A preliminary Ground Movement Assessment (GMA) has been carried out with Oasys Pdisp and Xdisp software for key construction stages; demolition, wall installation, excavation and proposed structure loading.

Thames Water & Cadent Gas Assets

The location of the Thames Water and Cadent Gas assets adjacent to the site are presented at the AKT drawing Ref. 4190-AKT-XX-XX-DR-S-00101 appended at the end of this document.
The figures below show the Thames Water sewers and mains, and Cadent Gas mains around the site as modelled in Oasys Xdisp in relationship to the basement layout. The geometry of the basement layout and assets have been slightly simplified for the purposes of this

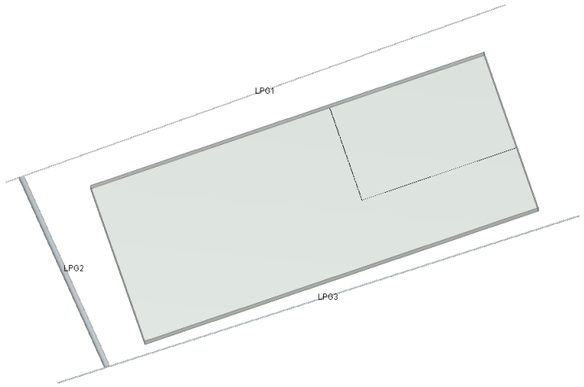

Figure 1 - Cadent Gas assets - Xdisp view

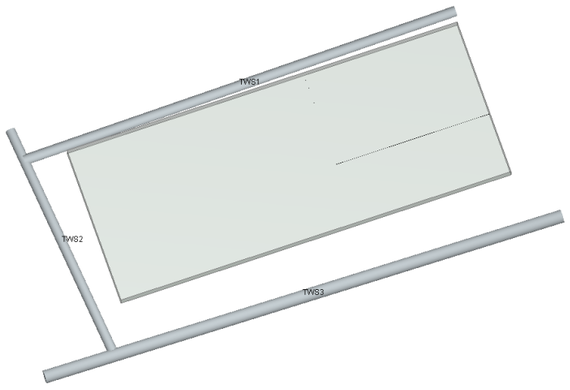

Figure 2 - Thames Water sewers - Xdisp view

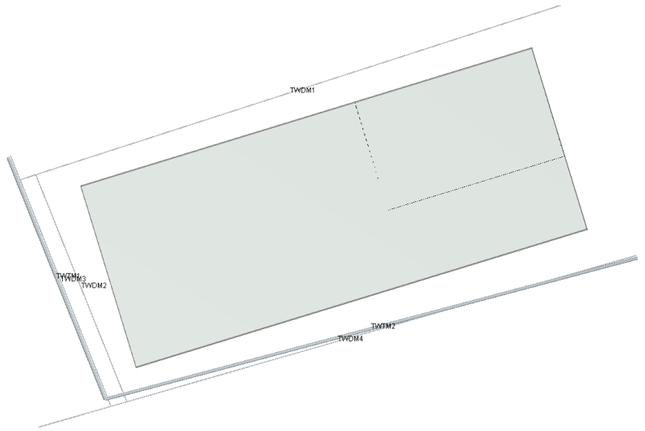

Figure 3 - Thames Water distribution and trunk mains - Xdisp view

The properties of the assets used in the analysis are presented in the table below. The properties were assigned in line with some local archive search data. Where some properties were not clear, these have been assumed, i.e. some material and lining thickness values.

The analysis should be updated if further data, i.e. future CCTV condition surveys or communication with the asset owners, prove these assumptions not to be valid.

Asset ID	Material	Diameter	Assumed lining Thickness (mm)
LPG1	PE Gas Main	125	20
LPG2	Cast Iron Gas Main	914	20
LPG3	PE Gas Main	180	20
TWS1	Masonry TW Sewer	1245	225
TWS2	Masonry TW Sewer	1143	225
TWS3	Masonry TW Sewer	1676	225
TWDM1	Cast Iron TW Main	102	20
TWDM2	Cast Iron TW Main	102	20
TWDM3	Cast Iron TW Main	102	20
TWDM4	Cast Iron TW Main	102	20
TWTM1	Cast Iron TW Main	406	20
TWTM2	Cast Iron TW Main	406	20

Table 1 - Thames Water distribution and trunk mains - Xdisp view

The acceptance criteria for each asset have been assumed based on previous experience in dealing with Thames Water and Cadent Gas assets and are summarised in the tables below.

In AKT's experience no assessment is required for PE gas mains. However, the results for this kind of assets have been included for reference.

