



Work Area: SMM
Work Type: I&M
Originator Company: GEOCISA

# C435 Farringdon Main Station

CRL Lead reviewer: [Redacted]
CRL Reviewer:

## Monitoring Close-Out Report: Automated Total Station ATS7 and 3D Targets read by ATS7.

**CRL Document Number: C435-BFK-C2-RGN-M123-51641**

**Supplier Document Number: N/A**

**Contract MDL reference C14.022**

### 1. Contractor Document Submittal History:

Revision:	Date:	Prepared by:	Checked by:	Approved by:	Reason for Issue:
1.0	19-04-2016	[Redacted]	[Redacted]	[Redacted]	For acceptance
2.0	20-05-2016	[Redacted]	[Redacted]	[Redacted]	For acceptance

### 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: \_\_\_\_\_ Role: \_\_\_\_\_ Name: \_\_\_\_\_ Date: \_\_\_\_\_

Sign: \_\_\_\_\_ Role: \_\_\_\_\_ Name: \_\_\_\_\_ Date: \_\_\_\_\_

### 2b. Review by Stakeholder (if required):

Stakeholder Organisation	Job Title	Name	Signature	Date	Acceptance
					<input type="checkbox"/>
			compliance with their contractual obligations and does not constitute ds or materials developed or selected by the designer/supplier.		<input type="checkbox"/>
		[Redacted]			<input type="checkbox"/>

15/10/2016

### 3. Acceptance by Crossrail:

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## A. INTRODUCTION

In line with the C122 – M&W Specification KX10 – Instrumentation & Monitoring C122-OVE-Z4-RSP-CR001-00007, this Close-Out Report aims to address the following points in relation to the instrumentation defined in Section B.

- Identify movements observed by the relevant instruments;
- Relate these movements to construction activities, where applicable;
- Identify trigger breaches that may have occurred;
- Demonstrate that the rate of change of the data is either in line with the required rate or such that residual risks are minimal;
- Identify any such residual risks should there be considered to be any.

Based on the above points, this close out reports will provide justification for the decommissioning of the instruments.

## B. INSTRUMENTS

### B.1 Description of the Instruments

This Close-Out Report relates the prisms read by ATS07. See Table 1 below with the details of the prisms read by ATS07

Sensor	Location	Easting (m)	Northing (m)	Elevation (mATD)
C435-RP00701	23-28 Charterhouse Sq.	82276.62	36584.89	121.6992
C435-RP00702	23-28 Charterhouse Sq.	82264.72	36566.36	122.2641
C435-RP00703	38 Charterhouse St	82228.86	36555.08	121.7275
C435-RP00704	38 Charterhouse St	82236.55	36559.15	121.1135
C435-RP00705	38 Charterhouse St	82242.64	36562.33	121.4574
C435-RP00708	38 Charterhouse St	82229.09	36555.2	130.2813
C435-RP00709	38 Charterhouse St	82236.55	36559.08	130.2654
C435-RP00710	38 Charterhouse St	82243.08	36562.63	129.8457
C435-RP00711	23-28 Charterhouse Sq.	82276.65	36584.8	141.5055
C435-RP00712	23-28 Charterhouse Sq.	82264.99	36566.47	141.5131
C435-RP00713	Lindsey St Bridge	82274.8669	36541.0658	112.5118
C435-RP00714	Lindsey St Bridge	82273.1179	36544.7618	115.0046
C435-RP00715	Lindsey St Bridge	82276.0433	36538.7332	114.874
C435-RP00716	Lindsey St Bridge	82281.6272	36527.7404	111.6555
C435-RP00717	Lindsey St Bridge	82282.8406	36524.993	112.1968
C435-RP00718	Lindsey St Bridge	82281.8242	36525.9813	115.2591
C435-RP00719	Lindsey St Bridge	82282.2387	36524.979	112.1972
C435-RP00720	Lindsey St Bridge	82285.396	36520.7037	111.5487
C435-RP00721	Lindsey St Bridge	82286.902	36518.0902	112.7317
C435-RP00722	Lindsey St Bridge	82288.0678	36515.2466	112.8977
C435-RP00728	Barbican Station Retaining Wall South	82325.1346	36545.5759	122.4415
C435-RP00729	Barbican Station Retaining Wall South	82325.3497	36544.8857	128.5303
C435-RP00731	38-40 Charterhouse Sq.	82343.43	36585.98	133.1581

Sensor	Location	Easting (m)	Northing (m)	Elevation (mATD)
C435-RP00732	38-40 Charterhouse Sq.	82347.7	36587.91	133.1543
C435-RP00733	33-37 Charterhouse Sq	82328.26	36569.56	133.184
C435-RP00734	33-37 Charterhouse Sq	82319.09	36568.89	133.2004
C435-RP00735	33-37 Charterhouse Sq	82313.29	36568.5	133.2168
C435-RP00736	33-37 Charterhouse Sq	82329	36579.56	133.1909
C435-RP00737	33-37 Charterhouse Sq	82316.91	36574.22	133.1863
C435-RP00738	33-37 Charterhouse Sq	82308.66	36570.69	133.1901
C435-RP00743	ETH-Trapezoidal Shaft	82282.7475	36532.6504	108.1686
C435-RP00744	ETH-Trapezoidal Shaft	82280.3192	36537.4532	108.1202
C435-RP00745	ETH-Trapezoidal Shaft	82276.791	36544.4052	108.1230

Table 1: Details of the prisms read by ATS07

The prisms reading by ATS07 installed on 33-37 Charterhouse Sq. are shown in the following documents:

Drawings:

- C435-BFK-C2-DWG-M123-50045. 3D Targets Installed for Farringdon Station

Installation Reports:

- C435-BFK-C2-RGN-M123-50058. Installation Report of 3D Targets read by ATS07.
- C435-BFK-C2-RGN-M123-50011. Installation Report of ATS07

## B.2 Location of the Instruments

Prisms associated with ATS07 are located on the plan below highlighted in yellow.

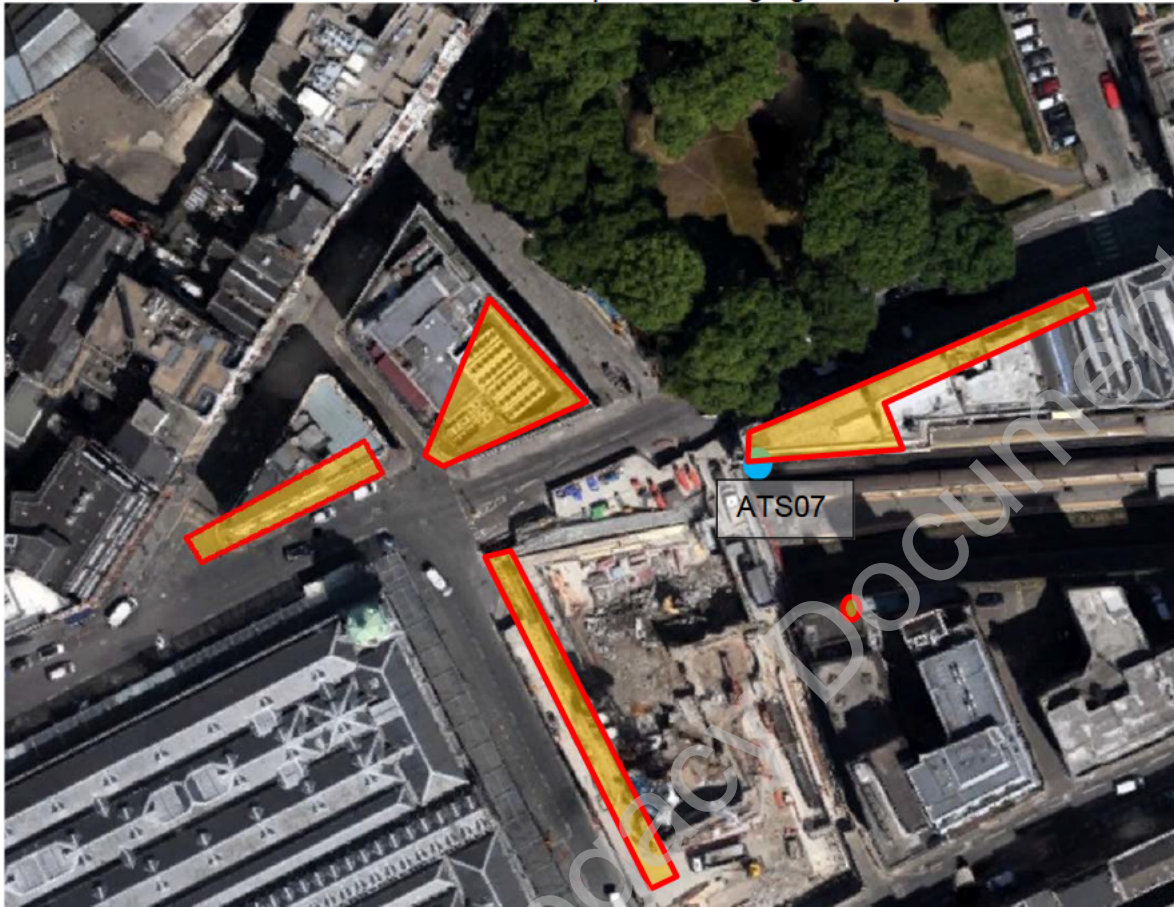


Figure 1 – Plan showing the Location prisms read by ATS07.

## C. MOVEMENTS

### C.1 Movements Resulting from Construction Activities

#### C.1.1 Relevant Crossrail (BFK) Works

The construction activities affecting these instruments are outlined in the Table 2 below:

Activity	Start Date	End Date
ETH Excavation	21-03-2013	28-10-2014
EB TBM	20-01-2014	24-01-2014
PTE	27-10-2014	27-01-2015
CH2	05-03-2015	28-05-2015
CP6	12-11-2014	25-11-2014
CP7	23-02-2015	25-02-2015
CP8	16-06-2015	22-06-2015
CP9	10-06-2015	14-06-2015
VA2	16-04-2015	02-05-2015
STE2	02-02-2015	12-02-2015

Table 2 – Construction Activities associated to ATS07.

### C.1.2 Resulting Movements

To analyse the result for the prisms buildings will be looked at individually

- 38-42 Charterhouse St.
- 23-28 Charterhouse Sq.
- 33-37 Charterhouse Sq.
- 38 Charterhouse Sq.
- Lindsey St Bridge.
- ETH-Trapezoidal Shaft.
- Barbican Station Retaining Wall South.

- 38-42 Charterhouse St.

The monitoring data for the prisms is shown in Appendix B.

