F09LP157	PLP	Green

### 2.16.2. Comments

The points in Kirby Street and Bleeding Heart Yard settled up to approx. 12mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have been breached as per Table 12: it is noted that the behaviour of this point diverged from adjacent points both before and between the TBM drives and it is considered that this is probably due to external factors.

Some of the long-term settlement trends are slightly over 2mm/year.

## 2.17. Saffron Hill

### 2.17.1. Data

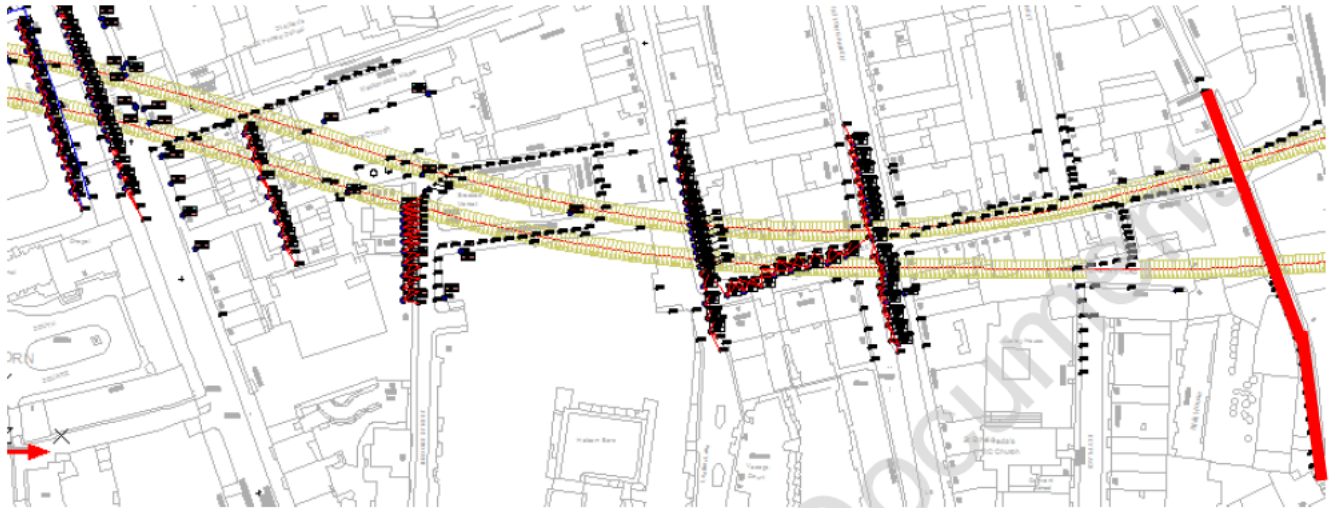
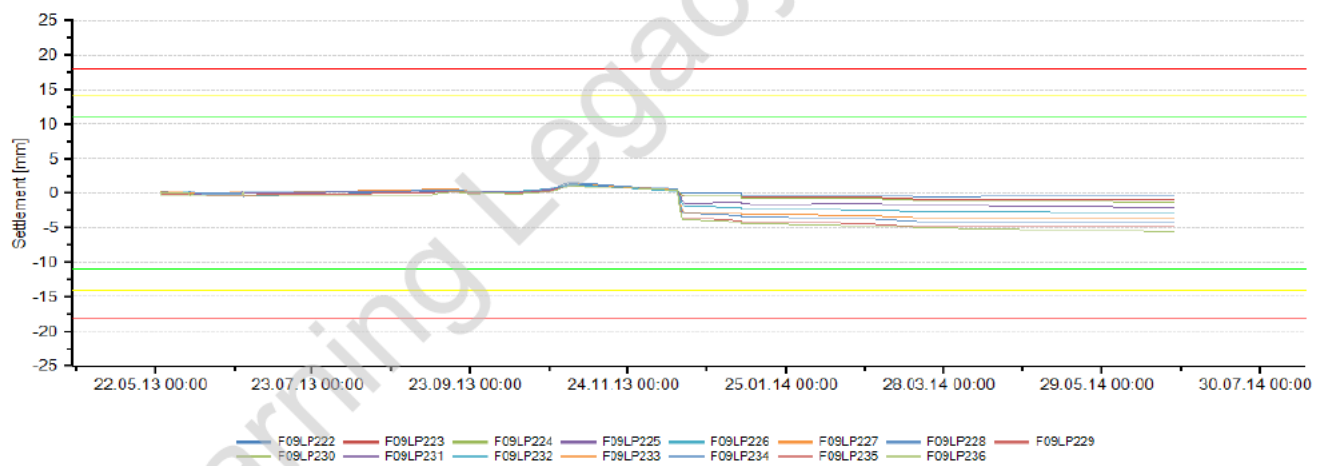


Figure 57: location

#### PLP Saffron Hill North



#### PLP Saffron Hill

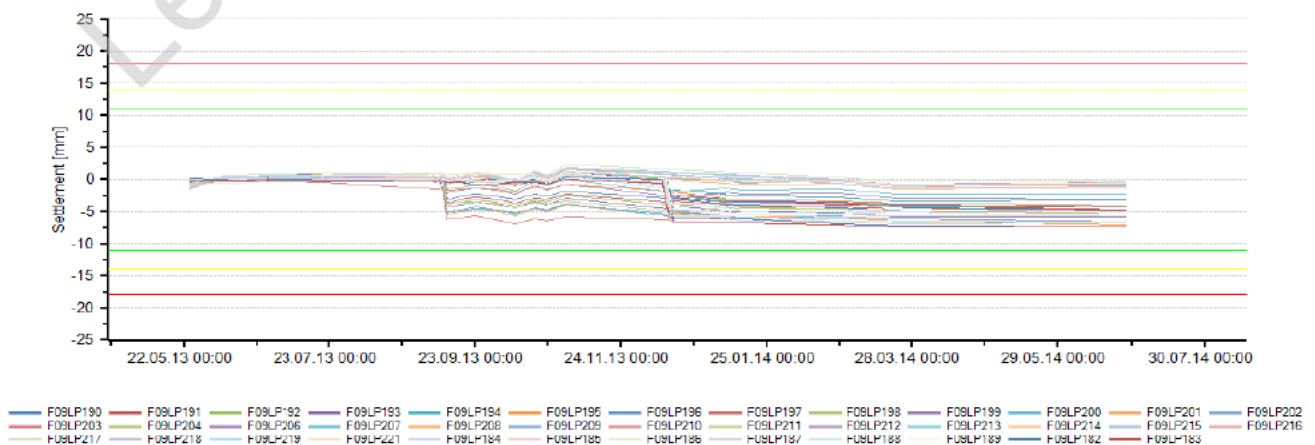


Figure 58a,b: data time-plots - comparison against settlement triggers

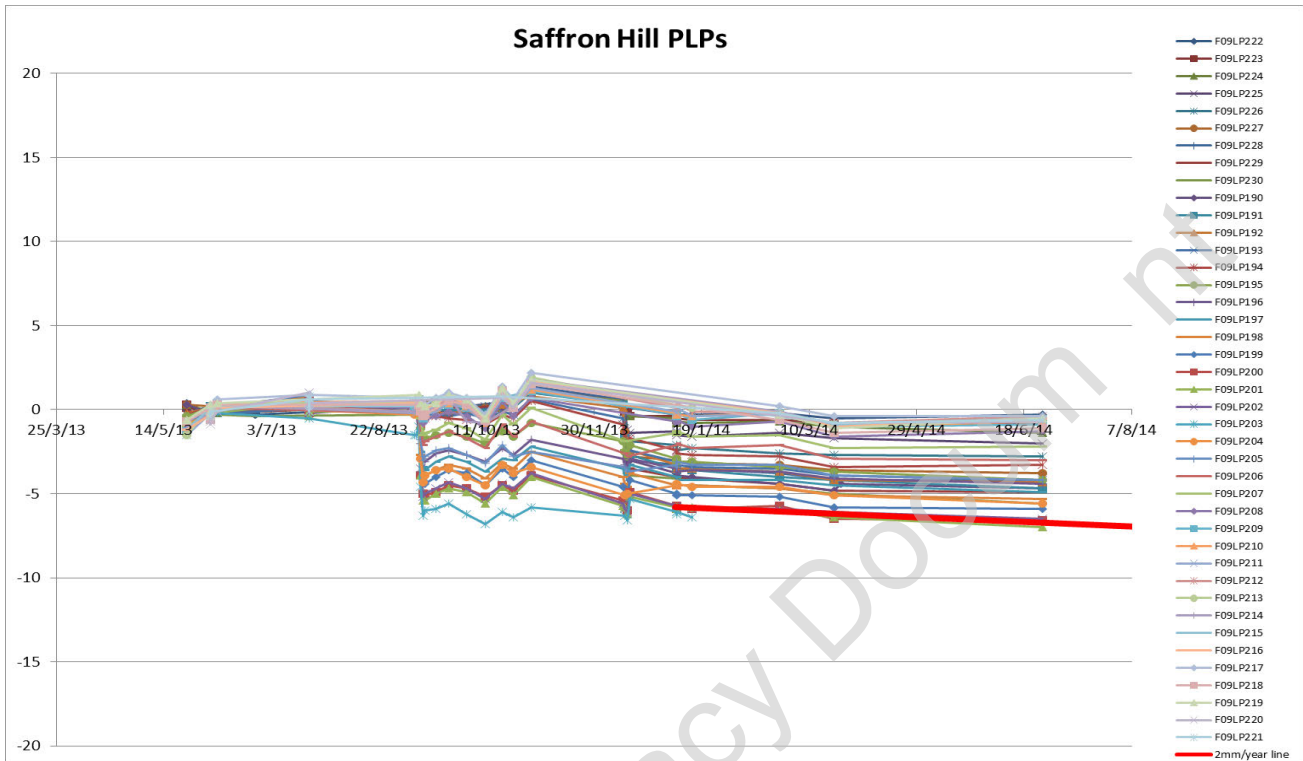


Figure 59: data time-plots - comparison against 2mm/year settlement rate (long-term)

### 2.17.2. Comments

The points in Saffron Hill settled up to approx. 7mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have not been breached.

Long-term settlement trends are about 2mm/year.

## 2.18. Post Office Tunnel

### 2.18.1. Data



Figure 60: location

#### Hydrostatic Levelling Cells - PO Tunnel Saffron Hill

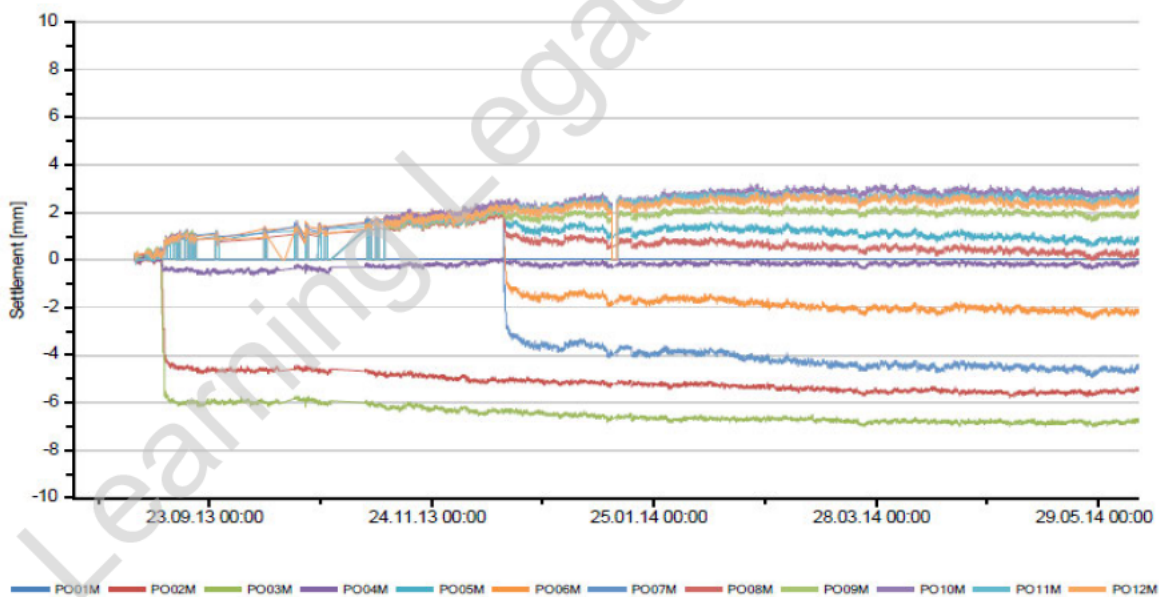


Figure 61: data time-plots - comparison against 2mm/year settlement rate (long-term)

### 2.18.2. Comments

The HLCs within Post Office Tunnel settled up to approx. 7mm due to the C300 running tunnels excavation. The effect of the WB and EB TBMs is visible from the settlement time-plots. Settlement triggers have not been breached.