Table 1 - Assessment Criteria for Existing Thames Water Pipeline and Sewer Assets

PIPE TYPE	Diameter (mm)	Allowable Increase in Strain (□□)		Rotation (deg.)
		Tension	Compression	
Brick Sewer (red / yellow / blue brick)	N/A	500	25% of the allowable stress	N/A
Cast Iron Lead-yarn joints	N/A	100	1200	0.1
Ductile Iron (Lead-yarn gasket joints)	N/A	500	700	0.5
Ductile Iron (Rubber gasket joints)	N/A	500	700	2.0
Steel	N/A	450	450	1.5
Vitrified Clay	<125	80	400	0.5
	>125	80	400	See Table 2
Concrete (unreinforced)	<225	20	400	0.5
	225 – 750	40	400	See Table 2
	>750	60	400	

Table 2 - Maximum Rotation for Vitrified Clay and Concrete Pipes

Diameter (mm)	Rotation (deg.)
< 375	2.0
375 – 750	1.0
750 – 1400	0.5
> 1400	0.3

Figure 4 - Thames Water limitng criteria (extract from Thames Water - Guidance on piling, heavy loads, excavations, tunnelling and dewatering)

Thames Water Asset Type	Pullout		Rotation	Axial Strain		Flexural Strain	
	Axial	Flexural		Tensile	Compressive	Tensile	Compressive
Masonry	1	1	1	1	1	2	1
Cast Iron	0.2	1	1	0.2	0.2	1	1

Table 2 - Thames Water reduction factors

Cadent Gas Asset Type	Pullout	Rotation	Allowable Strain	
			Tension	Compression
	(mm)	(°)	(mm)	(mm)
Cast Iron Gas Main	1.5	0.45	150	1200

Table 3 - Cadent Gas limiting criteria

Cadent Gas Asset Type	Reduction Factors						
	Pullout		Rotation	Axial Strain		Flexural Strain	
	Axial	Flexural		Tensile	Compressive	Tensile	Compressive
Cast Iron Gas Main	0.4	1	1	0.4	0.4	0.4	0.4

Table 4 - Cadent Gas reduction factors

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PROJECT 247 Tottenham Court Road		TITLE Preliminary Thames Water & Cadent Gas GMA	
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DRAWN LK	CHECKED MW	PROJECT No. 4190	DRAWING No. -	REV R00

Ground Conditions

The following ground conditions have been assumed based on historical boreholes and limited draft logs from a recent site investigation carried out on site. If the ground conditions on site are found significantly variable than presented below, the analysis shall be re-taken.

Stratum	Top Level (mOD)*	Thickness (m)	C_U (kN/m^2)	E_U for GMA (kN/m^2)	E' for GMA (kN/m^2)
Ground Level/ Existing Basement/ Made Ground	27.2	5.2	-	-	10000
Lynch Hill Gravel	22	3	-	-	40000
London Clay	19	25	70+7z	30000+3000z	24000+2400z
Lambeth Group	-6	10	200	200000	160000
Thanet Sand	-16	-	-	-	300000
* Ground Level varies from North to South					

Figure 4 - Summary of assumed ground conditions

Methodology & Results

The demolition and loading stages were carried out in Pdisp using the Boussinesq method. Movements due to wall installation have been estimated with the use of the ground movement curves provided in CIRIA C760, modified according to the findings presented in Ball et al.

A preliminary retaining wall analysis has been carried out in order to estimate the excavation induced movements behind the secant piled wall. Two levels of temporary props of a minimum equivalent stiffness of 50MN/m/m have been assumed for the double basement, one at the top and one near the middle of the excavation, and a single level of props for the single basement. Piling has been assumed to be carried out from existing ground level, but the excavation level within Xdisp has been assumed to be carried out from existing basement level. Construction details shall be confirmed when a competent Contractor gets on board and the current analysis might have to be retaken. The deflection profile from Wallap for the double basement was assumed to be limited to about a maximum horizontal deflection of less than 10mm or just under 0.15% of the excavation depth modelled within Xdisp. A rigorous propping system shall be developed in order to allow for this movement not to be exceeded during excavation stage. The defection profile was “stretched” to an influence zone of about 4 times the excavation depth for the horizontal movements in accordance with the suggestions of CIRIA C760. The vertical deflection was taken as half the horizontal movement value and the profile was stretched in a similar way to about 3.5 times the excavation depth.

The results in terms of ground movement plots at surface level are presented below as well as a summary of the estimated maximum movement, strain, rotation, pullout and curvature values for each asset for each stage. The displacement contour plots are presented separately for each construction stage, to highlight the effect of each stage, but the cumulative effect was taken into account for the asset assessment.

A smoothing exercise was carried out in order to smooth out the predicted displacement profiles and avoid unrealistic peaks in displacement values that might result to unrealistic exceedances of the limiting criteria for one of the Thames Water sewers. Smoothing was undertaken for all stages following wall installation stage for TWS1. The exercise was mostly limited to smoothing unrealistic peaks related to the geometry of the modelled basement and it is not considered to have significantly influenced the results in an onerous way.