- ETH excavation caused 2mm of settlement from 21-03-2013 to 28-10-2014.
- Compensation grouting from Moorgate Shaft 2 caused 2mm of heave in August 2013 and September 2013.
- Eastbound TBM caused 6-8mm maximum of settlement in 20-01-2014.
- Residual settlement caused 4mm of settlement.
- Compensation grouting caused 5-6mm of heave from July 2014 to September 2014.
- Ground Treatment caused 12mm of heave in October 2014.
- PTE enlargement works caused 12-14mm of settlement between 29-10-2015 and 07-01-2015.
- Compensation grouting caused 8-10mm of heave in January 2015.
- CP7 construction caused 4-5mm of settlement from 23-02-2015 to 25-02-2015.
- CH2 construction caused 2-3mm maximum of settlement from 05-03-2015 to 28-05-2015.
- Maximum Longitudinal displacement +13mm
- Maximum Transversal displacement +28mm
- Maximum settlement at the end of the works -29mm

- 23-28 Charterhouse Sq.

The monitoring data for the prisms is shown in Appendix B.

- ETH excavation caused 2-3mm of settlement from 21-03-2013 to 28-10-2013.
- Compensation grouting from Charterhouse Shaft caused 4-6mm of heave in October 2013.
- EB TBM caused 6mm maximum of settlement between 21-01-2013 and 23-01-2013.
- Ground Treatment on October 2014 caused 12mm of heave.
- PTE works caused 20mm maximum of settlement from 07-11-2014 to 27-01-2015.
- Compensation grouting caused 2mm of heave in May 2015.
- CP8 and CP9 combination works caused 6-7mm maximum of settlement.
- Maximum Longitudinal displacement -16mm
- Maximum Transversal displacement -32mm
- Maximum settlement at the end of the works -31mm

- 33-37 Charterhouse Sq.

The monitoring data for the prisms is shown in Appendix B.

- Eastbound TBM caused 8-10mm maximum of settlement from 22-01-2014 to 24-01-2014.
- Compensation grouting from Charterhouse Shaft caused 3-4mm of heave in May 2014.
- Ground treatment on October 2014 caused 8mm maximum of heave.
- Second ground treatment caused 3-4mm of heave in November 2014.
- PTE caused 4-5mm of settlement from 18-01-2015 to 27-01-2015.
- STE2 construction caused 8-10mm maximum of settlement from 02-02-2015 to 12-02-2015.
- Compensation grouting carried out in March 2015 caused 2-3mm maximum of heave.
- VA2 construction activities caused 2-3mm of settlement from 16-04-2015 to 02-05-2015.
- Maximum Longitudinal displacement -8mm
- Maximum Transversal displacement +14mm
- Maximum settlement at the end of the works -26mm

- 38-40 Charterhouse Sq.

The monitoring data for the prisms is shown in Appendix B.

- Compensation grouting carried out in January 2014 caused 3-4mm of heave.
- EB TBM caused maximum 2-3mm of settlement from 22-01-2014 to 24-01-2014.
- Residual settlement caused 1-2mm of settlement.
- Compensation grouting from Charterhouse Shaft caused 4-5mm of heave from October 2014 to January 2015.
- STE2 construction caused 2mm maximum of settlement from 02-02-2015 to 12-02-2015.
- Maximum Longitudinal displacement -8mm
- Maximum Transversal displacement +24mm
- Maximum settlement at the end of the works -11mm

- Lindsey Street Bridge.

The monitoring data for the prisms is shown in Appendix B.

These prisms were removed or covered before the tunnelling works. The work affected to these prisms was the ETH Excavation and compensation grouting episodes.

- TaM's drilling from Moorgate Shaft 2 caused 7-8mm maximum of heave from 29-04-2013 to 11-05-2013.
- ETH Excavation caused maximum 5-6mm of settlement from 21-03-2013 to 28-10-2013.
- Compensation grouting from Moorgate Shaft 2 caused maximum 4-5mm of heave from 12-07-2013 to 22-07-2013.
- Maximum Longitudinal displacement +10mm
- Maximum Transversal displacement -6mm
- Maximum settlement at the end of the works -2mm

- ETH-Trapezoidal Shaft.

The monitoring data for the prisms is shown in Appendix B.

These prisms were removed or covered before the tunnelling works. The work affected to these prisms was the ETH Excavation.

- No significant movement in Z direction during the ETH Excavations works from 21-03-2013 to 28-10-2013.
- Maximum Longitudinal displacement -6mm
- Maximum Transversal displacement -5mm
- Maximum settlement at the end of the works +1mm

- Barbican Station Retaining Wall South.

The monitoring data for the prisms is shown in Appendix B.

These prisms were installed by C704. C435 monitoring these prisms to verify that C704 was working. These prisms did not show any significant movement by the Crossrail works. The only work affected to these prisms was STE2 construction. These prisms were re-installed by C701 on 10-01-2016. For this reason both prisms showed a jump in the data.

- Maximum Longitudinal displacement +6mm
- Maximum Transversal displacement -4mm
- Maximum settlement at the end of the works -4mm



## C.2 Trigger Breaches

The Instrumentation and Monitoring Plan: Farringdon Station Ground Movement and Asset Protection C122-OVE-C2-RGN-M123-50013 outlines the triggers associated with the devices. No triggers associated with the prisms installed inside of the compensation influence area only 10mm alerts are associated.

For the prisms installed outside of the compensation influence area are:

- Green trigger, 24mm
- Amber trigger, 30mm
- Red trigger, 38mm

No triggers breached. The Table 3 below shows the default alerts breached.

MONITORING GROUP (Location)	POINT ID	TYPE	DIRECTION	DATE OF LAST READING	LAST READING VALUE (mm)	TRIGGER LEVEL	
						WORST HISTORICAL STATUS	CURRENT STATUS
23-28 Charterhouse Sq	C435-RP00701	AUTOMATIC RP	Settlement	20/01/2016 11:00	-10.1	Default Alert	Default Alert
	C435-RP00702	AUTOMATIC RP	Settlement	03/04/2016 11:00	-31.20	Default Alert	Default Alert
38 Charterhouse Sq	C435-RP00703	AUTOMATIC RP	Settlement	07/03/2016 11:00	-25.5	Default Alert	Default Alert
	C435-RP00704	AUTOMATIC RP	Settlement	07/03/2016 11:00	-22.9	Default Alert	Default Alert
	C435-RP00705	AUTOMATIC RP	Settlement	09/08/2015 05:00	-19.9	Default Alert	Default Alert
	C435-RP00708	AUTOMATIC RP	Settlement	07/03/2016 11:00	-25.1	Default Alert	Default Alert
	C435-RP00709	AUTOMATIC RP	Settlement	07/03/2016 11:00	-25.2	Default Alert	Default Alert
	C435-RP00710	AUTOMATIC RP	Settlement	07/03/2016 11:00	-22.6	Default Alert	Default Alert
23-28 Charterhouse Sq	C435-RP00711	AUTOMATIC RP	Settlement	08/02/2016 13:00	-11.2	Default Alert	Default Alert
	C435-RP00712	AUTOMATIC RP	Settlement	16/02/2016 11:00	-26.8	Default Alert	Default Alert
Hayne St Bridge	C435-RP00713	AUTOMATIC RP	Settlement	19/08/2013 07:00	2.9	Default Alert	Clear
	C435-RP00714	AUTOMATIC RP	Settlement	17/08/2013 01:00	-1.2	Clear	Clear
	C435-RP00715	AUTOMATIC RP	Settlement	20/08/2013 09:00	1.2	Default Alert	Default Alert
	C435-RP00716	AUTOMATIC RP	Settlement	30/08/2013 15:00	0	Default Alert	Default Alert
	C435-RP00717	AUTOMATIC RP	Settlement	02/09/2013 05:00	2.9	Default Alert	Default Alert
	C435-RP00718	AUTOMATIC RP	Settlement	17/03/2013 09:00	6.3	Default Alert	Default Alert
	C435-RP00719	AUTOMATIC RP	Settlement	02/09/2013 05:00	2.6	Default Alert	Default Alert
	C435-RP00720	AUTOMATIC RP	Settlement	21/08/2013 15:00	4.2	Default Alert	Default Alert
	C435-RP00721	AUTOMATIC RP	Settlement	21/08/2013 05:00	6.4	Default Alert	Default Alert
	C435-RP00722	AUTOMATIC RP	Settlement	22/08/2013 08:00	3.6	Default Alert	Default Alert
Barbican Station Retaining Wall South	C435-RP00728	AUTOMATIC RP	Settlement	09/06/2016 11:00	-15.4	Default Alert	Default Alert
	C435-RP00729	AUTOMATIC RP	Settlement	09/06/2016 11:00	-15.8	Default Alert	Default Alert
38-40 Charterhouse Sq	C435-RP00731	AUTOMATIC RP	Settlement	09/06/2016 10:00	-8	Clear	Clear
	C435-RP00732	AUTOMATIC RP	Settlement	14/10/2015 16:00	-3.5	Clear	Clear
33-37 Charterhouse Sq	C435-RP00733	AUTOMATIC RP	Settlement	09/06/2016 11:00	-21.6	Default Alert	Default Alert
	C435-RP00734	AUTOMATIC RP	Settlement	09/06/2016 11:00	-23.7	Default Alert	Default Alert
	C435-RP00735	AUTOMATIC RP	Settlement	09/06/2016 11:00	-25.5	Default Alert	Default Alert
	C435-RP00736	AUTOMATIC RP	Settlement	09/06/2016 10:00	-20.3	Default Alert	Default Alert
	C435-RP00737	AUTOMATIC RP	Settlement	09/06/2016 10:00	-24.9	Default Alert	Default Alert
	C435-RP00738	AUTOMATIC RP	Settlement	09/06/2016 11:00	-23	Default Alert	Default Alert
ETH- Trapezoidal Shaft	C435-RP00743	AUTOMATIC RP	Settlement	15/08/2014 09:31	1.4	Clear	Clear
	C435-RP00744	AUTOMATIC RP	Settlement	02/03/2014 12:35	1.1	Clear	Clear
	C435-RP00745	AUTOMATIC RP	Settlement	21/02/2014 06:40	2.6	Clear	Clear

Table 3 – Default alerts breached by the prisms read by ATS07.

## C.3 Significant Issues with the Instrumentation

The prisms installed on the 23-28 Charterhouse Sq have been covered by a scaffold due refurbishment works.

Prisms installed on Hayne Street Bridge and on Trapezoidal shaft were covered by the different structures (Scaffolds, safety nets, props, etc.) during the excavation of the shaft.

## C.4 Residual Risks

The rate of settlement for all instrumentation within this report has been analysed and in all cases the rate is less than 2mm/year.