During the passage of the WB TBM (September 2013), some of the HLCs within the Post Office tunnel showed heave instead of settlement. This behaviour does not seem realistic and is maybe connected with some instrument issue. However, during the passage of the EB TBM (January 2014) the HLCs behaved as expected. The settlement measured values are similar to those from Saffron Hill PLPs (see Section 2.17).

Long term settlements have stabilised.

## 2.19. Cross Passage 5 (Running Tunnels)

### 2.19.1. Data

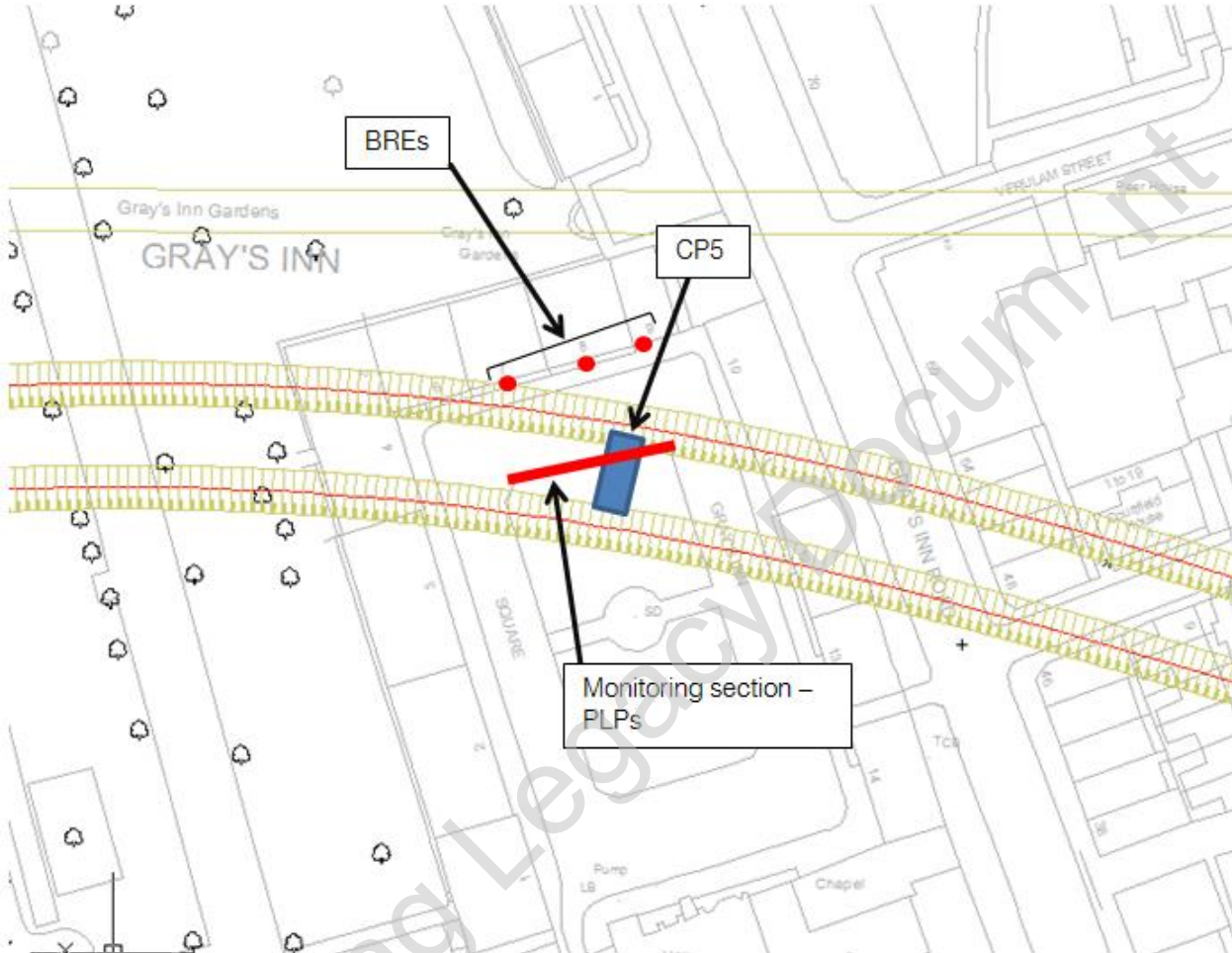


Figure 62: Location

PLP Gray's Inn Square North CP5

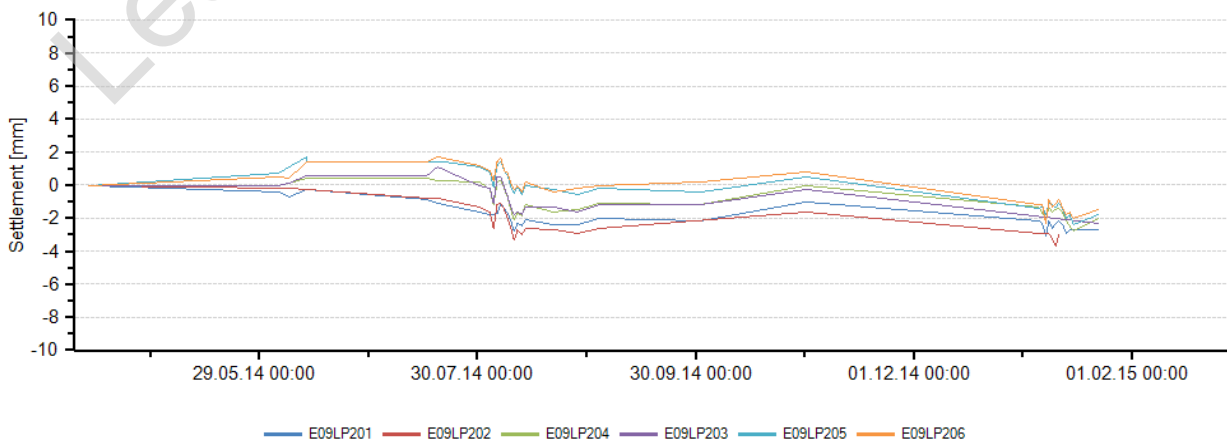


Figure 63: PLPs data time-plot

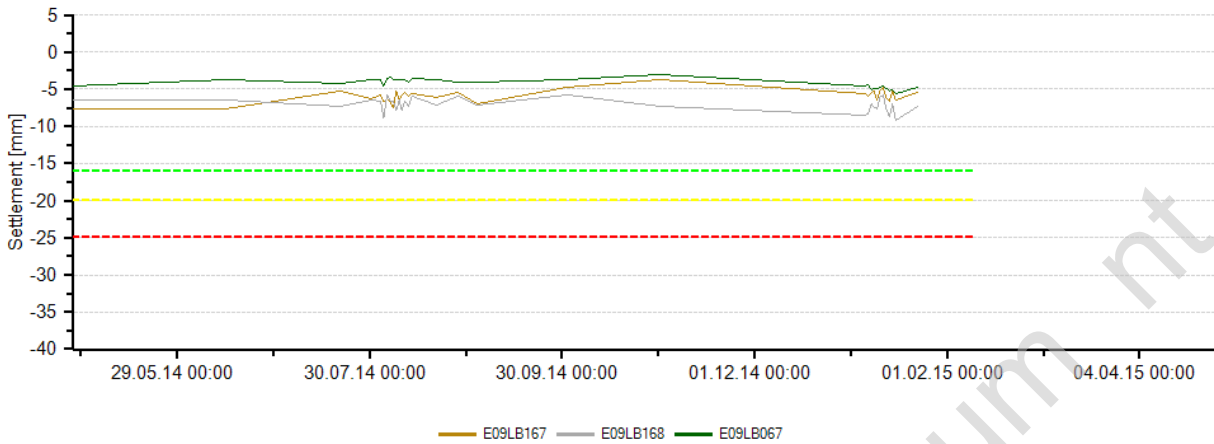


Figure 64: BREs data time plot

**2.19.2. Comments**

The PLPs in Gray's Inn Square settled up to approx. 3mm due to the CP5 excavation works (note that these points were installed after the TBMs had passed). The last readings are showing stability. The BRE data (Figure 64) and verticality checks data (Appendix 2) show little effect and are also stable.

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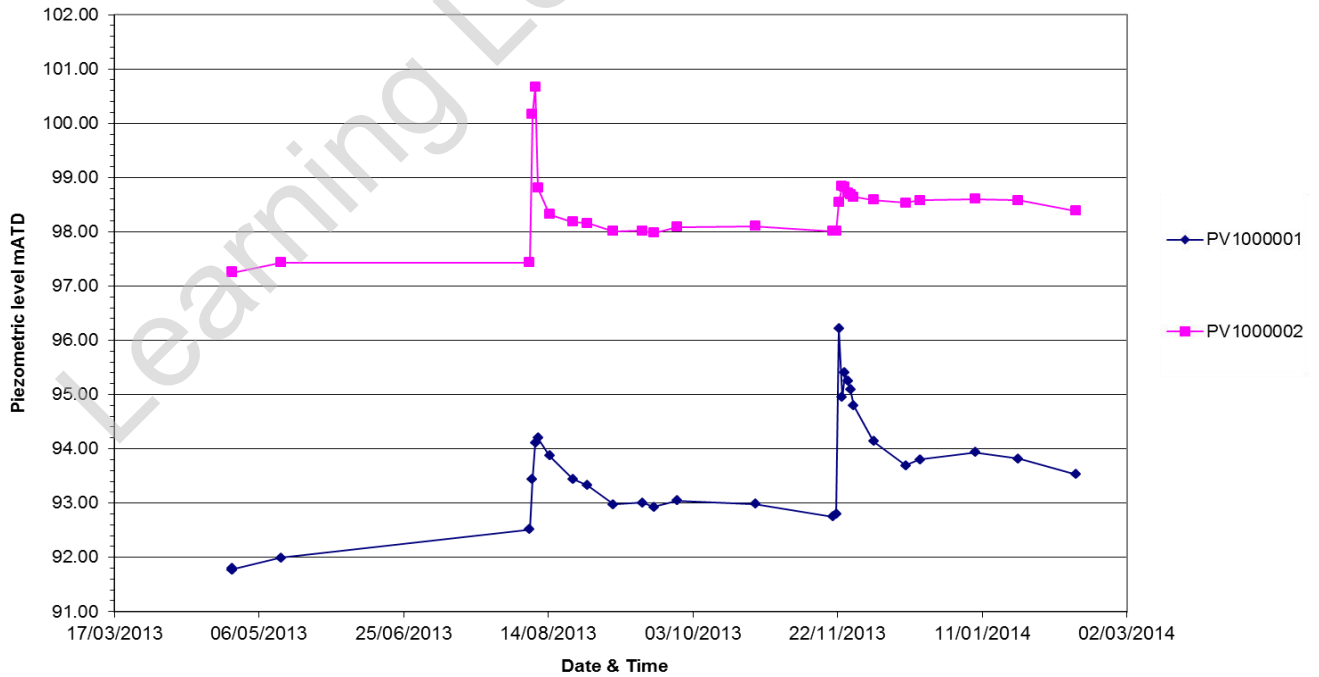