Vertical movement is considered to be positive when downwards (compression) and negative when upwards (heave). Positive horizontal movement is movement towards the excavation.

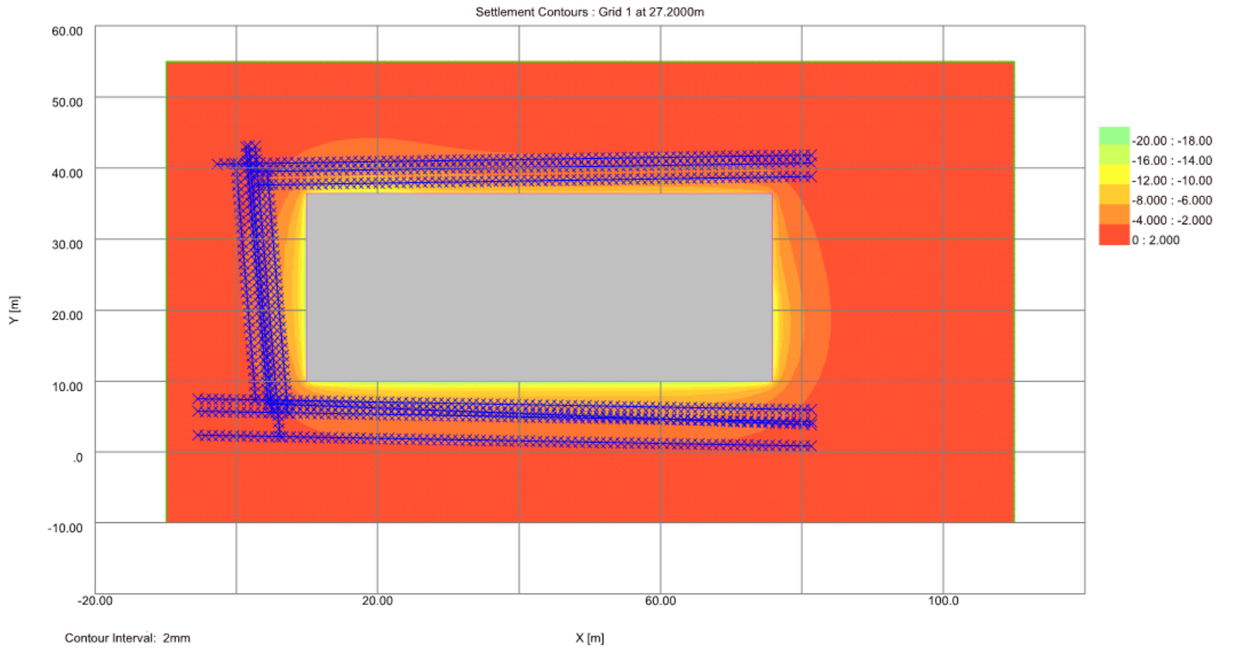

Figure 5 - Vertical Movement Contour Plot - Demolition Stage (PDisp)