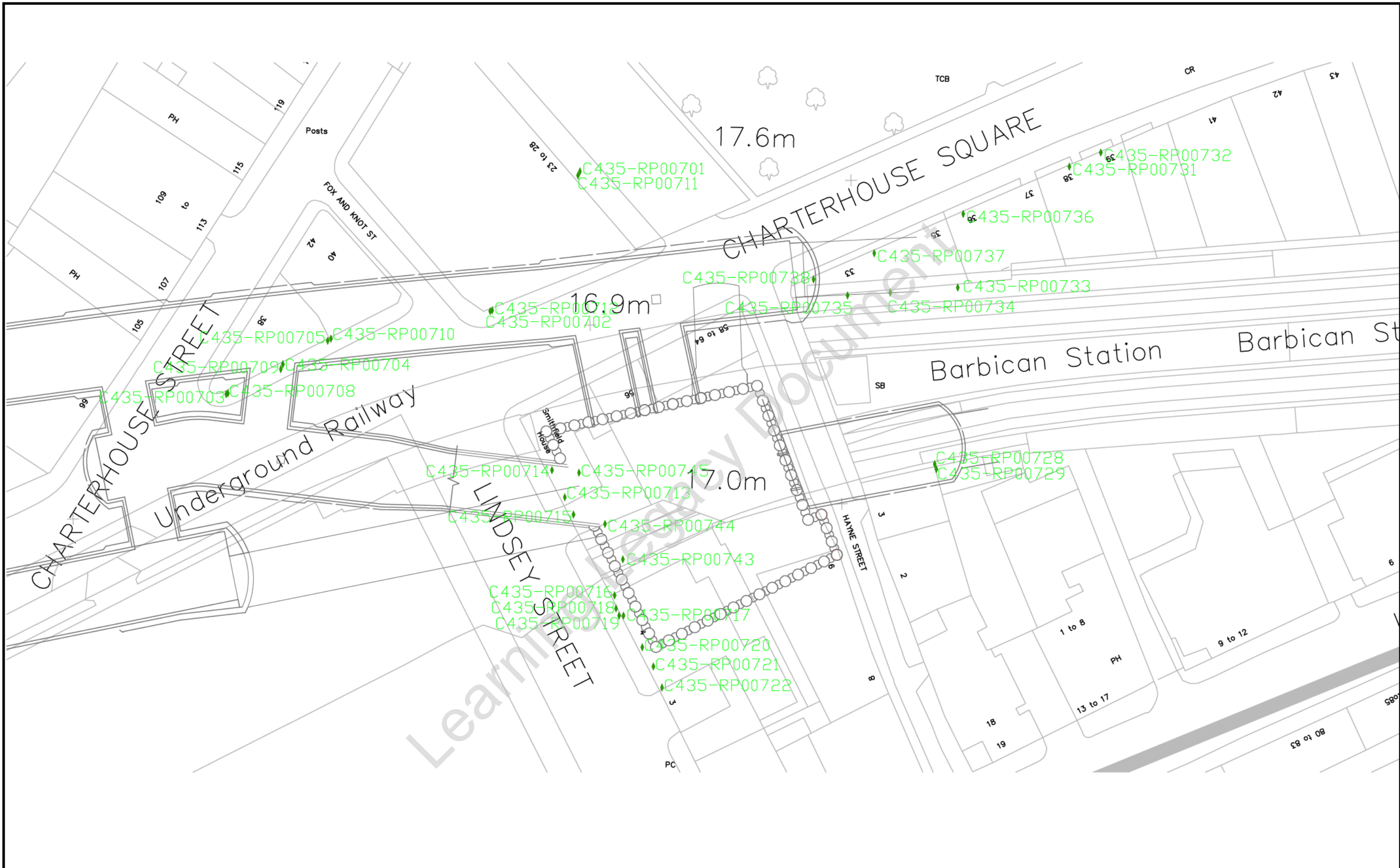
## **D. CONCLUSIONS**

No triggers breached, monitoring stable. No residual risks remain. Long term monitoring to be completed by Crossrail.

Learning Legacy Document

APPENDIX A: DRAWINGS

Learning Legacy Document



Rev.	Date	Description	By	Chkd	App	Auth

Notes:

**GEOCISA**  
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Contract : BORED TUNNELS (ALIGNMENT AND TRACK)  
 Originator : OVE ARUP & PARTNERS LIMITED  
 Location : CROSSRAIL GENERAL  
 Title :  
 3D TARGETS INSTALLED FOR FARRINGTON STATION

Scale : @ A3

Drg No : C435-BFK-C2-DWG-M123-50045

Rev : Sult : Auth : **GEOCISA**

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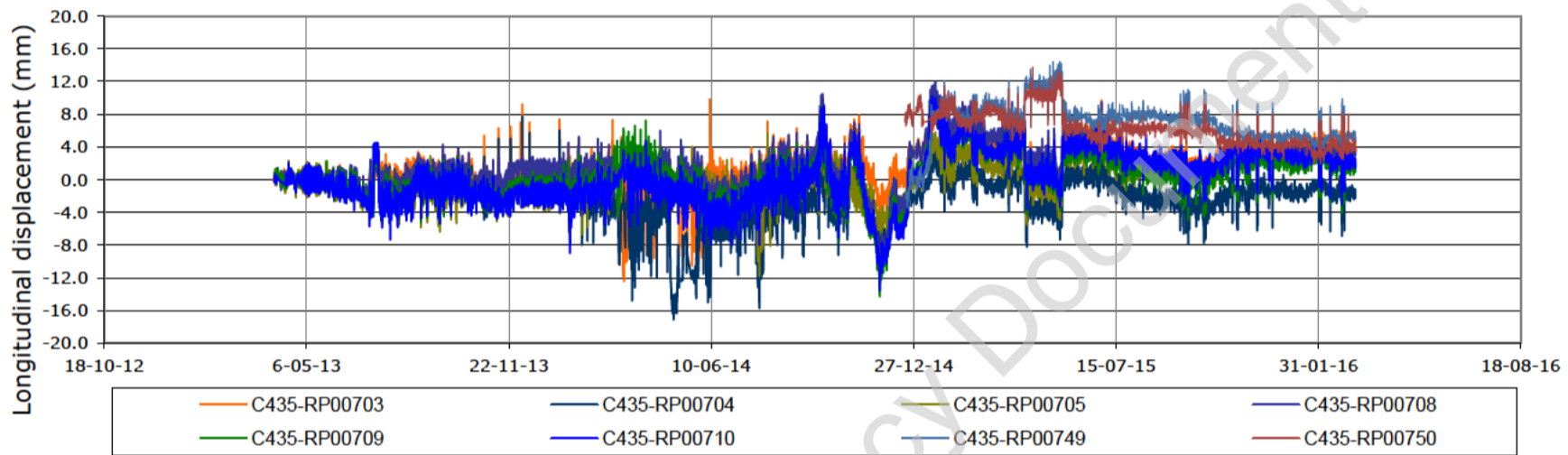
APPENDIX B: GRAPHS

Learning Legacy Document

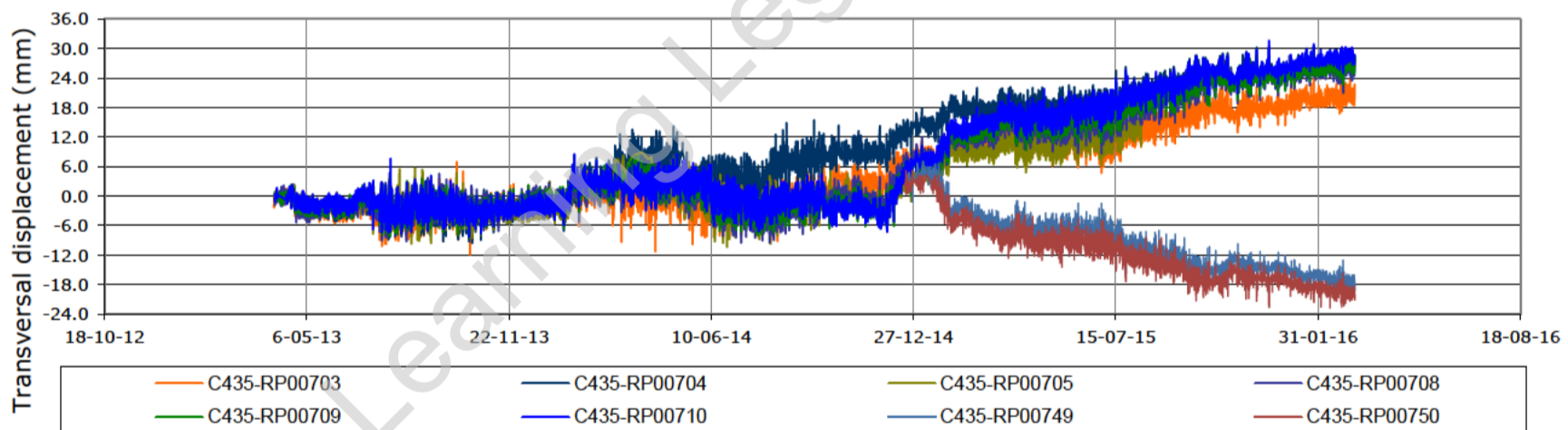
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 DEVICE 3D Target



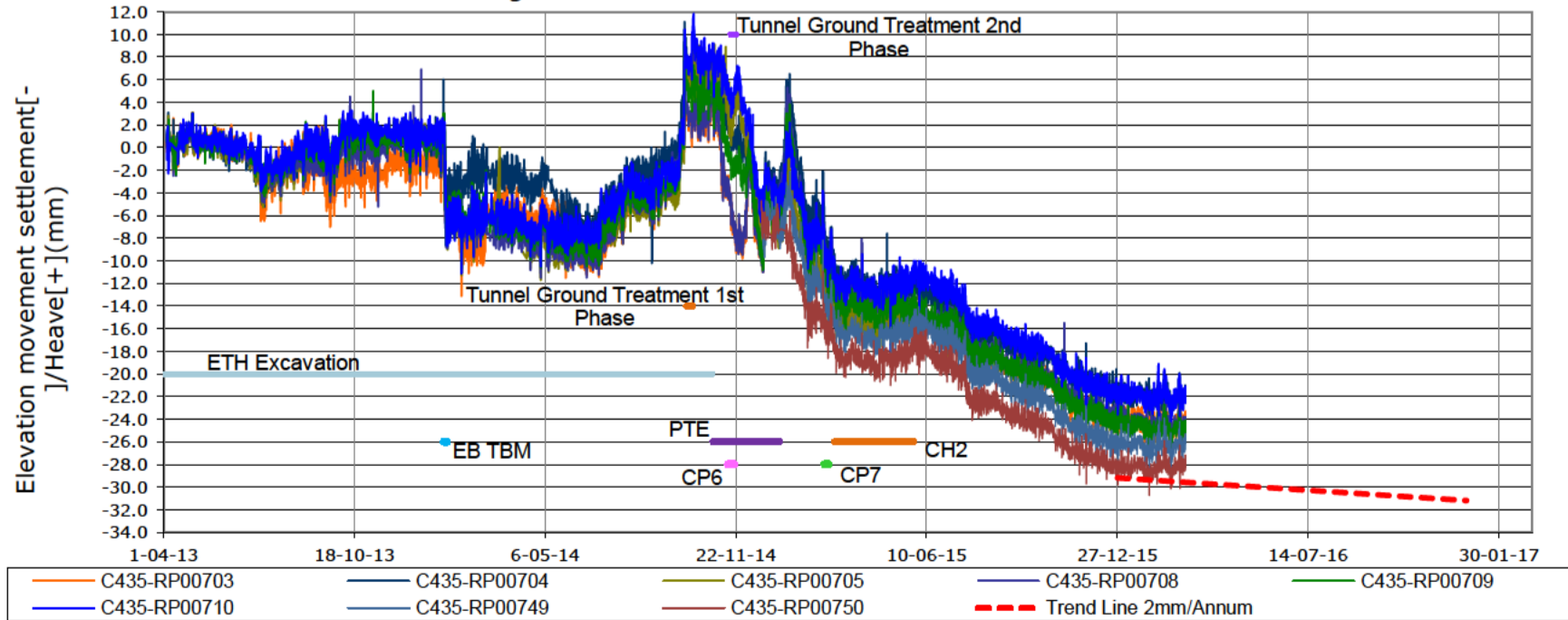
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Building: 38-42 CHARTERHOUSE STREET