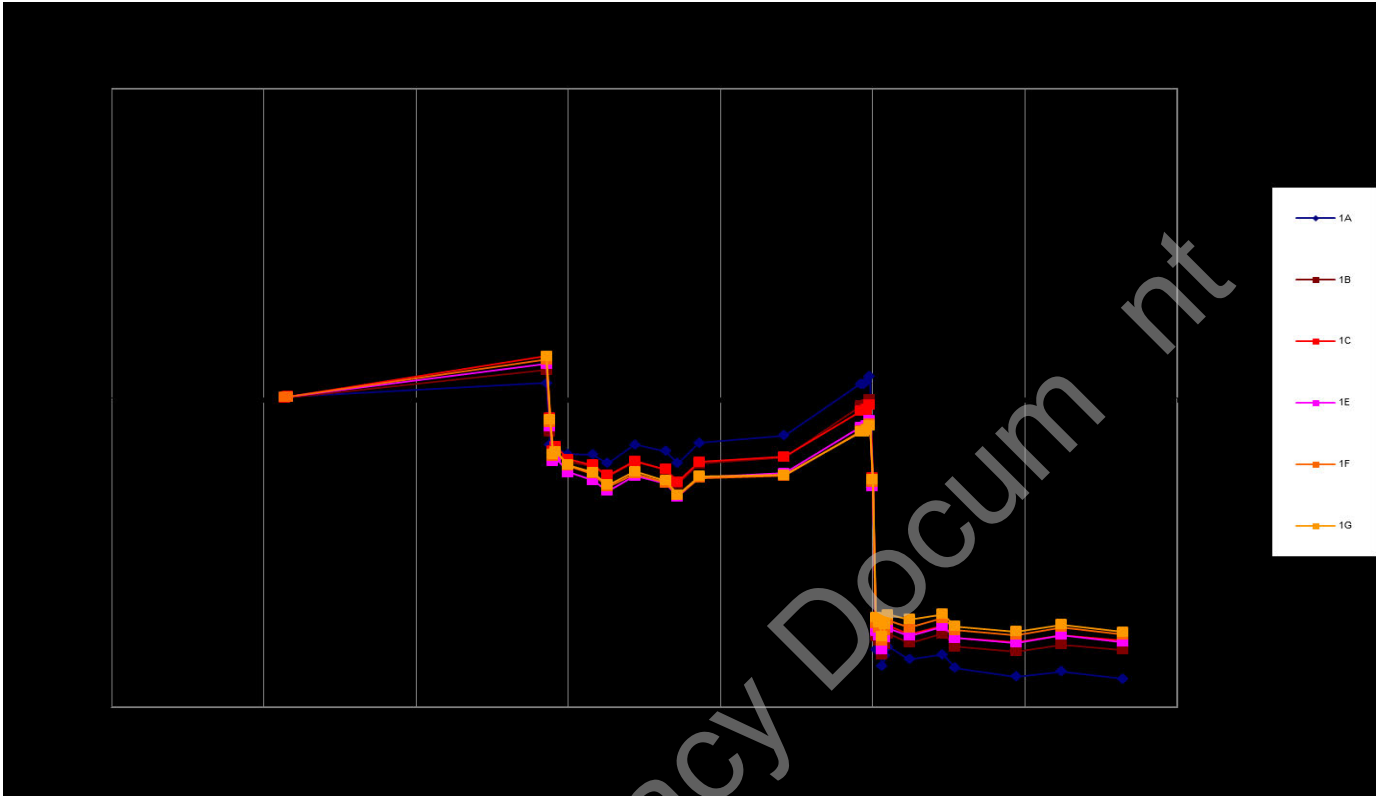
## 2.20. Deep Instruments



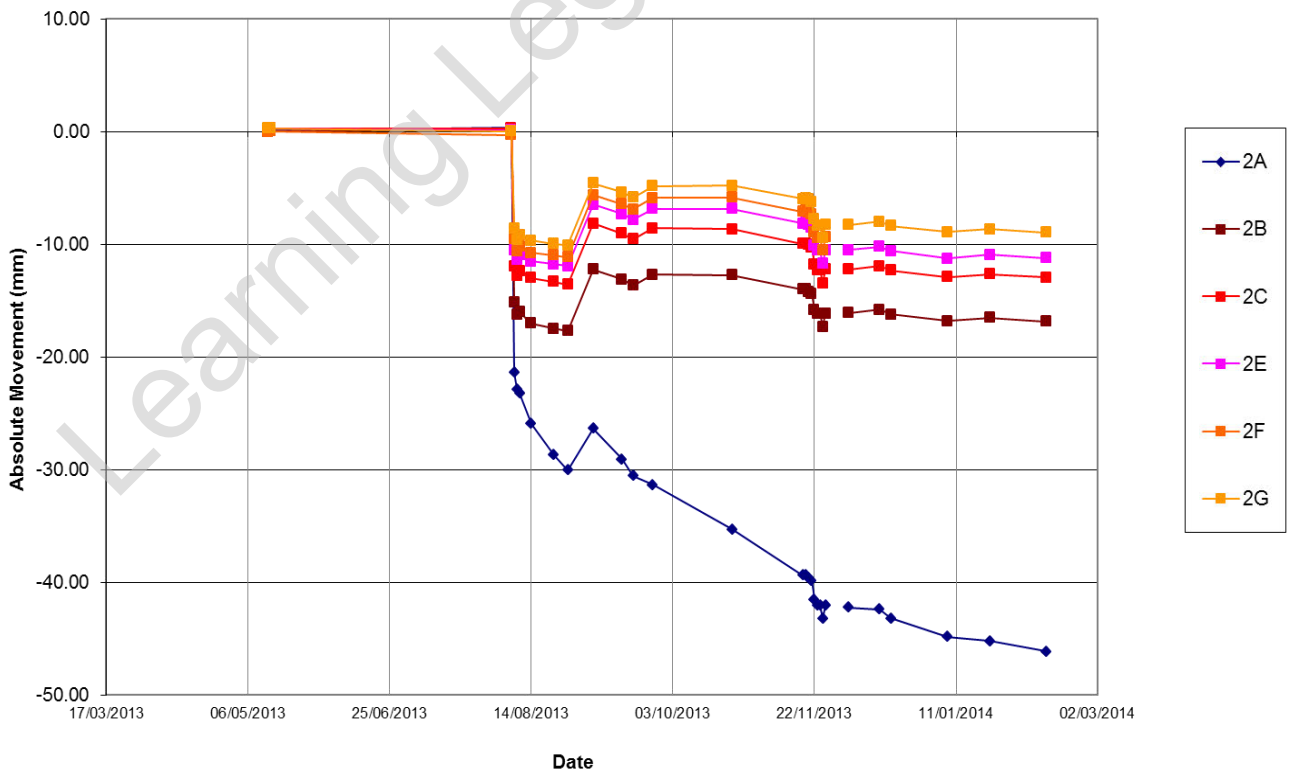
### 2.20.1. Gray's Inn Gardens

Gray's Inn, VW Piezometers, Reduced Data, (mATD)

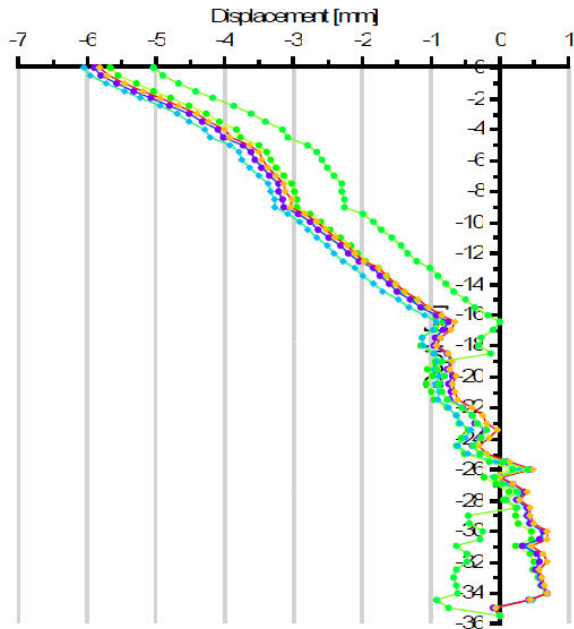




C300 Gray's Inn - Rod Extensometer XR1000010  
Absolute Movement of Targets Since Commissioning.

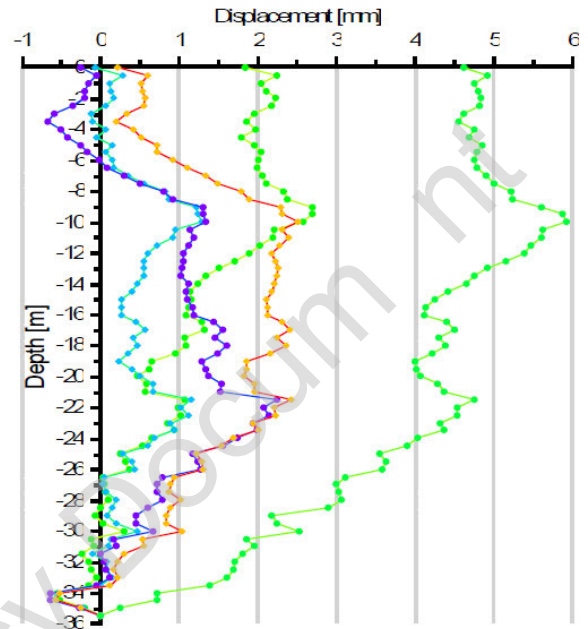


**Inclinometer: C300-IM1000010 Dir. X 100.0 Grad**



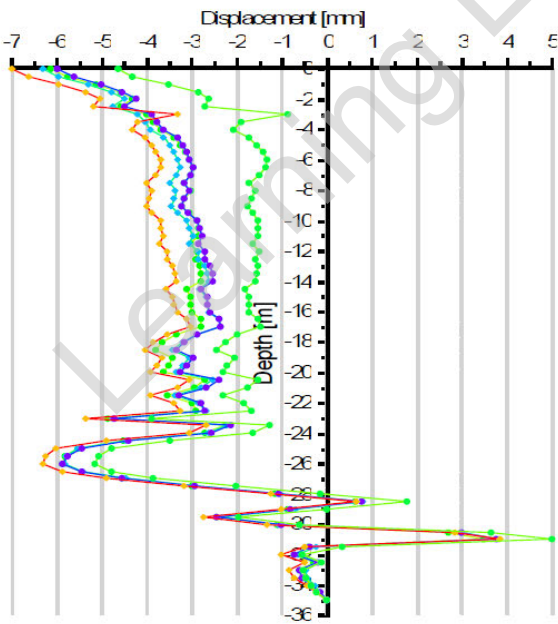
20.12.2013 14:08 08.01.2014 15:18 24.01.2014 13:43  
12.02.2014 09:47 04.06.2014 11:07

**Inclinometer: C300-IM1000010 Dir. Y 0.0 Grad**



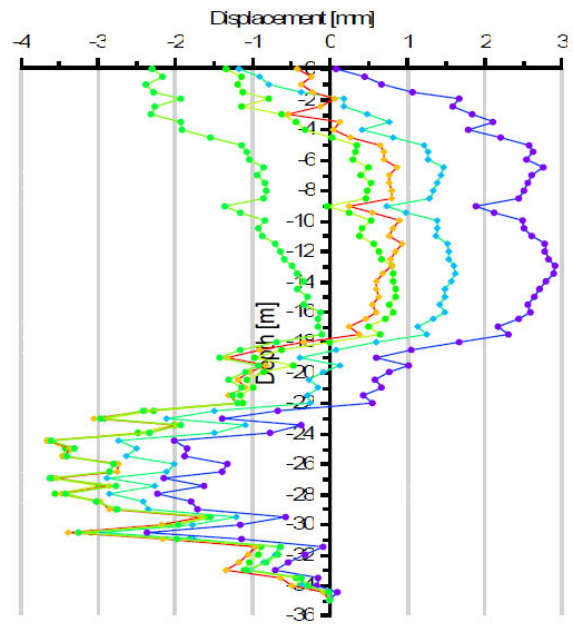
20.12.2013 14:08 08.01.2014 15:18 24.01.2014 13:43  
12.02.2014 09:47 04.06.2014 11:07

**Inclinometer: C300-IM1000011 Dir. X 100.0 Grad**



08.01.2014 14:44 24.01.2014 13:06 12.02.2014 10:23  
04.05.2014 09:36 27.10.2014 10:32