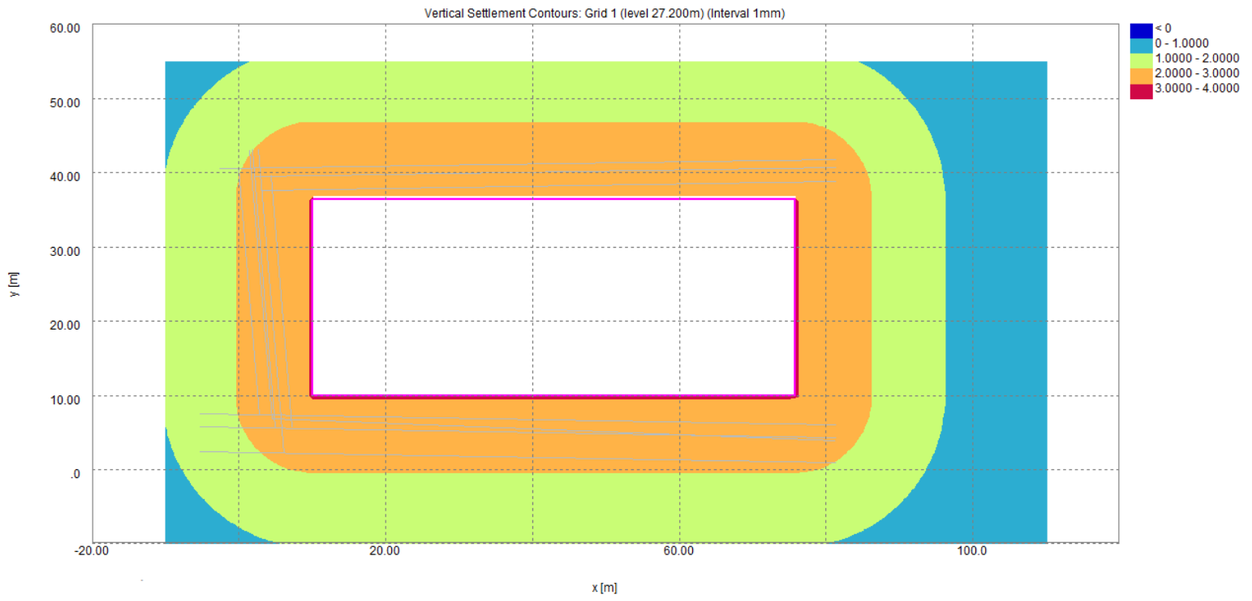

Figure 6 - Vertical Movement Contour Plot - Wall Installation Stage (CIRIA C760 curves reduced as per Ball et al.)

PROJECT	247 Tottenham Court Road			TITLE	Preliminary Thames Water & Cadent Gas GMA
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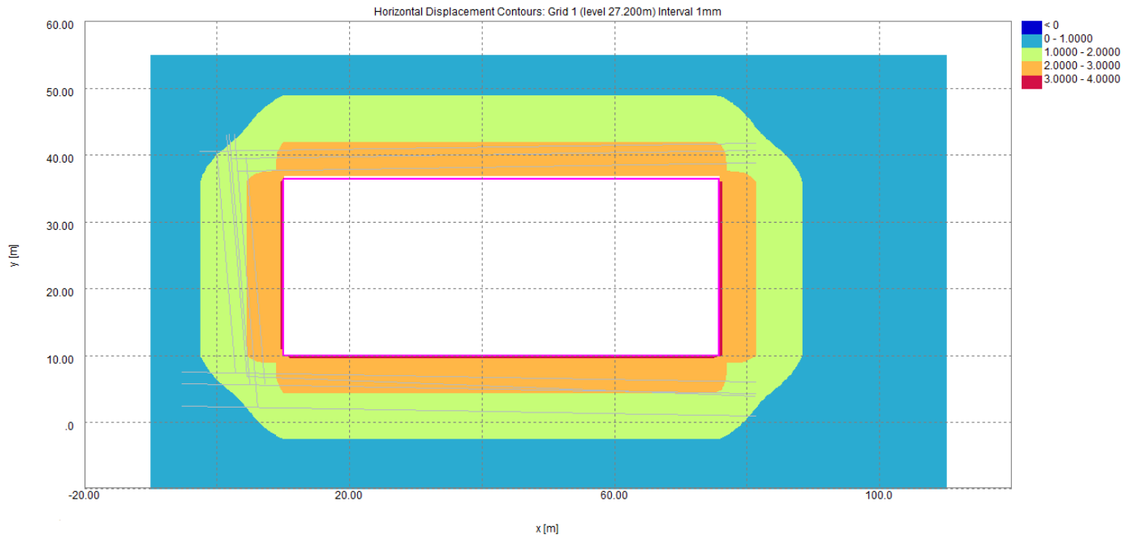

Figure 7 - Horizontal Movement Contour Plot - Wall Installation Stage (CIRIA C760 curves reduced as per Ball et al.)