Building: 38-42 CHARTERHOUSE STREET

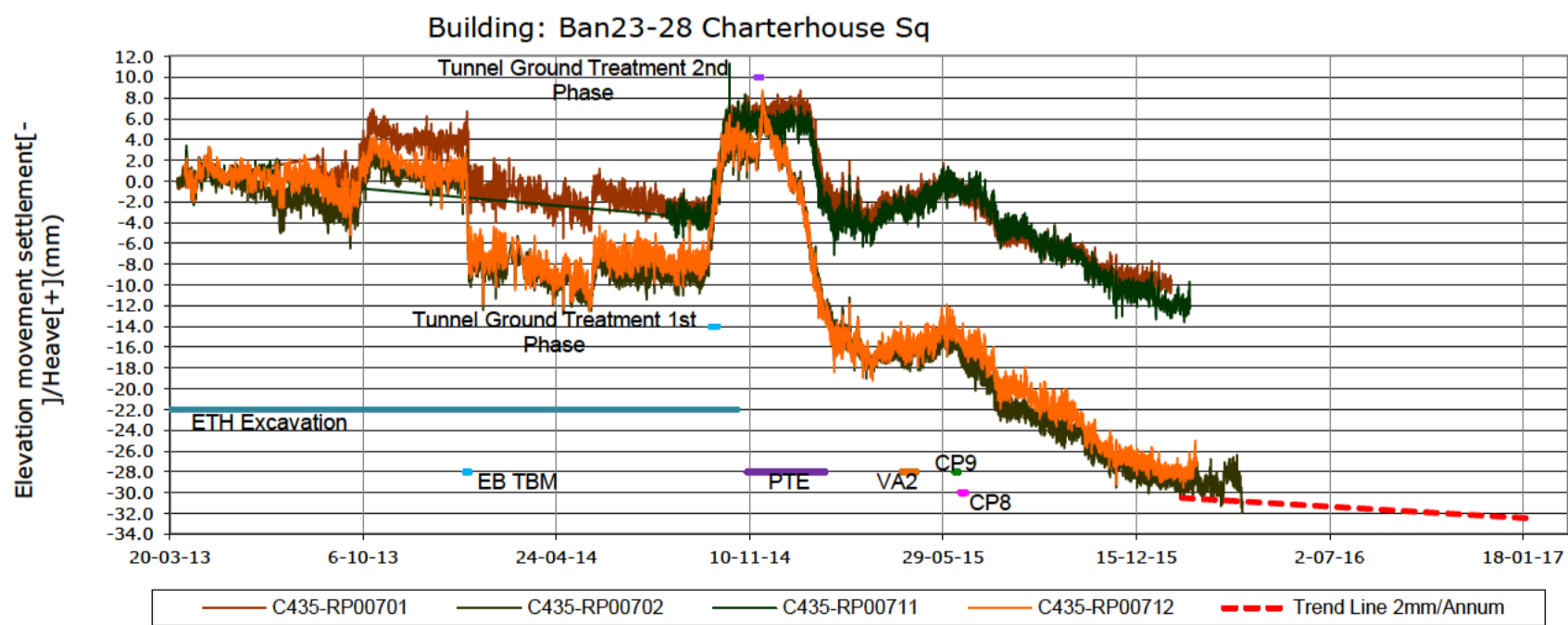
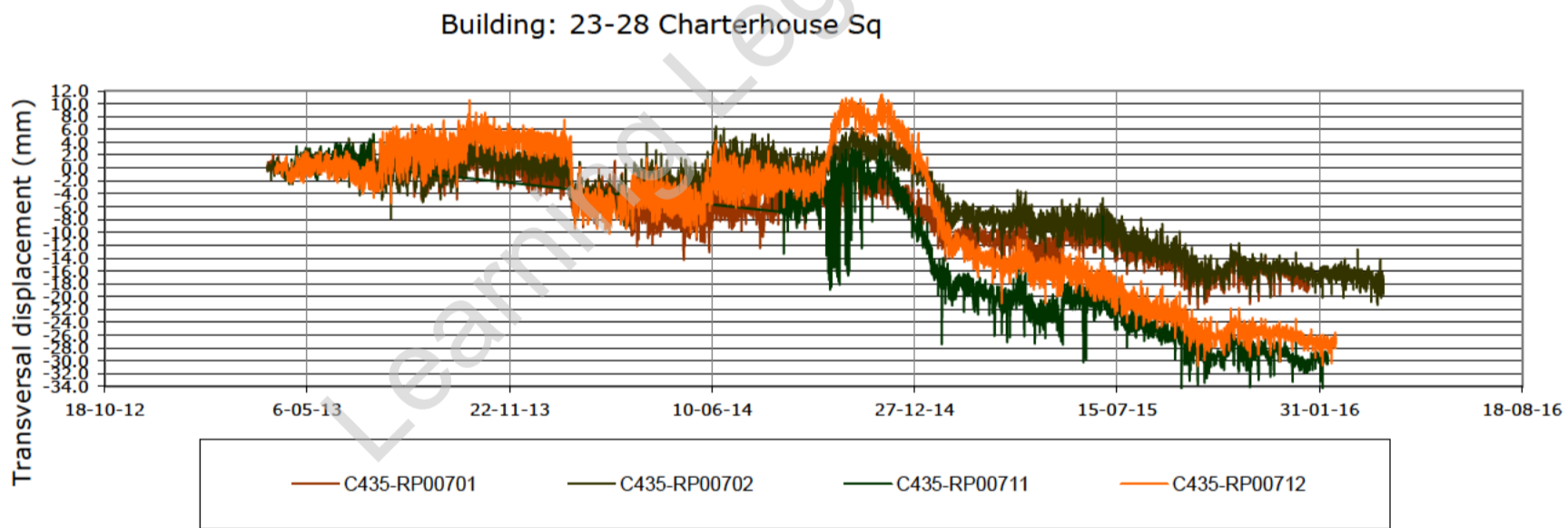
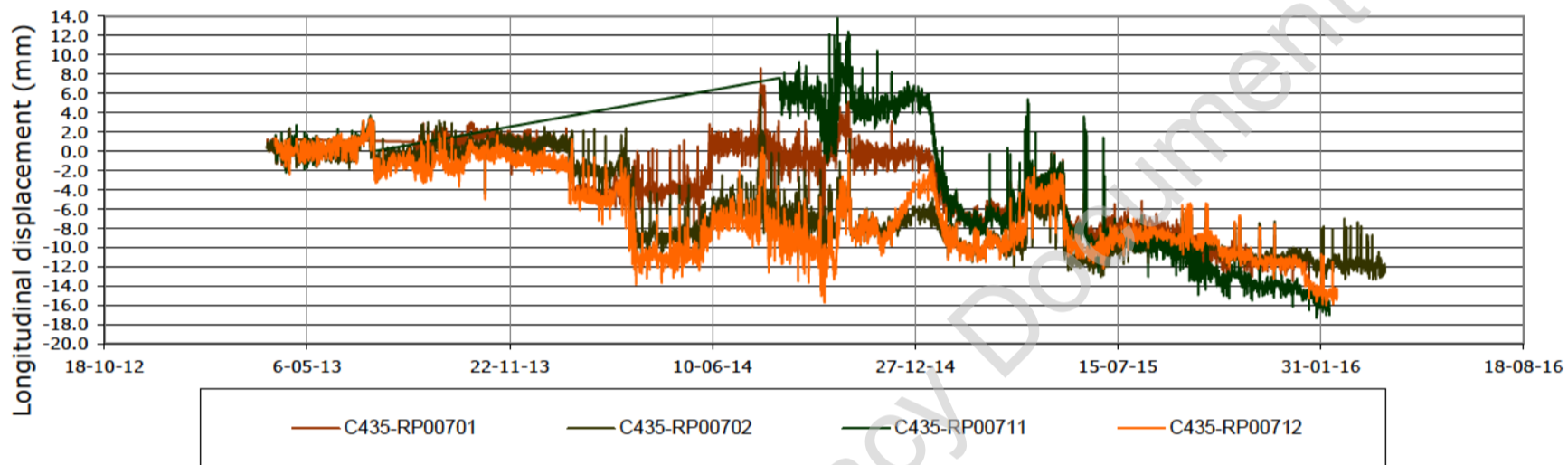


REMARKS:



REPORT  
AREA  
DEVICE

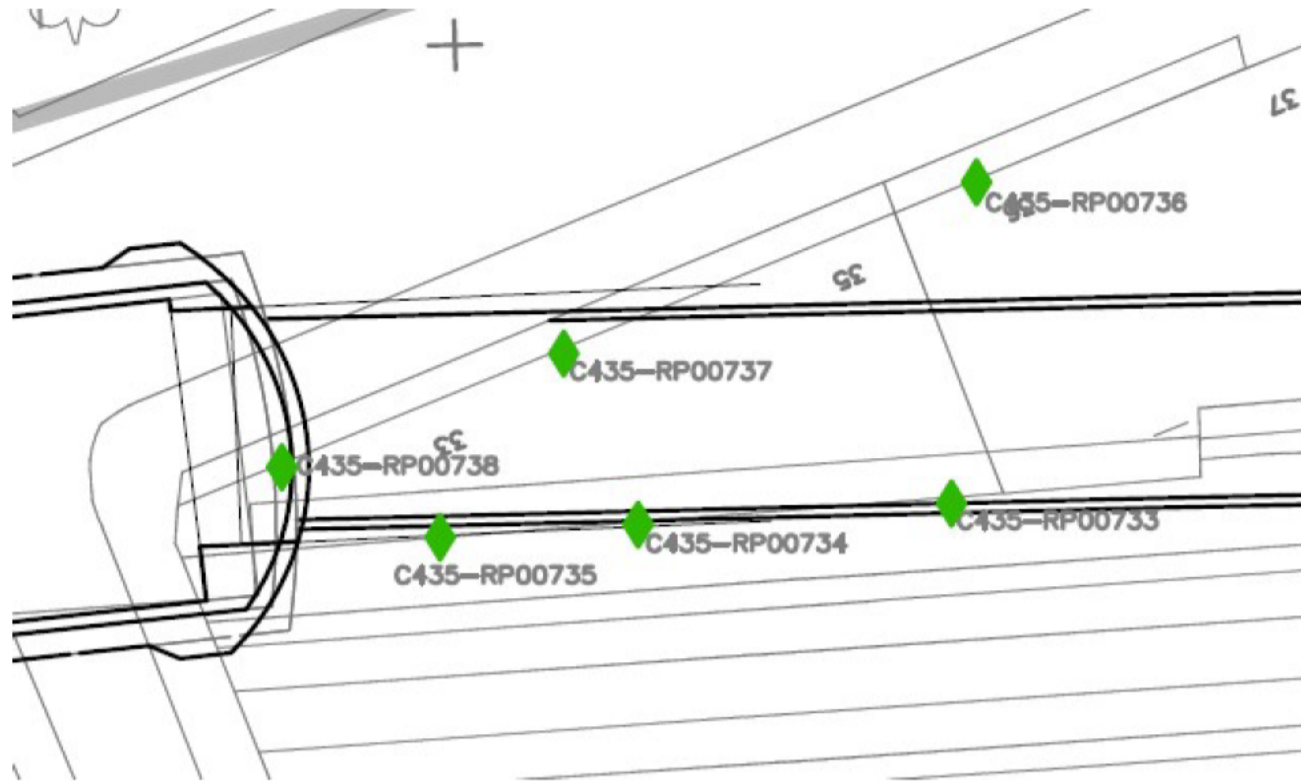
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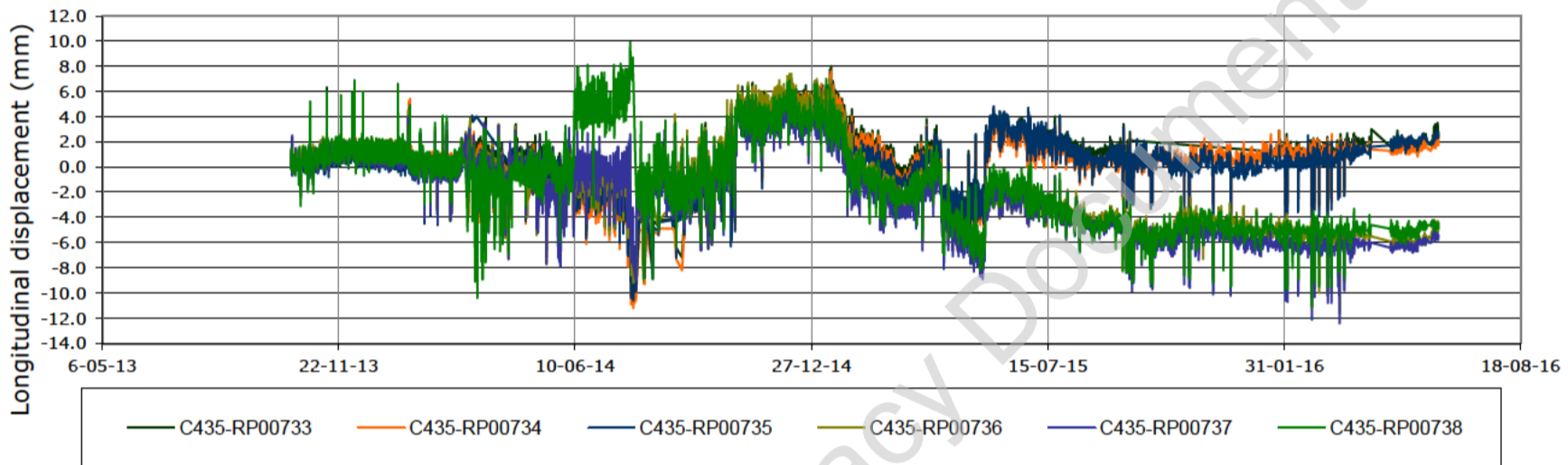
REMARKS:

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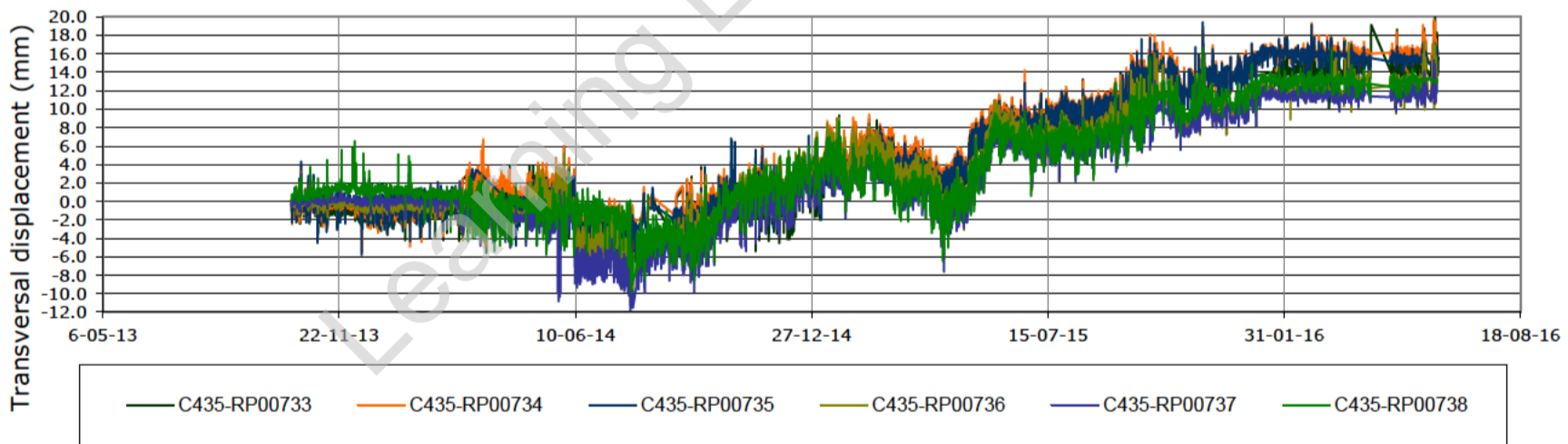
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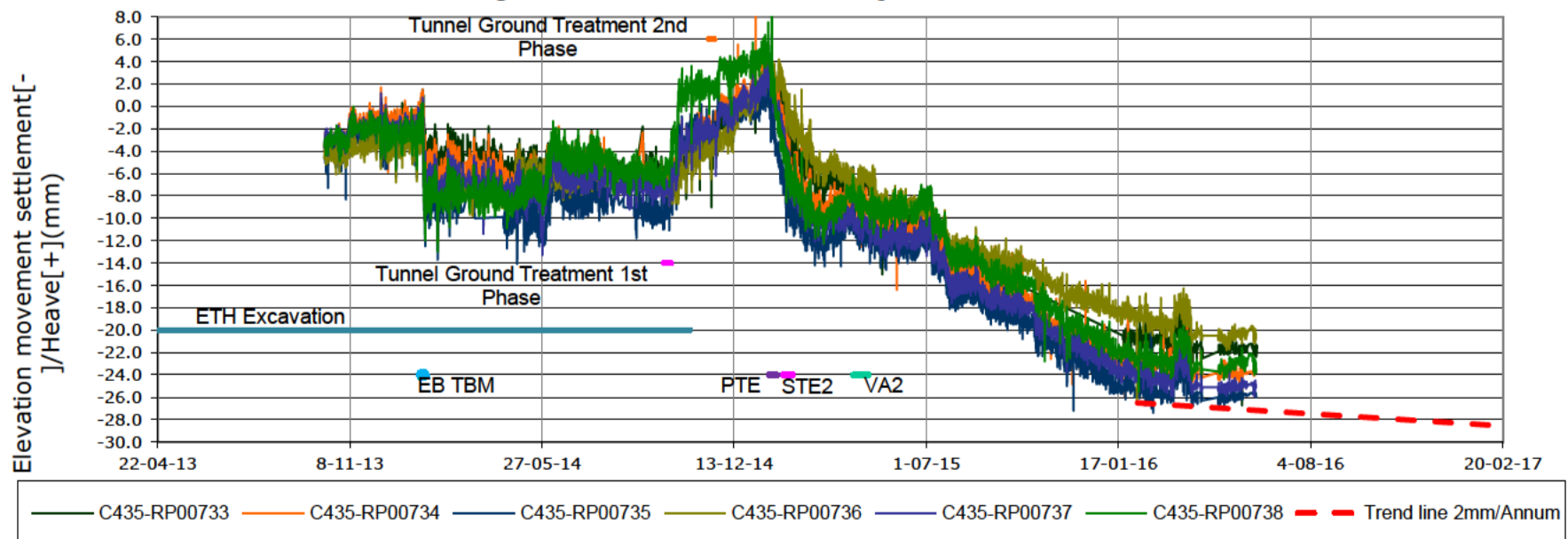
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Building: 33-37 CHARTERHOUSE SQUARE



Building: 33-37 CHARTERHOUSE SQUARE



REMARKS:



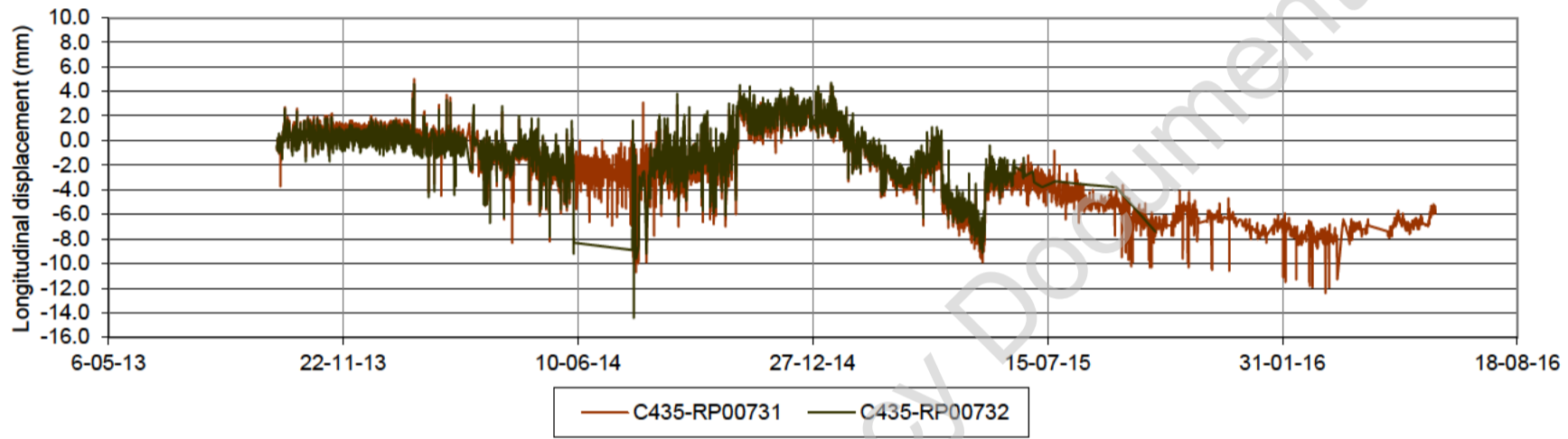


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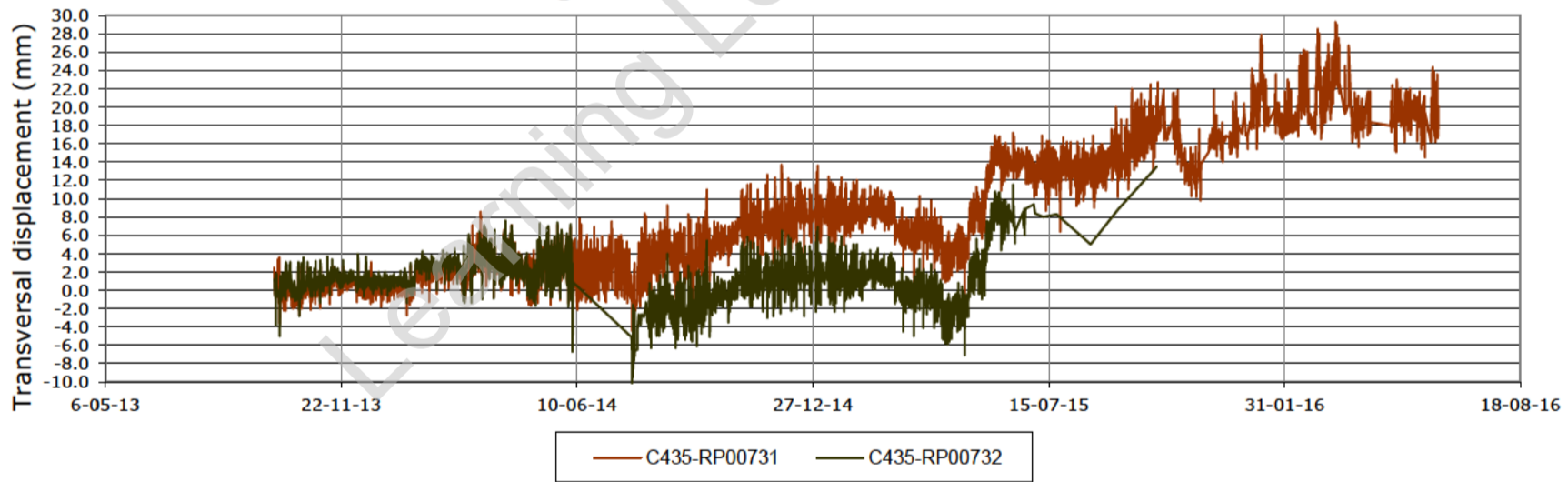
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Farringdon Station  
3D Target



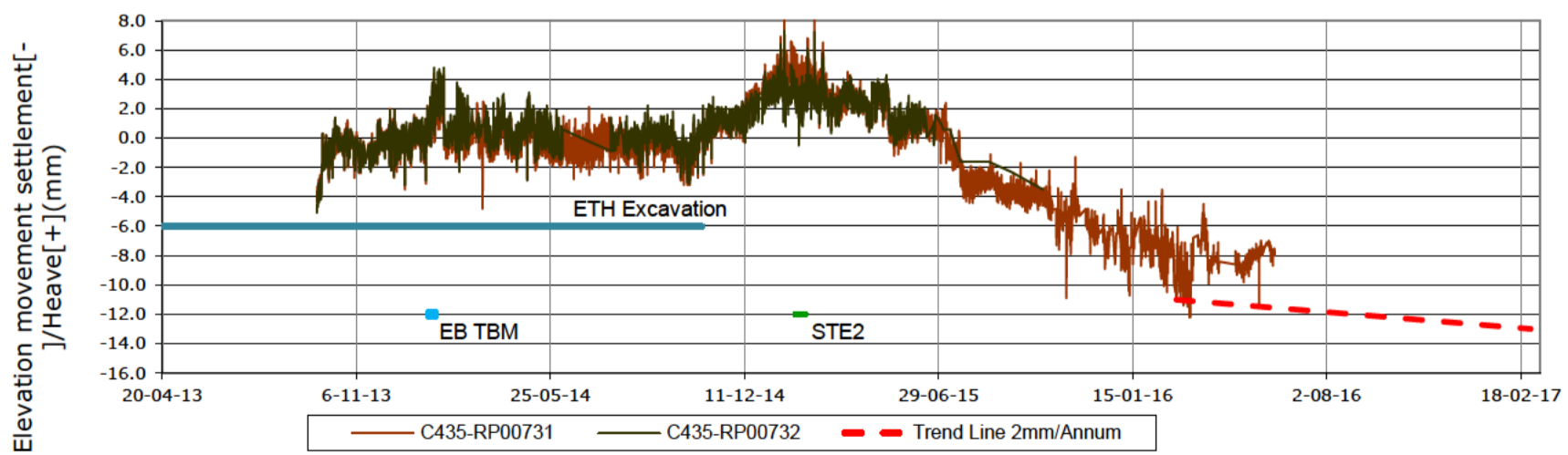
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Building: 38-40 CHARTERHOUSE SQUARE



Building: 38-40 CHARTERHOUSE SQUARE

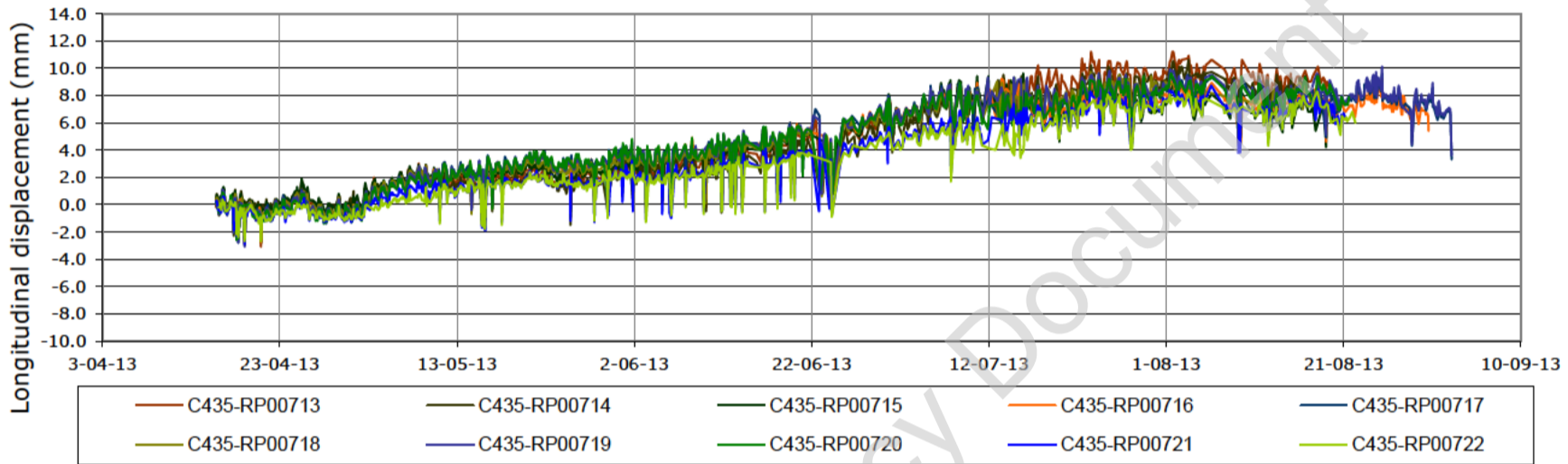


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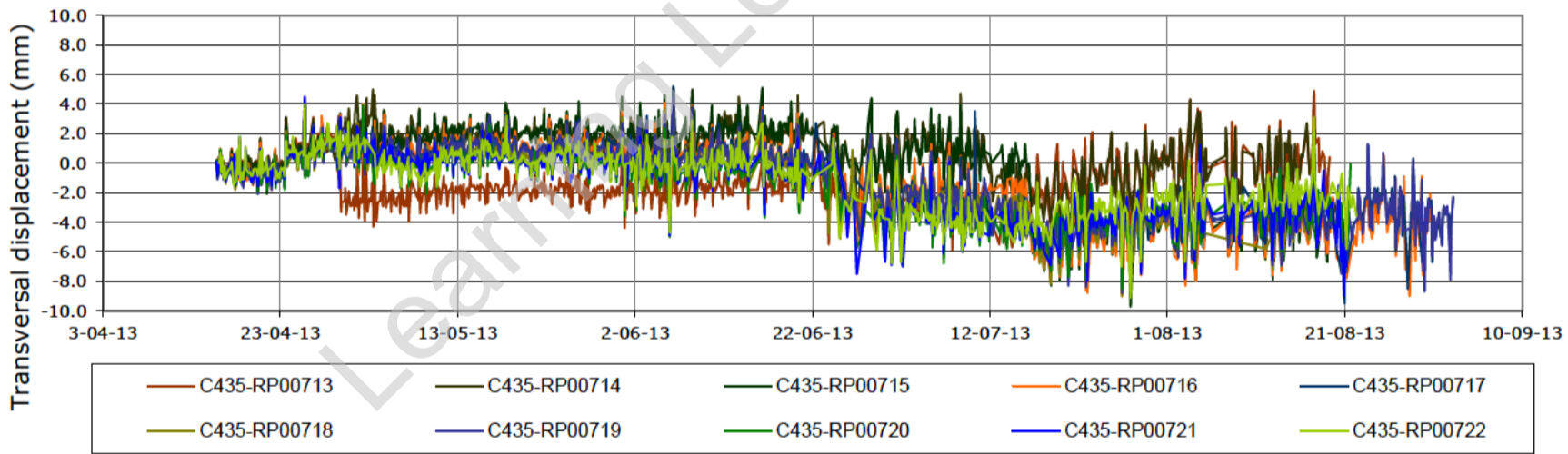
REPORT Automatic Prisms  
 AREA Farringdon Station  
 DEVICE 3D Target