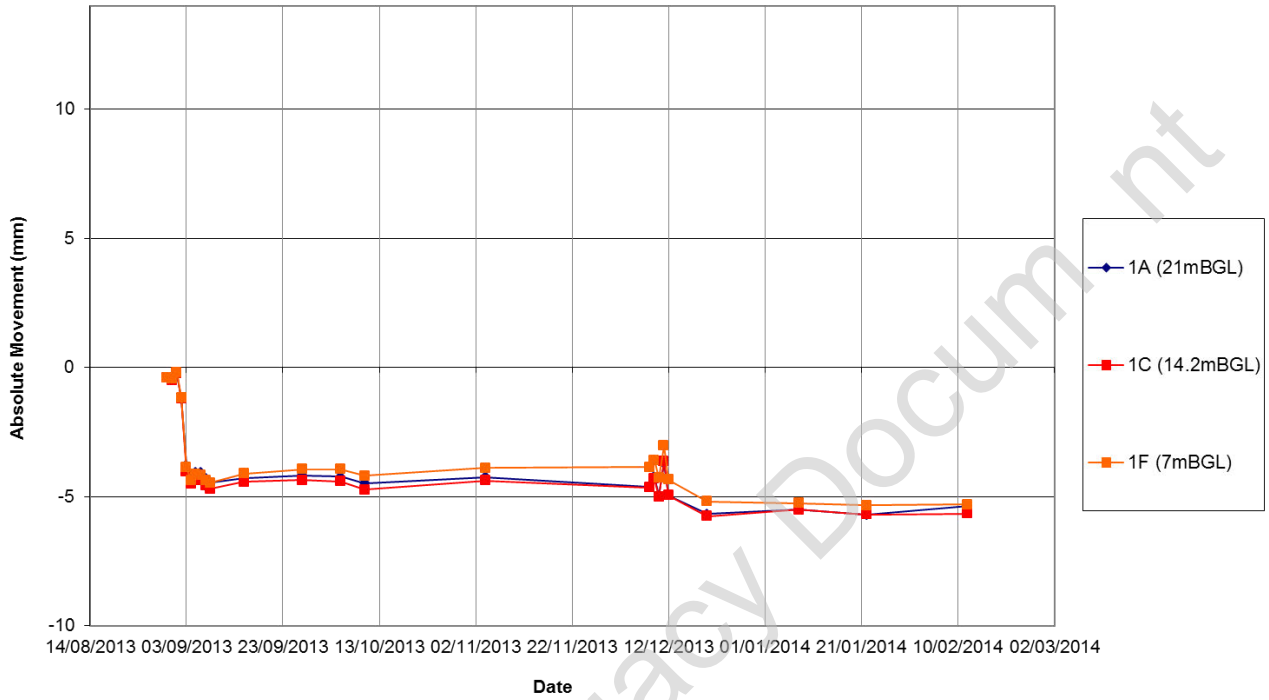
**Inclinometer: C300-IM1000011 Dir. Y 0.0 Grad**



08.01.2014 14:44 24.01.2014 13:06 12.02.2014 10:23  
04.05.2014 09:36 27.10.2014 10:32

### 2.20.2. Hatton Gardens

C300 Hatton Gardens Rod Extensometer XR1000011  
Absolute Movement of Targets Since Commissioning.



## Appendix 1. TBMs charts and sections' chainages

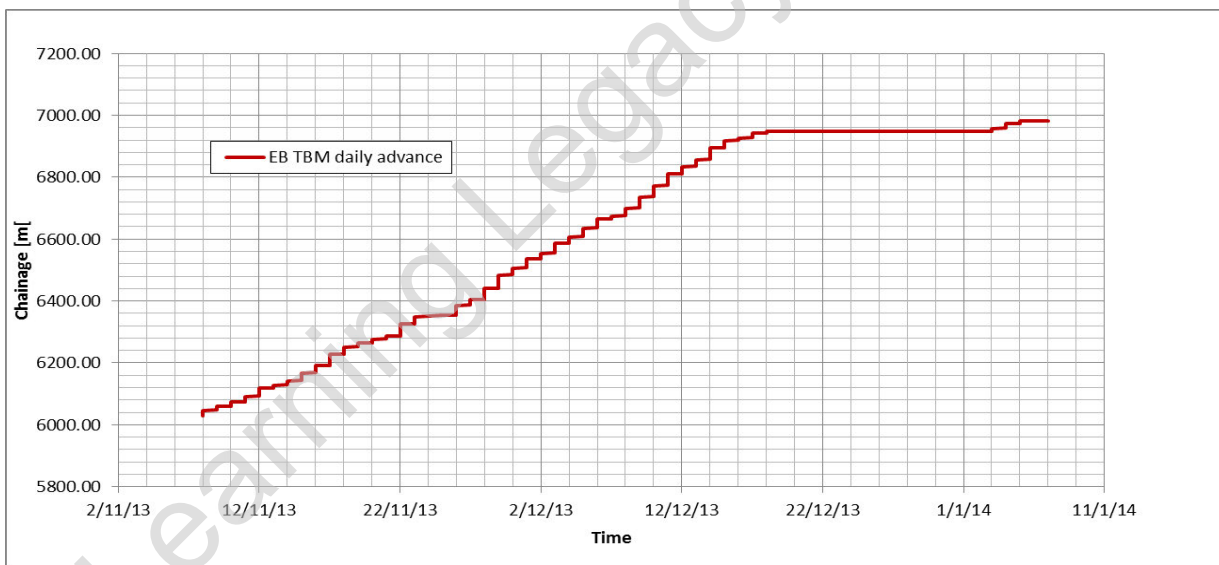
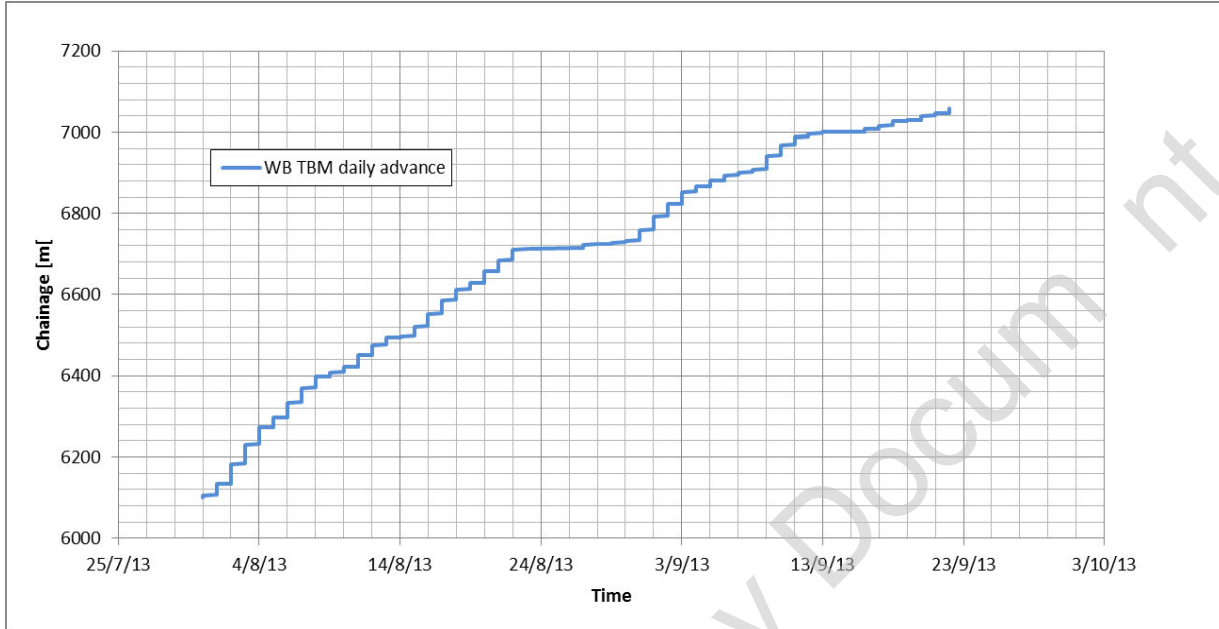


Figure 65a,b: WB and EB TBMs progress charts along FIS-FAR drive

Table 13: transects chainages

	WB Chainage	EB Chainage
Princeton Street	6193	6161
Bedford Row	6239	6171
Jockey's Fields	6299	6230
Raymond Buildings & Atkin Building	6322	6255
Gray's Inn Gardens	6372	6305
Gray's Inn Square	6450	6386
Gray's Inn Road	6601	6437
Baldwin's Gardens	6528	6490
Brooke's Court	6528	6490
St. Alban's Church	6591	6535
Brooke Street & Dorrington Street	6654	6597
Beauchamp Street	6654	6597
Leather Lane	6726	6663
Greville Street	6795	6731
Hatton Gardens	6795	6731
Kirby Street & bBleeding Heart Yard	6877	6811
Saffron Hill & Post Office Tunnel	6939	6866

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## Appendix 2. BREs, PLPs and Prisms data

Learning Legacy Document

## Appendix 3. Reference documents

Code	Document
C300-BFK-C4-STP-CRT00_ST005-	MANAGEMENT PLAN FOR THE CONTROL OF GROUND MOVEMENTS: ADDENDUM
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-NCR-000955	St. Albans BREs
C300-NCR-001115	Red Lion Sq. IPIs
C300-NCR-001120	Red Lion Sq. IPIs
C300-BFK-C4-RGN-CRT00_ST005-50506	ATS installation report - Kingsway tram tunnel
C300-BFK-C4-RGN-CRT00_ST005-50550	Installation report for prisms and BRE's Fisher St shaft
C300-BFK-C4-RGN-CRT00_ST005-50617	Installation of BRE 2-6 Southampton Row
C300-BFK-C4-RGN-CRT00_ST005-50718	Installation of geodetic prisms and BRE's in kingsway tram tunnel
C300-BFK-C4-RGN-CRT00_ST005-50720	Crackmeters in KTT Tunnel
C300-BFK-C4-RGN-CRT00_ST005-50731	As-Built report for subsurface instruments at Fisher Street
C300-BFK-C4-RGN-CRT00_ST005-50733	Installation of PLPs and Retro in short garden UKPN Tunnel
C300-BFK-C4-RGN-CRT00_ST005-50736	Strain Guages - As built report for Greys Inn Road
C300-BFK-C4-RGN-CRT00_ST005-50743	As-Built report for subsurface instruments at Dury Lane
C300-BFK-C4-RGN-CRT00_ST005-50744	As-Built report for subsurface instruments at Catton Street
C300-BFK-C4-RGN-CRT00_ST005-50745	As-Built report for subsurface instruments at Shaftsbury
C300-BFK-C4-RGN-CRT00_ST005-50746	As-Built report for subsurface instruments at Smarts Place
C300-BFK-C4-RGN-CRT00_ST005-50762	Installation Report for Subsurface Instruments at High Street St Giles
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_ST005-50773	Tiltmeters - Installation Report for 12-16 Southampton Row
C300-BFK-C4-RGN-CRT00_ST005-50803	As-built reports for Subsurface instruments at Greys In Gardens
C300-BFK-C4-RGN-CRT00_ST005-50819	Greys Inn Verticality Monitoring
C300-BFK-C4-RGN-CRT00_ST005-50841	As-built report for subsurface instruments at Hatton Gardens
C300-BFK-C4-RGN-CRT00_ST005-50845	TCR station Upgrade Installation Report
C300-BFK-C4-RGN-CRT00_ST005-50854	Installation of Precise level points in Shaftsbury Avenue Pipe Subway TCR-FIS (PMI325)
C300-BFK-C4-RGN-CRT00_ST005-50859	Installation report for Summit House
C300-BFK-C4-RGN-CRT00_ST005-50891	Installation Report for Geodetic Prisms and BREs - FIS-FARR
C300-BFK-C4-RGN-CRT00_ST005-50906	Installation Report for Proctor Street
C300-BFK-C4-RGN-CRT00_ST005-51981	Installation Report for Subsurface Instruments at Red Lion Square
C300-BFK-C4-RGN-CRT00_ST005-51982	Installation Report for Subsurface Instruments at Bedford Row
C300-BFK-C4-RGN-CRT00_ST005-51983	Installation Report for Subsurface Instruments at New Compton St
C300-BFK-C4-RGN-CRT00_ST005-51984	Installation Report for Subsurface Instruments at Endell Street



## Appendix 4. Thames Water Assets summary table

Area	Type	Sewer Name	Address	Alert Value (mm)	Deflection Alert Value	Deflection Amber Trigger Value	Deflection achieved (average of 3 values)
FIS- FAR	Sewer	Middle Level No 1 Flocadly Branch	Bedford Row		1 in 2000		1 in 8600
	Water Main	Gray's Inn Road (South Square)	Gray's Inn Road	-	1 in 2700	-	
	Water Main	Leather Lane	Leather Lane	-	1 in 2600	-	
	Sewer	TW333 Fleet Street Storm Relief (Hatton Garden)	Hatton Garden/Greville Street	-	1 in 5000	-	

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## Appendix 5. C300 Buildings Claims

The following sketches show the locations of the buildings for which damages claims were raised. The building addresses are reported in the **yellow boxes** and the position on the plan is indicated with a red arrow. This information was provided by C122. . These sketches are reported at the end of this document.