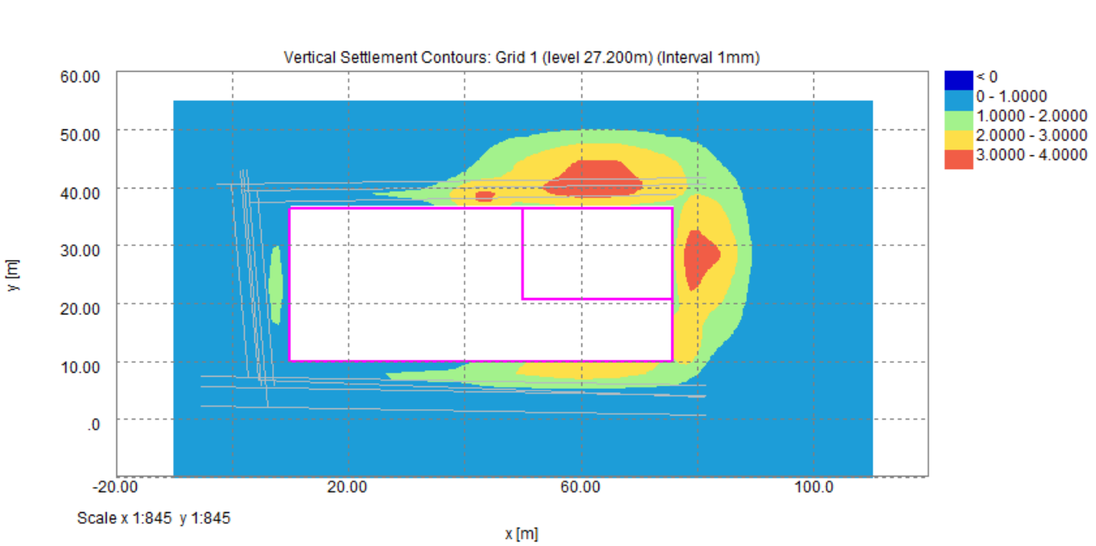

Figure 8 - Vertical Movement Contour Plot - Excavation Stage (CIRIA C760 curves)

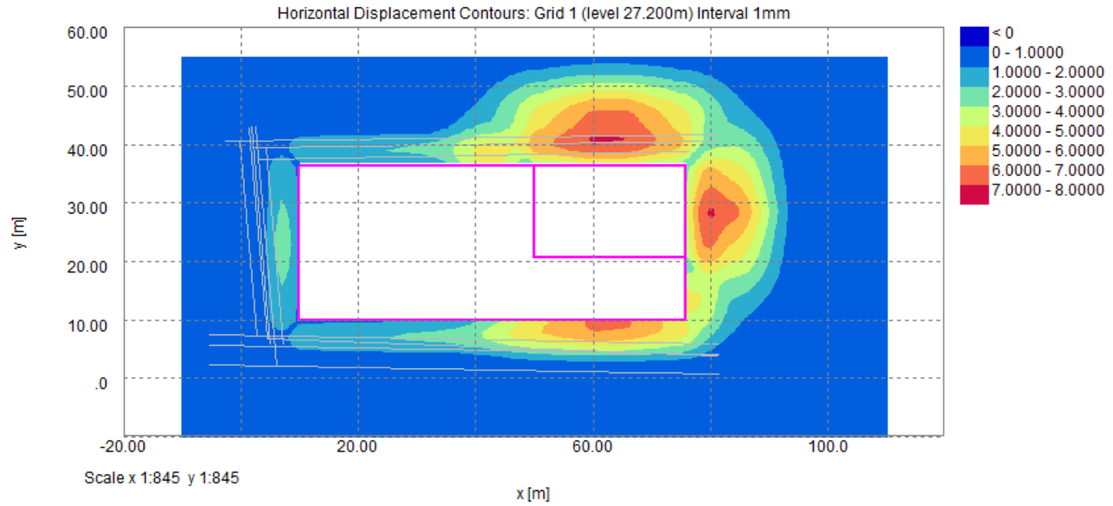

Figure 9 - Horizontal Movement Contour Plot - Excavation Stage (CIRIA C760 curves)

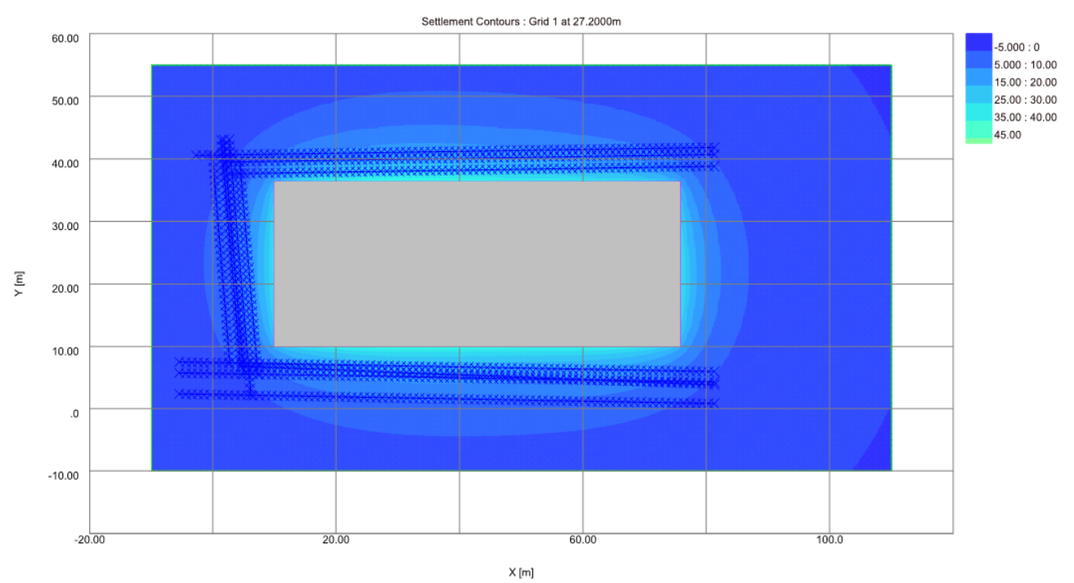

Figure 10 - Vertical Movement Contour Plot - Proposed Loading Stage (PDisp)