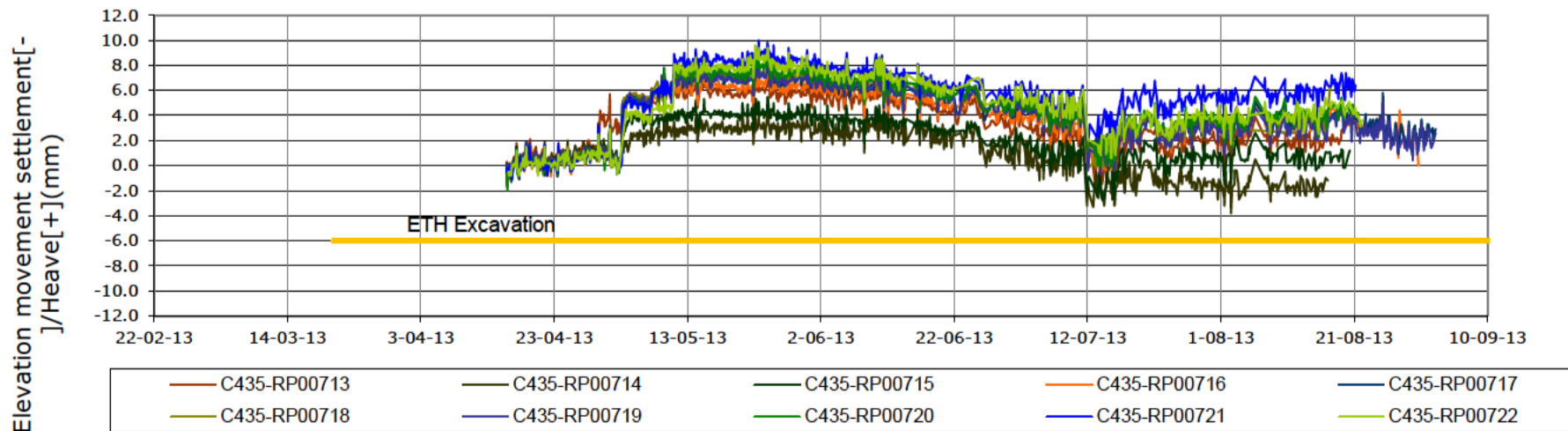
Building: Arch Lindsey Street Bridge



Building: Arch Lindsey Street Bridge



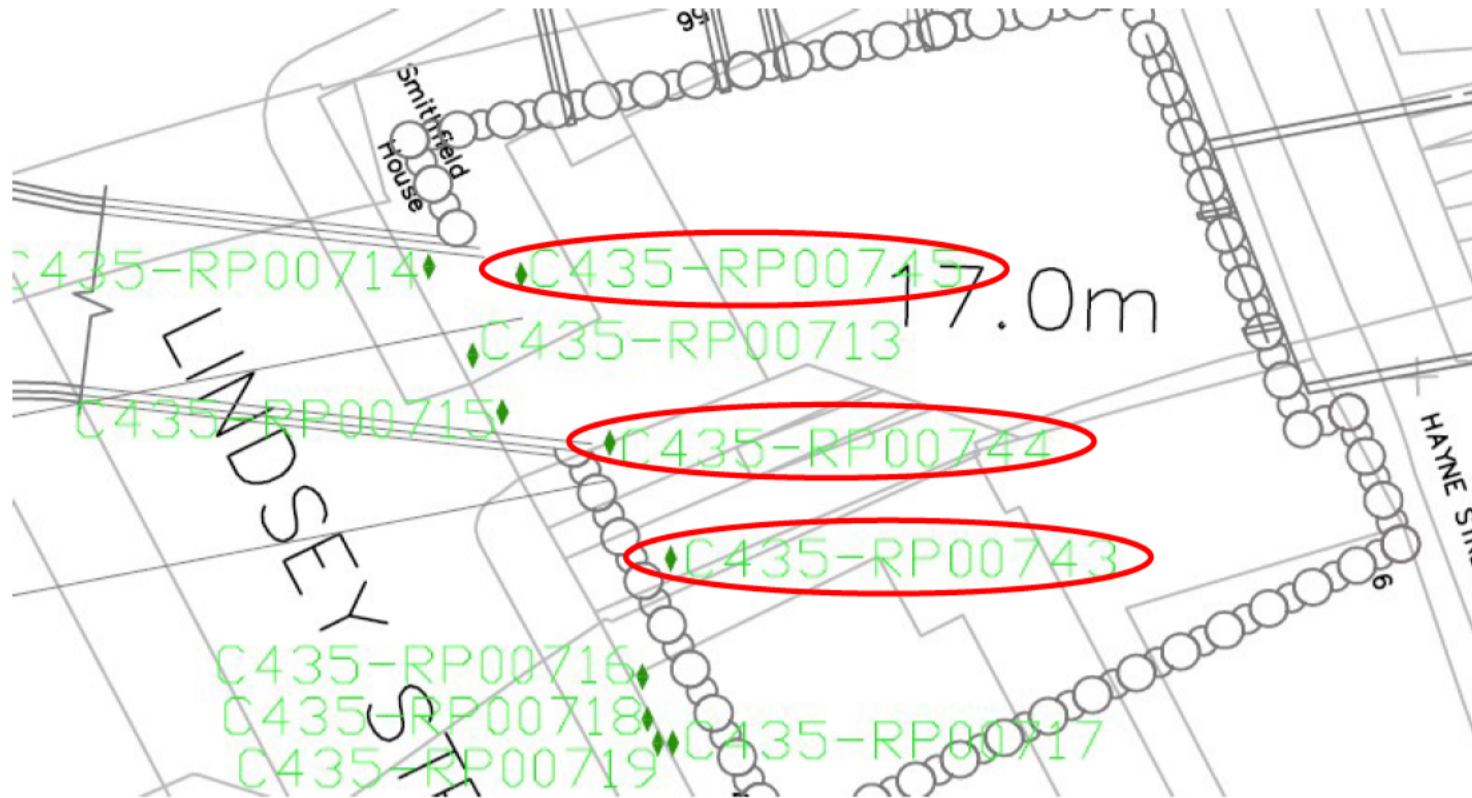
Building: Arch Lindsey Street Bridge



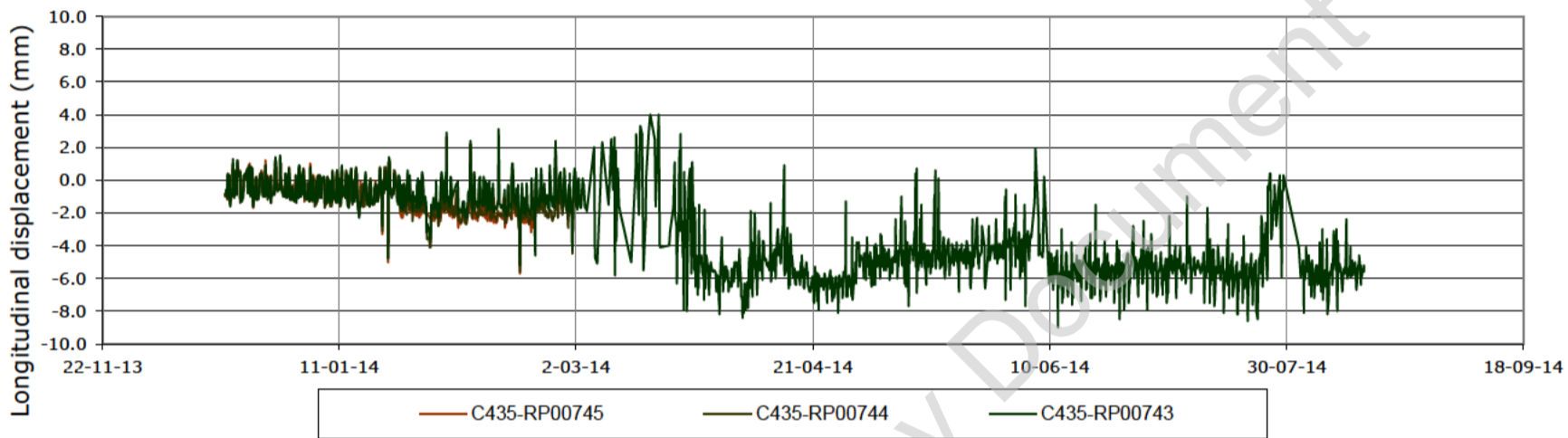
REMARKS:

REPORT  
AREA  
DEVICE

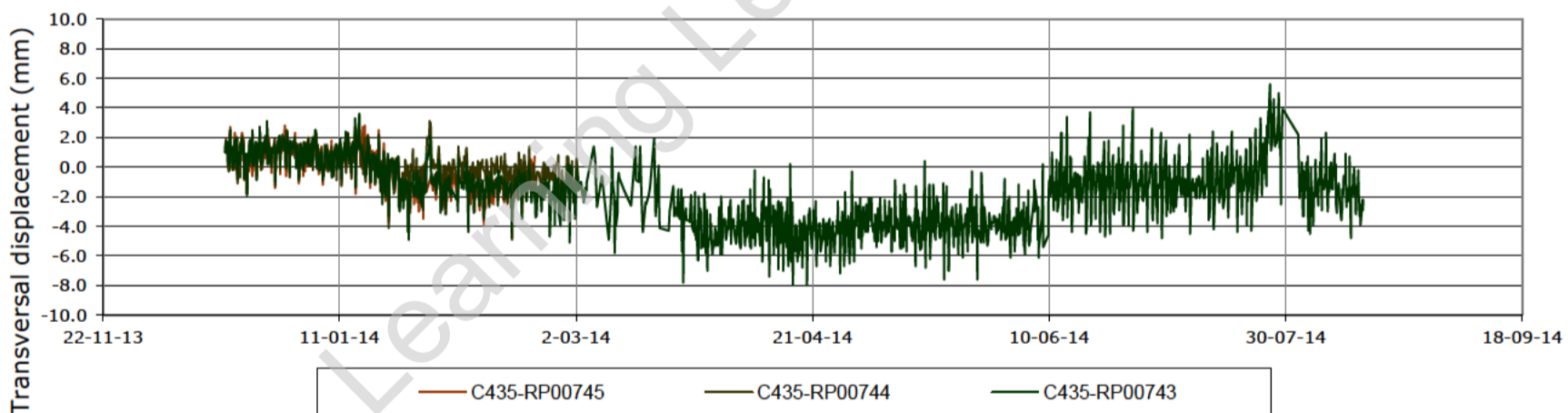
Automatic Prisms  
Farringdon Station  
3D Target