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**Safety Health and Environmental Information:**  
 1. C122 Design Team consider that over and above the general C300 Drive X specific hazards and risks presented in the General Notes Drawing (dtd in item 3 below), there are no location-specific hazards and risks additional to those normally associated with the work covered by this drawing which a competent contractor would not be readily aware of.  
 2. For SHE information relevant to all C300 Tunnel Drive X see: COM Risk Register: C122-OVE-N3-LRG-CR001-00003.  
 3. All location-specific drawings should be read in conjunction with the SHE content of General Notes Drawing No C122-OVE-C2-DDJ-CR001\_2-31000.  
 4. These notes are based on experienced and competent contractors carrying out the works using an approved safe method of working.

**Legend**

**Parties Responsible for the installation of the I & M**

- By C300
- By Others

**General**

- Tunnel Alignment
- Track shoe monitoring at 2m centres
- Track shoe monitoring at 3m centres

**Settlement Contours**

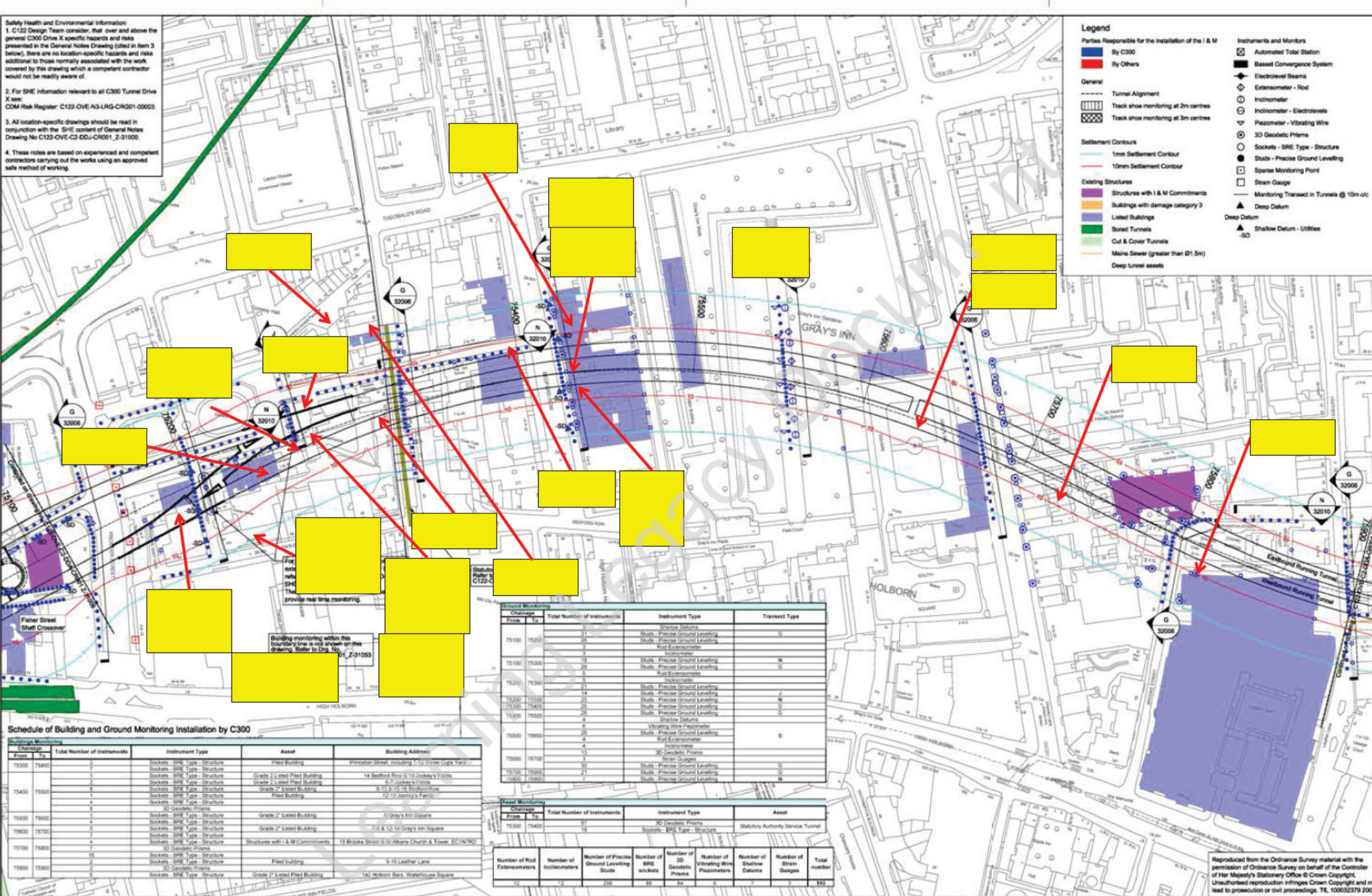
- 1mm Settlement Contour
- 10mm Settlement Contour

**Existing Structures**

- Structures with I & M Commitments
- Buildings with damage category 3
- Listed Buildings
- Bored Tunnels
- Cut & Cover Tunnels
- Main Sewer (greater than Ø1.5m)
- Deep tunnel assets

**Instruments and Monitors**

- Automated Total Station
- Basest Convergence System
- Electrolvel Beams
- Extensometer - Rod
- Inclinometer
- Inclinometer - Electrolevels
- Piezometer - Vibrating Wire
- 3D Geodetic Prisms
- Sockets - IRE Type - Structure
- Studs - Precise Ground Levelling
- Sparse Monitoring Point
- Strain Gauge
- Monitoring Transact in Tunnels Ø10m etc
- Deep Datum
- Shallow Datum - Utilities



**Schedule of Building and Ground Monitoring Installation by C300**

From Easement	To Easement	Total Number of Instruments	Instrument Type	Asset	Building Address
75300	75400	2	Sockets - IRE Type - Structure	Fixed Building	Princes Street, including 1-12 Three Gigs Yard
75400	75500	1	Sockets - IRE Type - Structure	Grade 2 Listed Building	14 Bedford Row & 14 Jockey's Lane
		2	Sockets - IRE Type - Structure	Grade 2 Listed Building	6-7 Jockey's Lane
75500	75600	1	Sockets - IRE Type - Structure	Grade 2 Listed Building	8-12 & 13 Bedford Row
		4	Sockets - IRE Type - Structure	Fixed Building	12-13 Jockey's Lane
75600	75700	1	Sockets - IRE Type - Structure	Grade 2 Listed Building	8 Jockey's Lane
		1	Sockets - IRE Type - Structure	Grade 2 Listed Building	10 & 12-14 Jockey's Lane
75700	75800	7	Sockets - IRE Type - Structure	Grade 2 Listed Building	13 Brookes Street & 30 Adams Church & Lower, EC1N 8DQ
		1	Sockets - IRE Type - Structure	Grade 2 Listed Building	141 Midland Row, Waterhouse Square
75800	75900	3	Sockets - IRE Type - Structure	Grade 2 Listed Building	3-15 Leathers Lane
		2	Sockets - IRE Type - Structure	Grade 2 Listed Building	141 Midland Row, Waterhouse Square

Chordance	Total Number of Instruments	Instrument Type	Transact Type
75100 75200	21	Shallow Datum	
75100 75300	28	Studs - Precise Ground Levelling	
	3	Extensometer	
75200 75300	18	Studs - Precise Ground Levelling	N
	2	Studs - Precise Ground Levelling	G
75200 75300	14	Extensometer	
	23	Studs - Precise Ground Levelling	N
75300 75400	19	Studs - Precise Ground Levelling	G
	2	Shallow Datum	
75500 75600	2	Vibrating Wire Piezometer	
	2	Studs - Precise Ground Levelling	B
75600 75700	13	3D Geodetic Prisms	
	3	Extensometer	
75700 75900	20	Studs - Precise Ground Levelling	G
	2	Studs - Precise Ground Levelling	G
75800 75900	21	Studs - Precise Ground Levelling	G
	1	Studs - Precise Ground Levelling	G

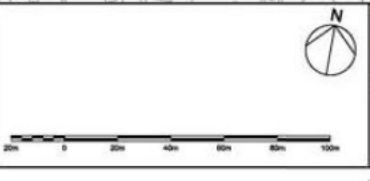
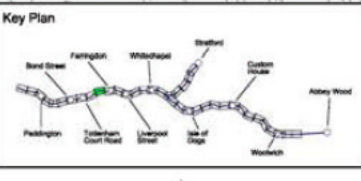
Chordance	Total Number of Instruments	Instrument Type	Asset
75300 75400	27	3D Geodetic Prisms	Statutory Authority Service Tunnel
	1	Sockets - IRE Type - Structure	

Number of Rod Extensometers	Number of Inclinometers	Number of Precise Ground Levelling Studs	Number of IRE Sockets	Number of 3D Geodetic Prisms	Number of Vibrating Wire Piezometers	Number of Shallow Datums	Number of Strain Gauges	Total number
1	2	22	20	20	1	2	0	55

Rev.	Date	Issued as	Description	By	Check	App	Auth
P01	20/11/2008	Issued for Tender Purposes		AB	AK		RM
P02	10/03/2010	Revised for Tender Purposes		JC	AB		RM
P03	28/04/2010	Revised for Tender Addendum Purposes		AB	AB		RM
P04	14/12/2010	Issued for Tender Addendum Purposes		JF	AB		RM
P05	14/12/2010	Issued for General Ref		JF	AB		RM
P06	11/05/2011	Designer's Revision		GP	CC		PC
P07	03/02/2012	Minimum Requirement for Construction		GP	JA		RM
C01	17/02/2012	Issued as I1 for construction		GP	JA		RM

**Notes**

- For instrumentation and monitoring general notes, monitoring frequencies and summary schedule, refer to Dig No. C122-OVE-C2-DDJ-CR001\_2-31000, C122-OVE-C2-DDJ-CR001\_2-30002 and C122-OVE-C2-DDJ-CR001\_2-30005 respectively.
- For C121 SCL I&M requirements and details by C300, refer to Dig No. C121-I&M-C4-DDJ-CR006\_2-31000-05001.
- For more details of the installations of the deep datums for TWL assets, refer to dig no. C122-OVE-C2-DDJ-CR001\_2-33302.