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PROJECT	247 Tottenham Court Road			TITLE	Preliminary Thames Water & Cadent Gas GMA		
DATE	30/10/2020	SCALE	NTS	CAD FILENAME	-	STATUS	-
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Asset ID	Max Pullout Factored (mm)	Max Rotation Factored (°)	Max Strain Tension Factored (με)	Max Strain Compression Factored (με)	Min Radius of Curvature (m)	Max Vertical Displacement mm)	Max Horizontal Displacement (mm)
LPG1	-	-	3	-3	27272	-2	-
LPG2	0.04	<0.01	3	-3	75099	1	-
LPG3	-	-	6	-6	19129	-5	-
TWS1	-	-	419	-209	4052	-10	-
TWS2	-	-	83	-41	19286	-4	-
TWS3	-	-	29	-15	72205	-1	-
TWDM1	0.02	0.01	4	-4	18995	-3	-
TWDM2	0.02	0.01	4	-4	18672	-3	-
TWDM3	0.01	<0.01	2	-2	41194	-1	-
TWDM4	0.01	<0.01	2	-2	35312	-3	-
TWTM1	0.03	<0.01	5	-5	46347	-1	-
TWTM2	0.05	0.01	10	-10	23335	-3	-

Table 5 - Results Summary - Demolition Stage

Asset ID	Max Pullout Factored (mm)	Max Rotation Factored (°)	Max Strain Tension Factored (με)	Max Strain Compression Factored (με)	Min Radius of Curvature (m)	Max Vertical Displacement mm)	Max Horizontal Displacement (mm)
LPG1	-	-	66	-275	3909	3	2
LPG2	0.13	0.01	3	-63	11892	3	2
LPG3	-	-	91	-428	3227	3	-2
TWS1*	-	-	325	-559	6962	-7	3
TWS2	-	-	255	-351	4068	3	2
TWS3	-	-	117	-179	13516	3	-2
TWDM1	0.06	0.02	6	-83	2364	3	2
TWDM2	0.05	0.02	4	-95	3398	3	2
TWDM3	0.03	0.01	2	-50	7015	3	2
TWDM4	0.05	0.02	15	-57	5918	3	-2
TWTM1	0.09	0.01	12	-67	5622	3	2
TWTM2	0.16	0.02	27	-113	4409	3	2

Table 6 - Results Summary - Demolition & Wall Installation Stage

** A smoothing exercise has been carried out.*

Asset ID	Max Pullout Factored (mm)	Max Rotation Factored (°)	Max Strain Tension Factored (με)	Max Strain Compression Factored (με)	Min Radius of Curvature (m)	Max Vertical Displacement mm)	Max Horizontal Displacement (mm)
LPG1	-	-	297	-579	2246	6	9
LPG2	0.16	0.01	11	-68	11262	3	2
LPG3	-	-	211	-649	1831	3	-7
TWS1*	-	-	464	-960	8593	-6	9
TWS2	-	-	255	-351	4068	3	2
TWS3	-	-	203	-188	8504	3	-2
TWDM1	0.18	0.05	70	-160	1314	5	9
TWDM2	0.09	0.04	6	-148	1970	3	4
TWDM3	0.05	0.02	4	-67	3871	3	3
TWDM4	0.07	0.03	15	-86	3212	3	-5
TWTM1	0.16	0.02	28	-95	3643	3	2
TWTM2	0.29	0.04	55	-189	2450	3	5

Table 7 - Results Summary - Demolition & Wall Installation & Excavation Stage

Asset ID	Max Pullout Factored (mm)	Max Rotation Factored (°)	Max Strain Tension Factored (με)	Max Strain Compression Factored (με)	Min Radius of Curvature (m)	Max Vertical Displacement mm)	Max Horizontal Displacement (mm)
LPG1	-	-	296	-578	2243	22	9
LPG2	0.17	0.01	12	-68	10978	10	2
LPG3	-	-	218	-648	1817	22	-7
TWS1*	-	-	414	-853	8138	29	9
TWS2	-	-	255	-355	4062	11	2
TWS3	-	-	203	-186	8599	11	-2
TWDM1	0.17	0.05	69	-160	1313	25	9
TWDM2	0.10	0.04	7	-148	1947	16	4
TWDM3	0.06	0.02	4	-67	3806	12	3
TWDM4	0.07	0.03	16	-86	3241	18	-5
TWTM1	0.16	0.02	28	-96	3601	11	2
TWTM2	0.30	0.04	56	-188	2424	19	5

Table 8 - Results Summary - Demolition & Wall Installation & Excavation & Loading Stage

Conclusions

The results indicate that all the assets are below the limiting criteria set by Thames Water and Cadent Gas.