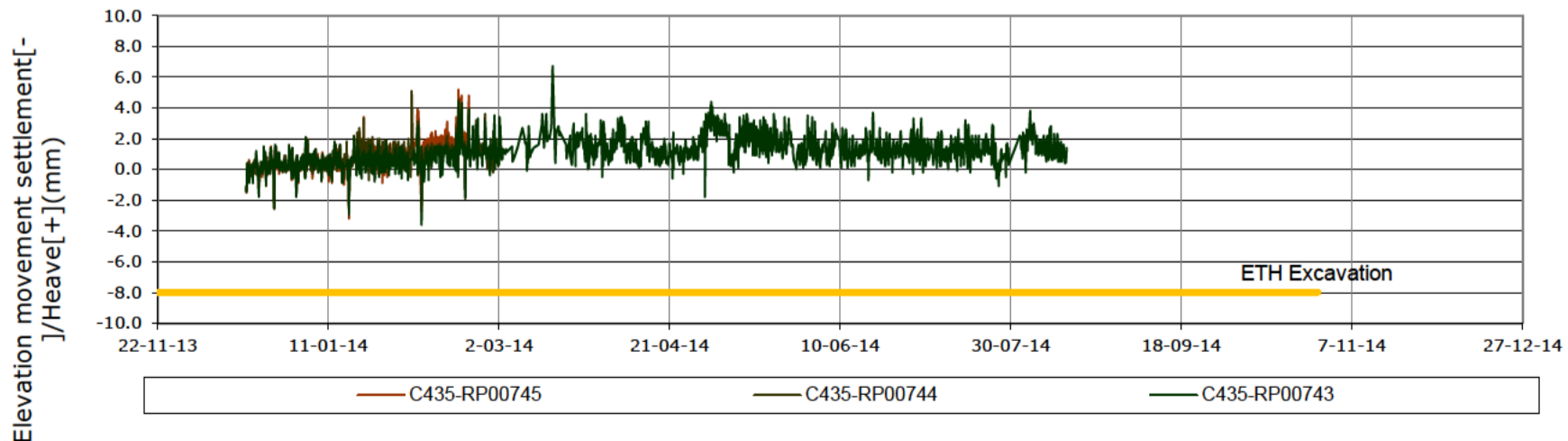
Building: ETH - Trapezoidal Shaft



Building: ETH - Trapezoidal Shaft



Building: ETH - Trapezoidal Shaft



**REMARKS:**

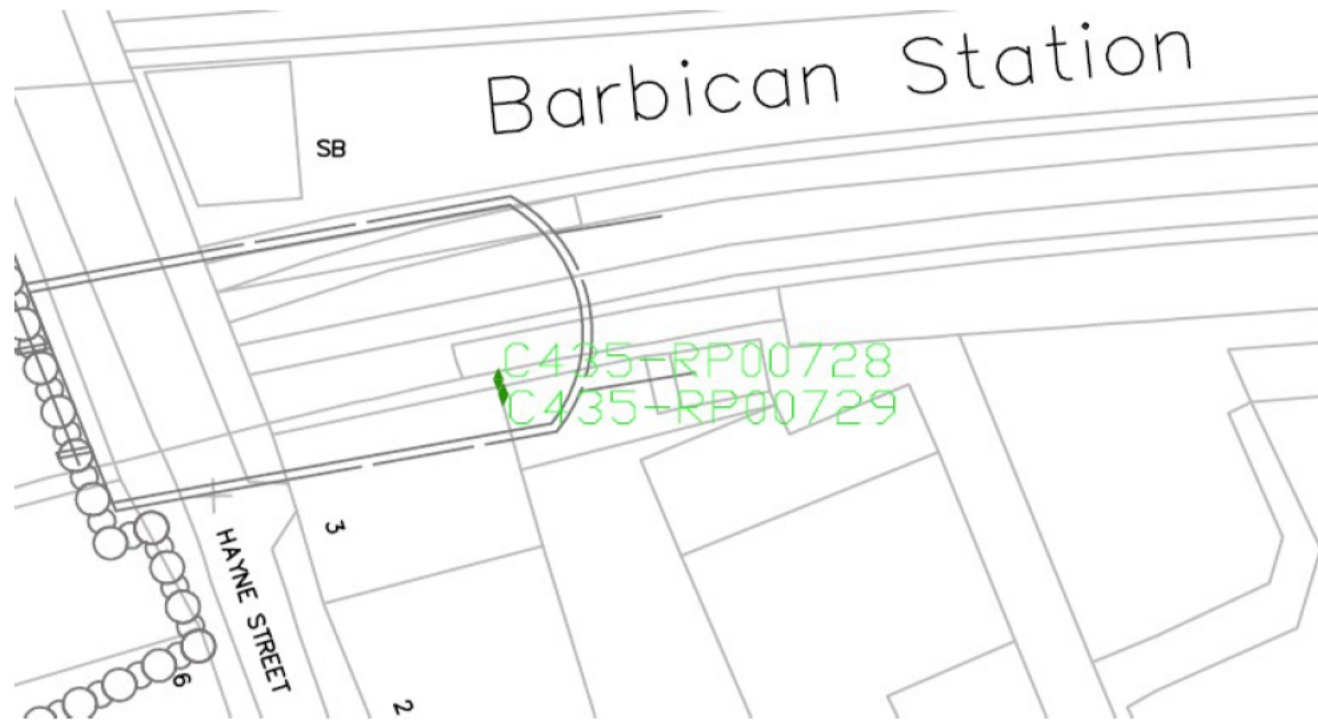
02-03-2014: Prisms C435-RP00744 and C435-RP00745 covered due to safety net installation.



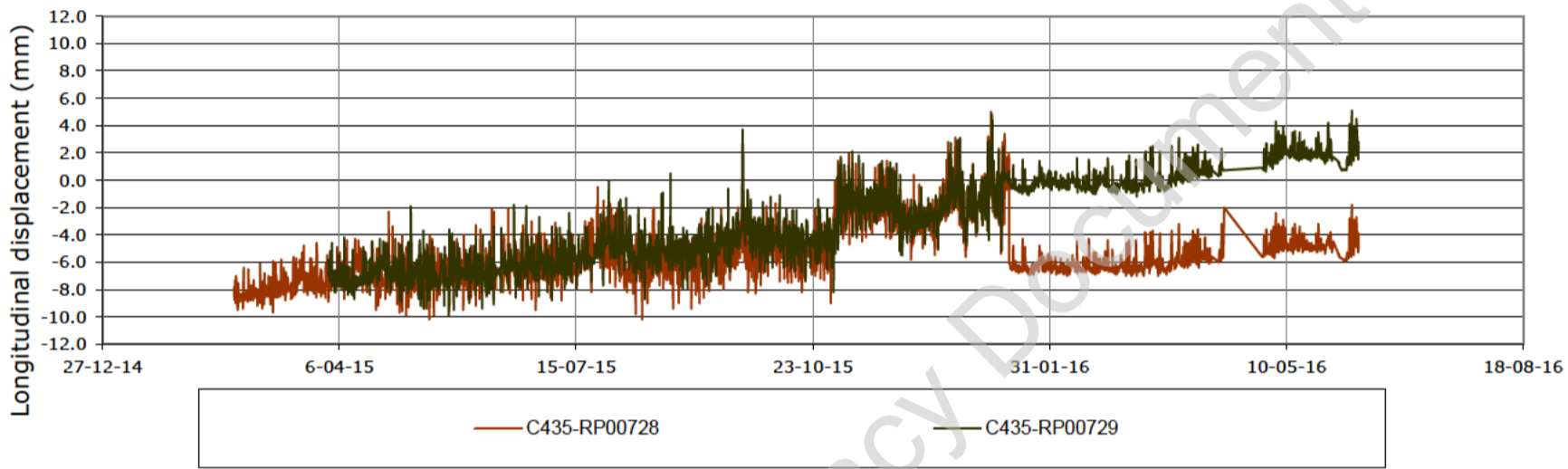
**GEOCISA UK**

REPORT  
AREA  
DEVICE

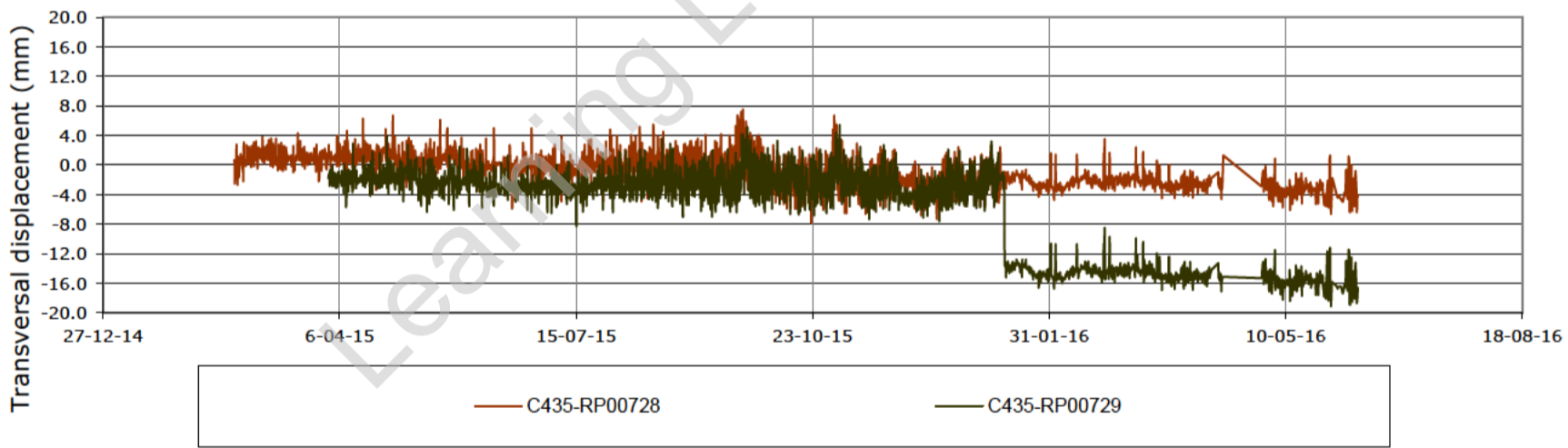
Automatic Prisms  
Farringdon Station  
3D Target



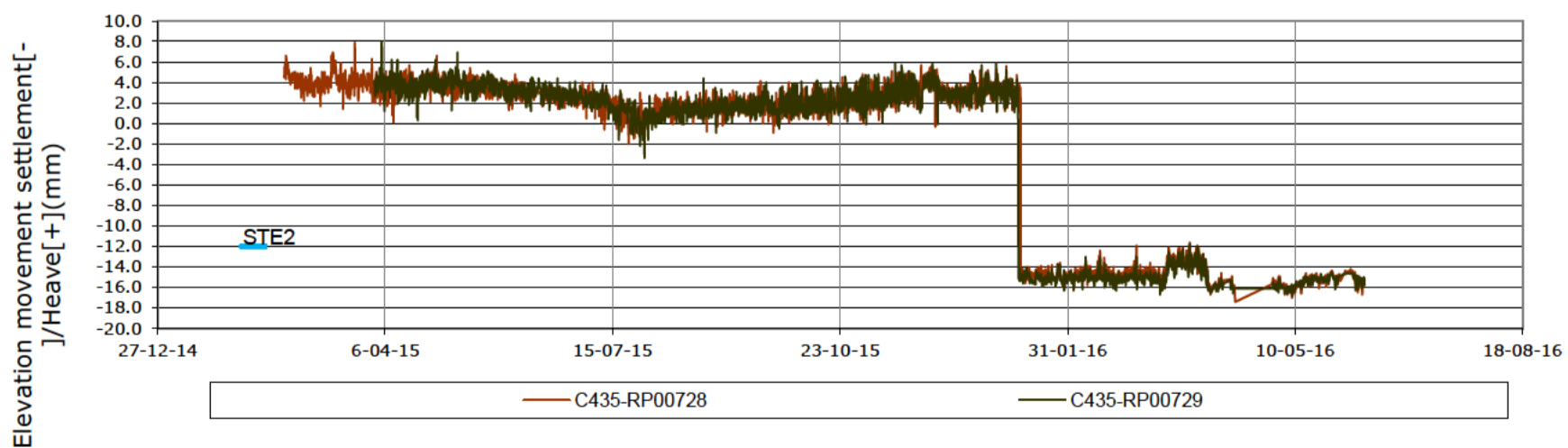
Building: Barbican Station Retaining Wall South



Building: Barbican Station Retaining Wall South



Building: Barbican Station Retaining Wall South



REMARKS:

## APPENDIX C: GLOSSARY

- ATS Automatic Total Station.
- ETH Eastern Ticket Hall.
- WB Westbound.
- TBM Tunnel Boring Machine.
- EB Eastbound.
- PTW Platform Tunnel West.
- PTE Platform Tunnel East.
- CP Cross Passages.
- CH Concourse Hall.
- VA Ventilation Adit.
- STE Stub Tunnel East.
- RTE Running Tunnel East.
- ES Escalator.
- TaM Tube a Machette.

Learning Legacy Document