**General**

**Bored Tunnels (Alignment and Track)**

Operator: **Ove Arup & Partners Limited**

Location: **Crossrail**

Client: **Transport for London**

Contract: **Instrumentation and Monitoring Combined I & M**

Project: **Routeview Plan Sheet 10 of 38 C300**

Scale: **1:1000 @ A1**

Drawing and CAD Rev No: **C122-OVE-C2-DDJ-CR001\_2-31010**

Drawn by: **G. POTTER**

Checked by: **J. JAFFES**

Approved by: **M. ALMDAR**

Author: **I. THOMSON**

Sheet: **C01**

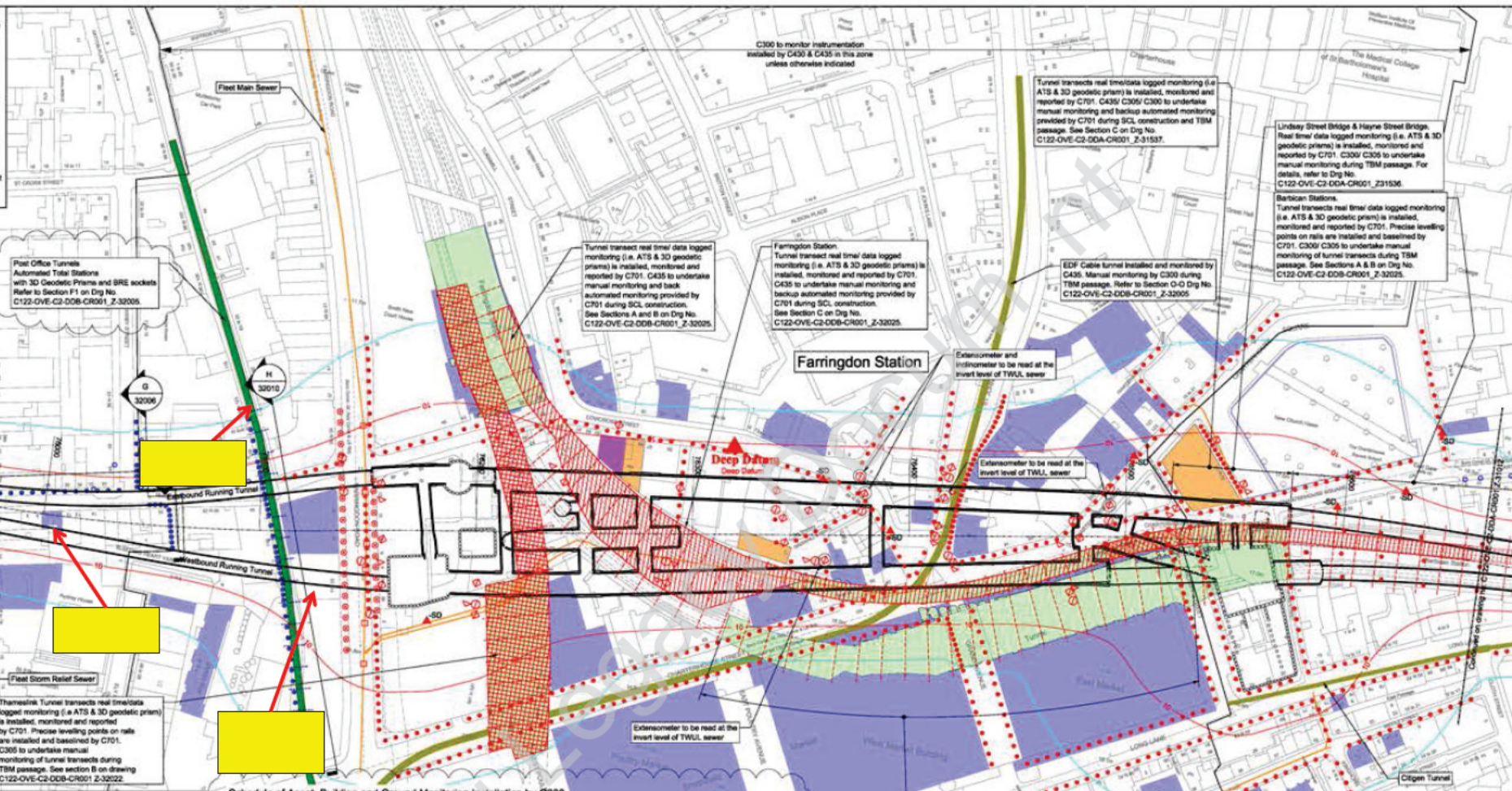
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**Safety Health and Environmental Information:**  
 1. C122 Design Team consider that over and above the general C300 Drive X specific hazards and risks presented in the General Notes Drawing (dtd in item 3 below), there are no location-specific hazards and risks additional to those normally associated with the work covered by this drawing which a competent contractor would not be readily aware of.  
 2. For SHE information relevant to all C300 Tunnel Drive X see:  
 COM Risk Register: C122-OVE-N3-LRG-CR01-00003.  
 3. All location-specific drawings should be read in conjunction with the SHE content of General Notes Drawing No C122-OVE-C2-DDB-CR01\_Z-31000.  
 4. These notes are based on experienced and competent contractors carrying out the works using an approved safe method of working.

**Post Office Tunnels**  
 Automated Total Stations with 3D Geodetic Prisms and BSE sockets Refer to Section F1 on Dtg No. C122-OVE-C2-DDB-CR01\_Z-32005

**Internal monitoring @ 20m c/c**  
 Refer to Section E1+E11 on Dtg No. C122-OVE-C2-DDB-CR01\_Z-32022

**Thermocline Tunnel** transects real time data logged monitoring (i.e. ATS & 3D geodetic prism) is installed, monitored and reported by C701. Precise levelling points on rails are installed and baseleined by C701. C305 to undertake manual monitoring of tunnel transects during TBM passage. See section B on drawing C122-OVE-C2-DDB-CR01\_Z-32022



**Legend**

**Parties Responsible for the installation of the I & M**

- By C300/ C305
- By Others

**General**

- Tunnel Alignment
- Track shoe monitoring @ 2m centres
- Track shoe monitoring @ 3m centres

**Settlement Contours**

- 1mm Settlement Contour
- 10mm Settlement Contour

**Existing Structures**

- Structures with I & M Comments
- Buildings with damage category 3
- Listed Buildings
- Bored Tunnels
- Cut & Cover Tunnels
- Mains Sewer (greater than Ø1.6m)
- Deep Tunnel assets

**Instruments and Monitors**

- Automated Total Station
- Baseed Seismic System
- Electrolevel
- Extensometer - Rod
- Inclinometer
- Inclinometer - Electrolevel
- Piezometer - Vibrating Wire
- 3D Geodetic Prisms
- Sockets - BSE Type - Structure
- Sluts - Precise Ground Levelling
- Spane Monitoring Point
- Strain Gauge
- Monitoring Transect in Tunnels @ 10m c/c
- Deep Datum
- Shallow Datum - UBises
- Internal monitoring Transect in TWUL asset @ 20m c/c

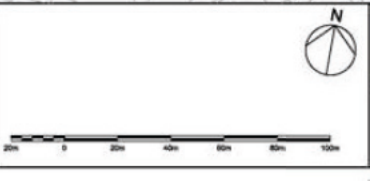
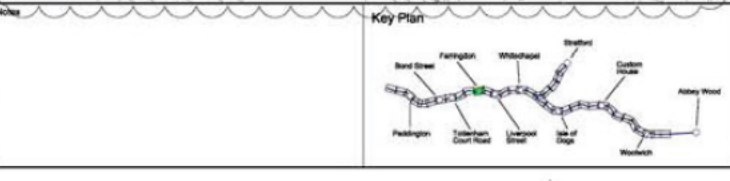
**Schedule of Asset, Building and Ground Monitoring Installation by C300**

Change		Total Number of Instruments	Instrument Type	Asset	Building Address
From	To				
75900	76000	1	Socket - BSE Type - Structure	Fleet Building	35 Hutton Garden
76000	76100	1	Socket - BSE Type - Structure	Fleet Building	37 Hutton Garden
76000	76100	1	Socket - BSE Type - Structure	Fleet Building	32-34 Grenville Street
<b>Ground Monitoring</b>					
From	To	Total Number of Instruments	Instrument Type	Transect Type	
75900	76000	2	Sluts - Precise Ground Levelling	G	
76000	76100	1	Sluts - Precise Ground Levelling	N	
76000	76100	1	Sluts - Precise Ground Levelling	N	
76000	76100	2	Sluts - Precise Ground Levelling	G	
76000	76100	4	Sluts - Precise Ground Levelling	N	
<b>Asset Monitoring</b>					
From	To	Total Number of Instruments	Instrument Type	Asset	
76000	76100	1	3D Geodetic Prisms	Fleet Office Tunnel	
76000	76100	1	Socket - BSE Type - Structure	Fleet Office Tunnel	
76000	76100	1	Socket - BSE Type - Structure	Fleet Storm Relief Sewer	
76000	76100	1	3D Geodetic Prisms	Fleet Storm Relief Sewer	
Number of Precise Ground Levelling Sluts		11			
Number of BSE Sockets		4			
Number of 3D Geodetic Prisms		0			
Total Number		16			

**Discused Mortgage Spur**  
 Real time data logged monitoring (i.e. ATS & 3D geodetic prism) is installed, monitored and reported by C701. Ratio targets on tie profile beams to be installed, monitored and reported by C701. C435 to undertake manual monitoring of tunnel transects and track monitoring during nearby SCL construction.

C305 and C300 to monitor instrumentation installed by C430 and C435 in this zone unless otherwise indicated

Rev.	Date	Description	By	Check	App	Auth
P02	20/11/2009	Issued for Tender Purposes	AB	AN	RM	
P03	12/05/2010	Revised for Tender Purposes	JF	AB	RM	
P04	21/04/2010	---	JF	AN	RM	
P05	19/04/2010	Revised for Tender Purposes	AB	AN	RM	
P06	20/04/2010	Revised for Tender Advertisement Purposes	AB	AN	RM	
P07	14/12/2010	Issued for Contract Set	JF	AB	RM	
P08	18/12/2010	---	JF	AB	RM	
P09	11/05/2011	Designers Recommendations for Use by Contractors	AB	OC	PC	
P10	24/05/2011	Minimum Requirements for Use by Contractors	JF	AN	PC	
P11	22/05/2011	Minimum Requirements for Use by Contractors	JF	PC	PC	
P12	03/02/2012	Minimum Requirements for Use by Contractors	GP	JA	PC	
C01	17/02/2012	Issued as F1 for authorisation	By	Chief	App	Auth



**Crossrail Limited**  
 25 Gresham Street  
 London  
 EC2A 4PU

**Bored Tunnels (Alignment and Track)**  
 Prepared by:  
 Ove Arup & Partners Limited  
 Location:  
 Crossrail General  
 Title:  
 Instrumentation and Monitoring Combined I & M  
 Route/wise Plan Sheet 11 of 38  
 C300 & C305

Scale: 1:1000 @ A1  
 Drawing and CAD No: C122-OVE-C2-DDA-CR01\_Z-31011  
 Date: 01