The impact to the Thames Water and Cadent Gas assets from the proposed development is considered to be low.

The analysis shall be re-taken in the case that any future surveys of the assets or site-specific ground investigations suggest different conditions than those assumed within this assessment or in the case of construction details not compatible with the assumptions of this assessment being adopted.

It is recommended that ground movement monitoring be undertaken, prior to and during the proposed construction works in the area surrounding the site, in order to verify the conservative nature of the assessment carried out. Pre and post condition surveys should be undertaken to record the existing and post construction condition of the sewers.

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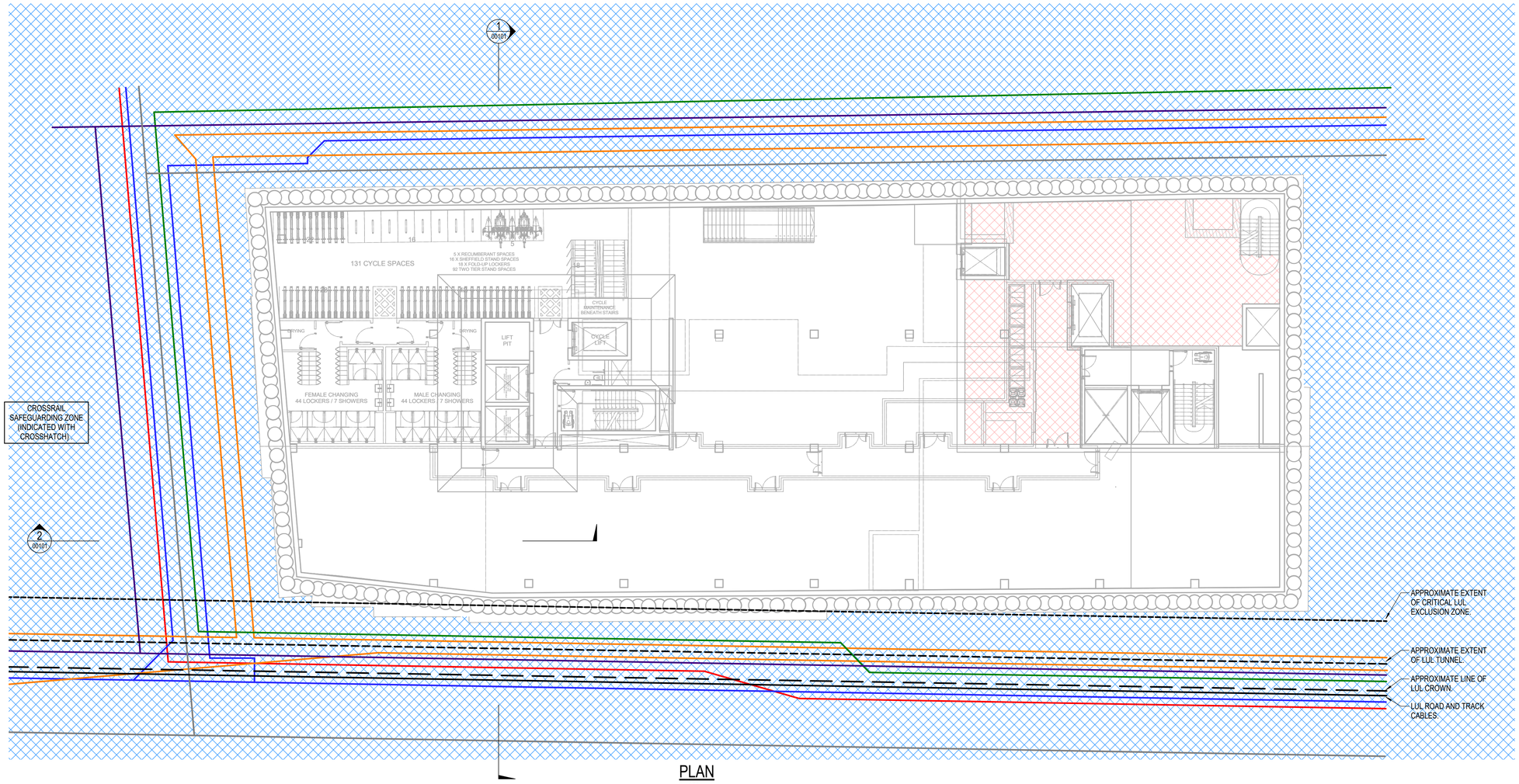
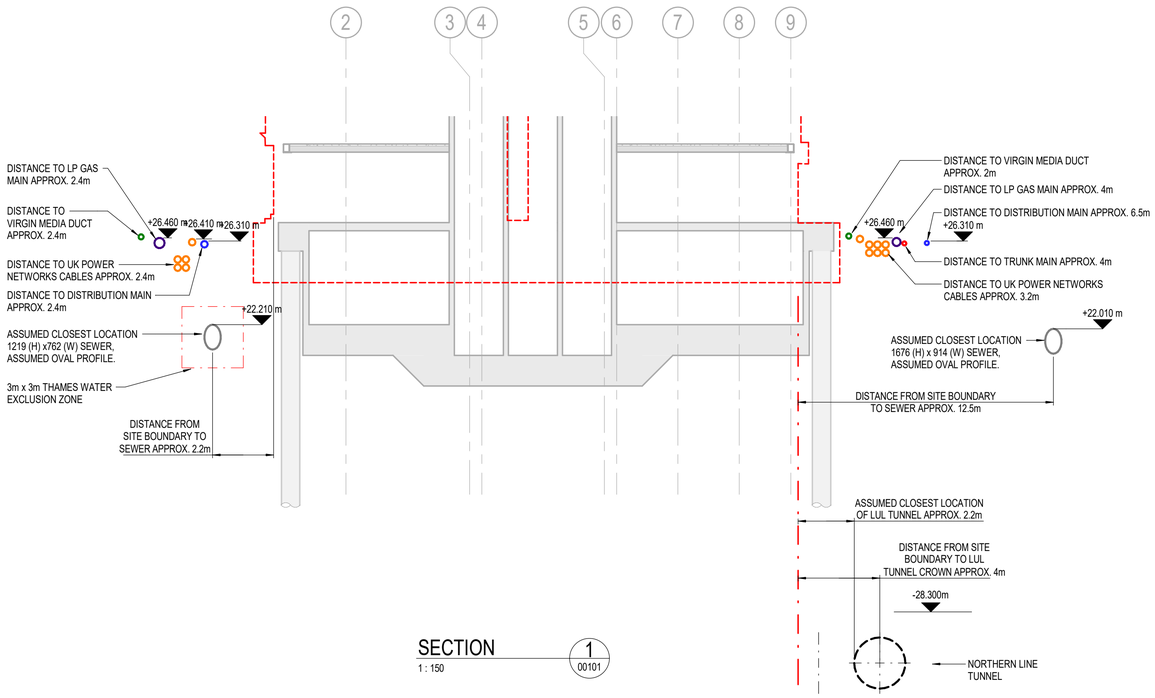