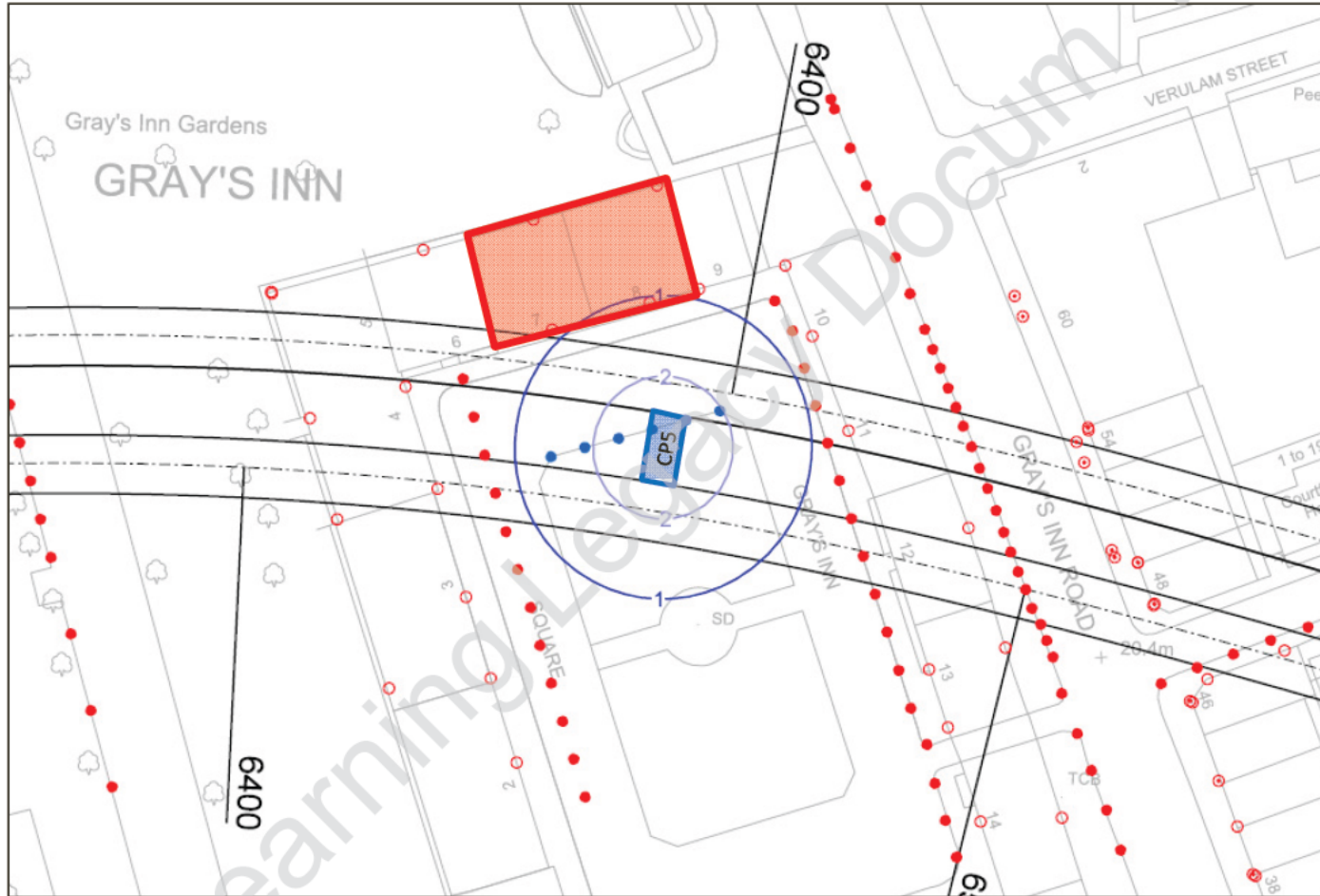
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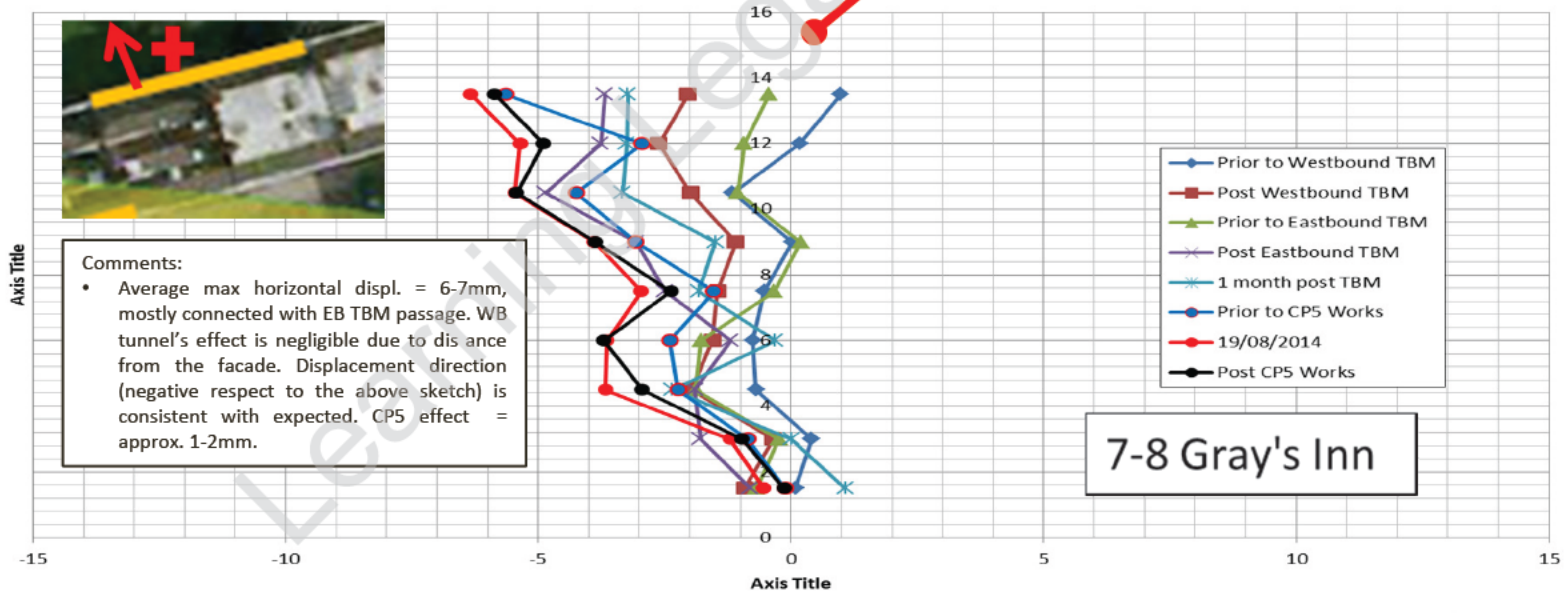
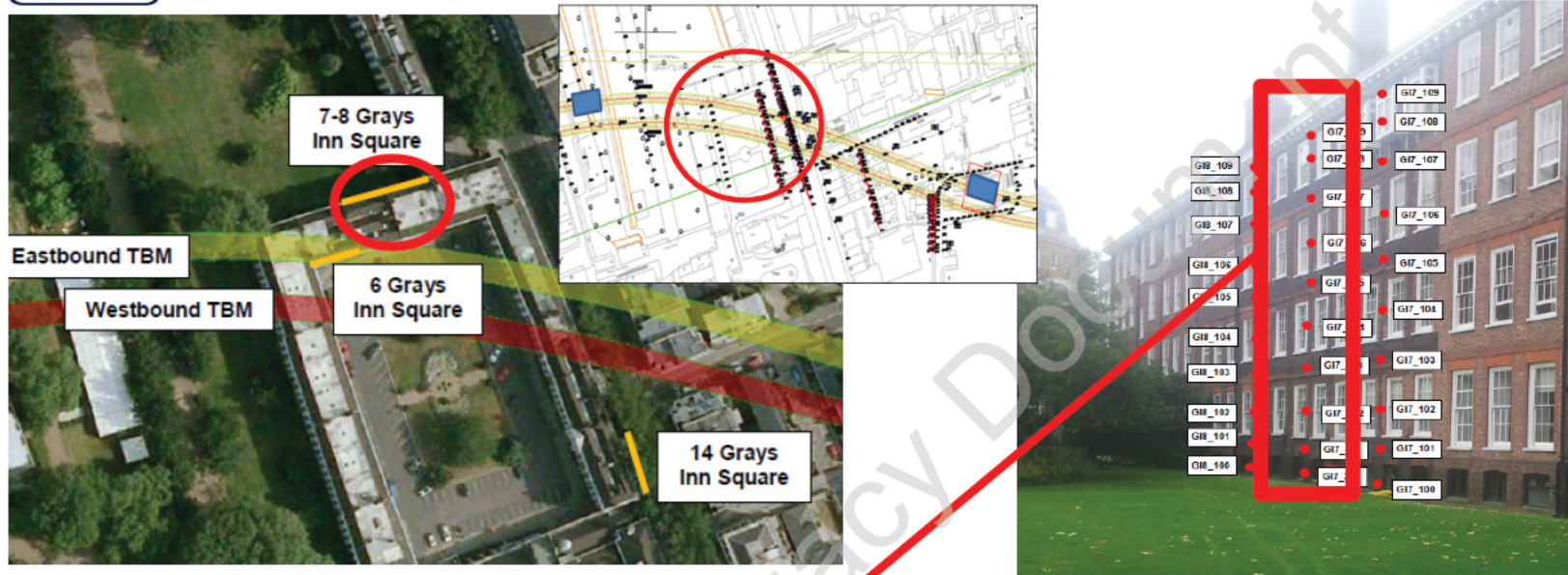
## Appendix 6. Verticality checks data

These slides have been prepared for Crossrail and C122 in order to report the monitoring results to the interested 3<sup>rd</sup> parties. They have also been presented to CRL and C122 representatives during CTCs and dedicated meetings. These sketches are reported at the end of this document.

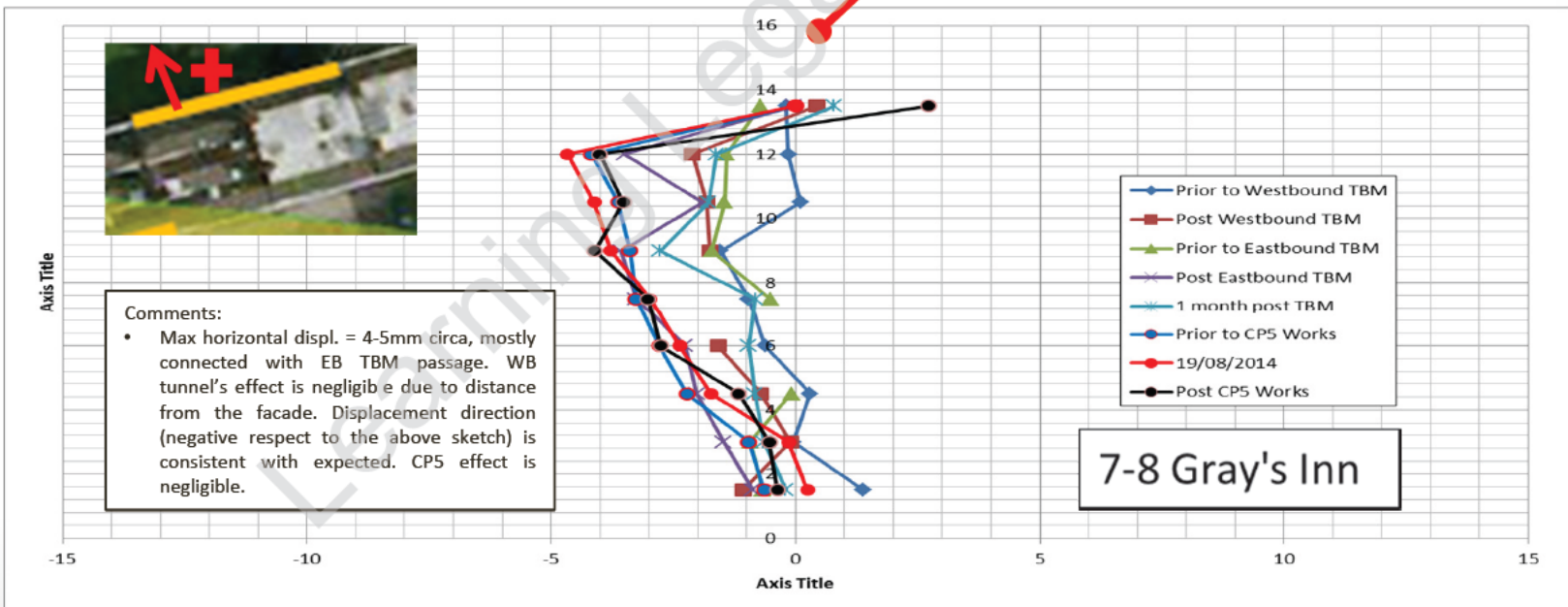
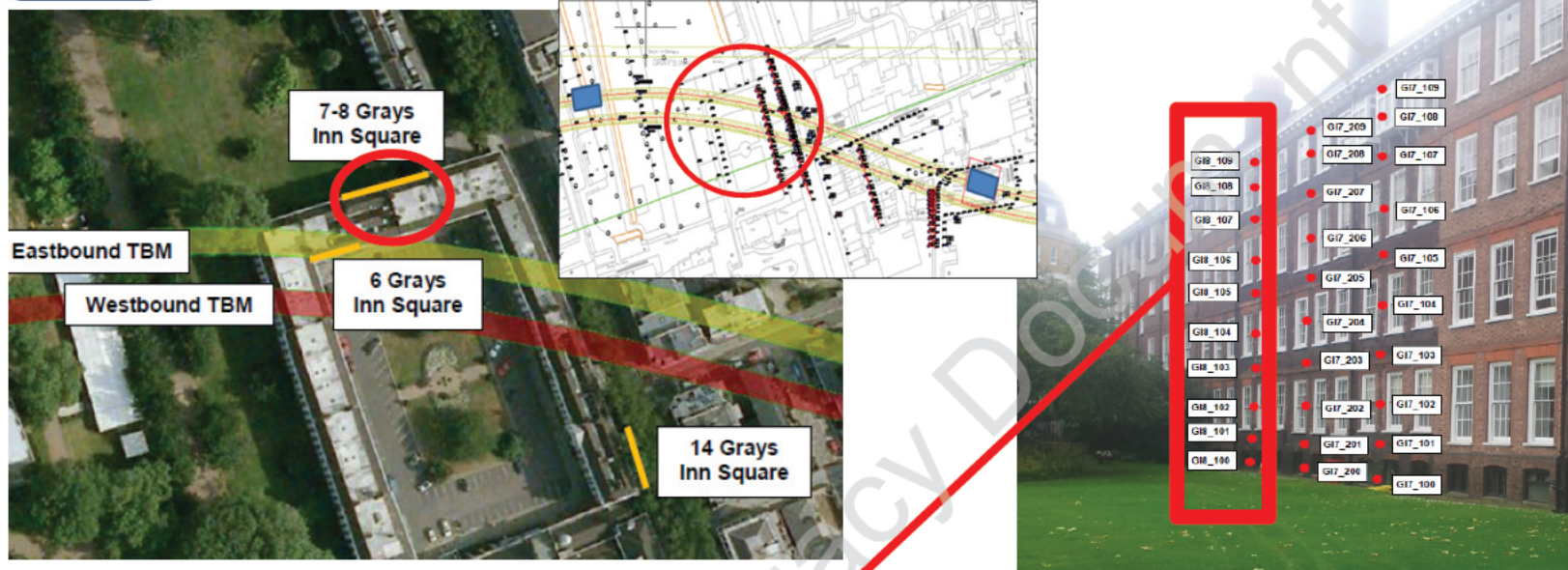
Learning Legacy Document



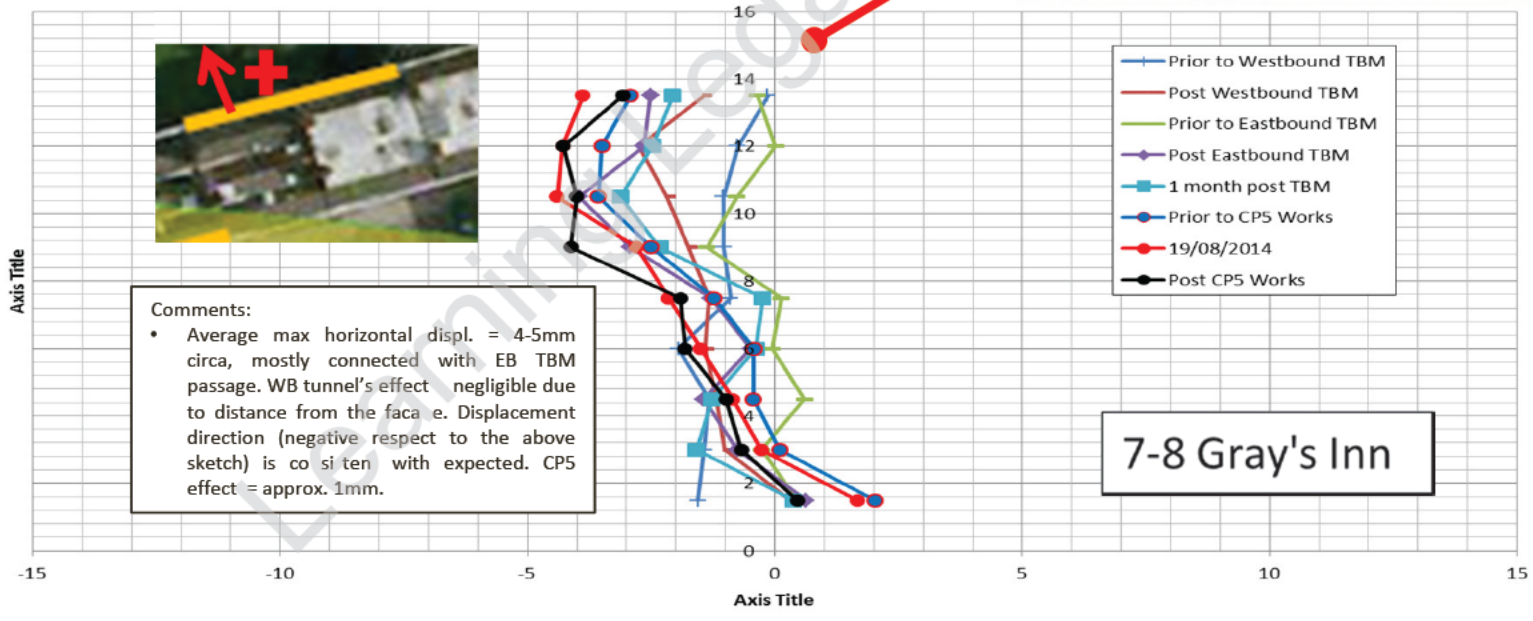
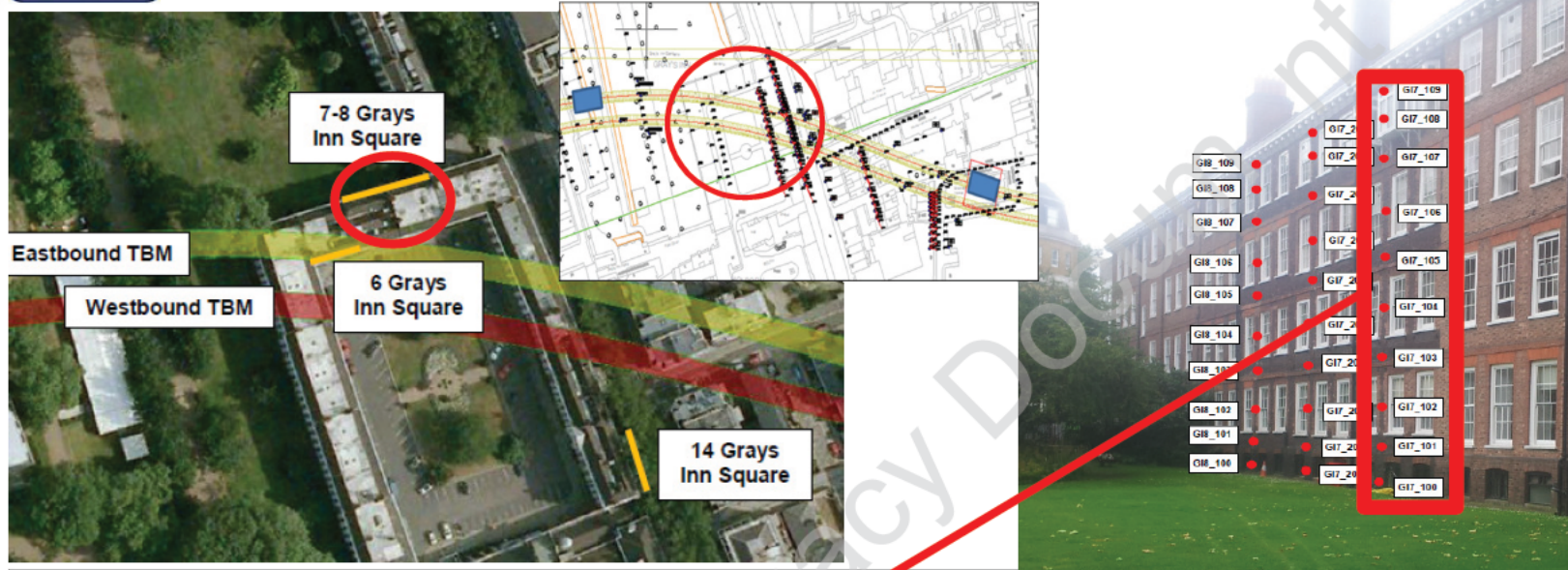
# Gray's Inn Square – Monitoring data



# Gray's Inn Square – Monitoring data

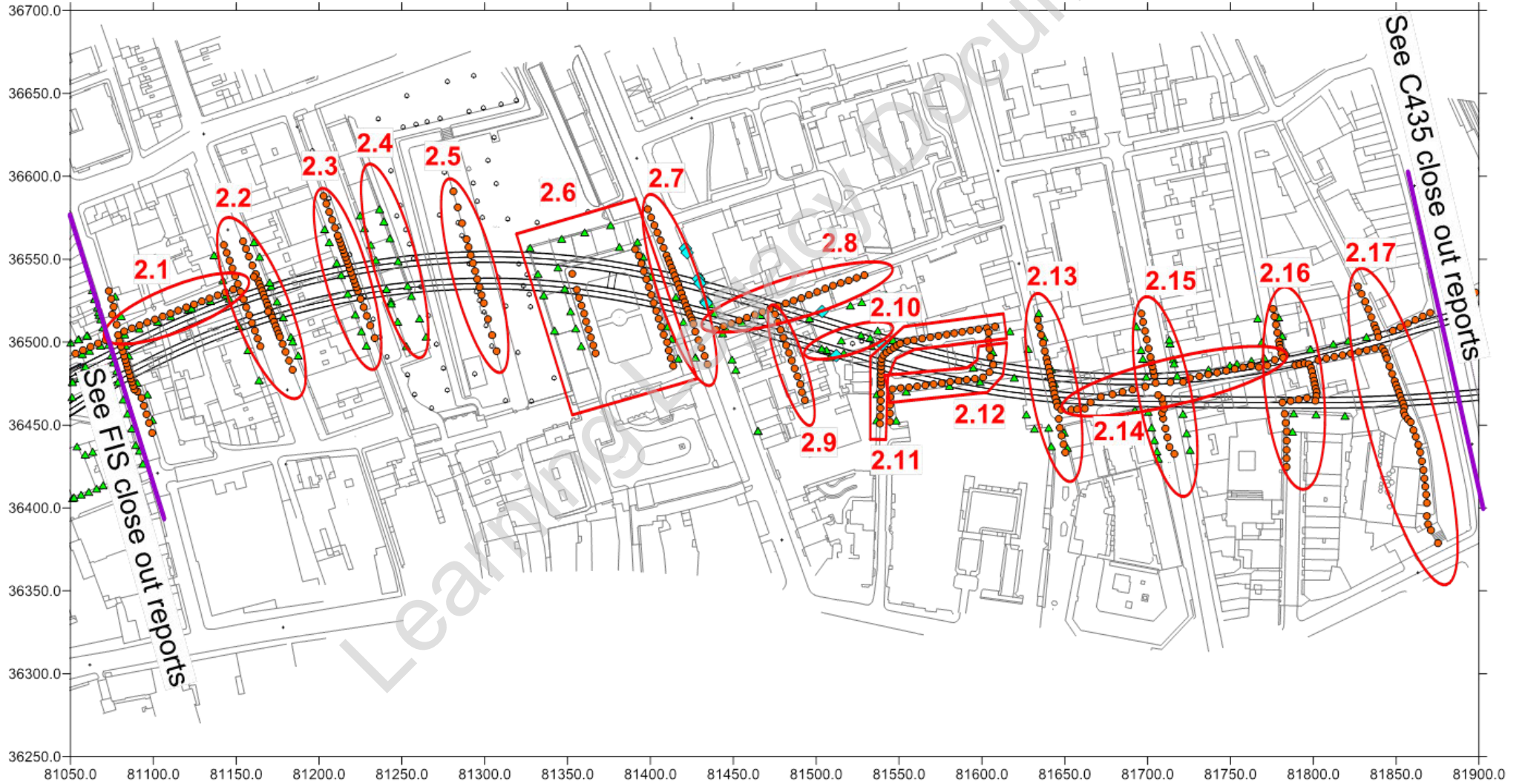






## Appendix 7. Summary Plots

Location and Section Numbers for data presented



Summary of final recorded settlement