PLAN
1 : 150



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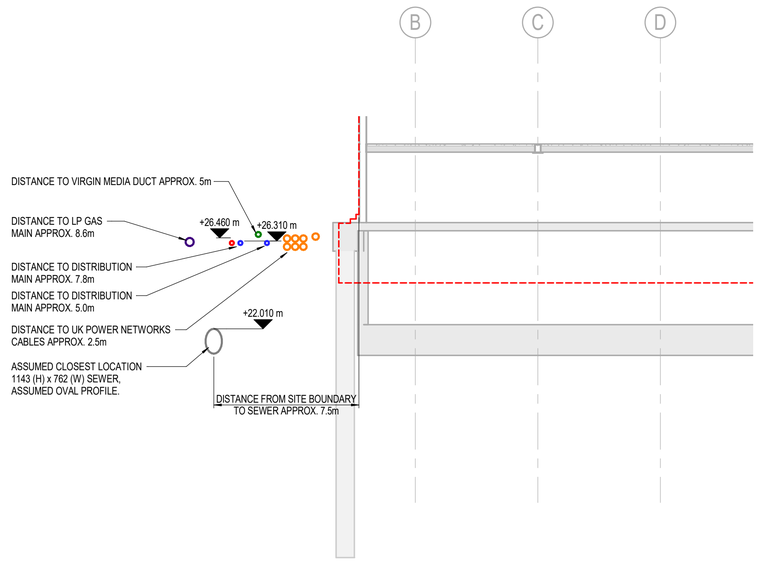

SECTION 2
1 : 150

NOTES

1. DO NOT SCALE FROM THIS DRAWING.
2. ALL DIMENSIONS ARE IN MILLIMETRES AND ALL LEVELS ARE IN METRES.
3. THIS DRAWING TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS AND ENGINEERS DRAWINGS AND SPECIFICATIONS.

EXISTING SERVICES LEGEND

- THAMES WATER TRUNK MAIN
- THAMES WATER DISTRIBUTION MAIN
- THAMES WATER SEWER PIPE
- NATIONAL GRID LP GAS MAIN
- UK POWER NETWORKS CABLE
- VIRGIN MEDIA CABLE
- LONDON UNDERGROUND TUNNEL
- LONDON UNDERGROUND CABLES

REV.	DATE	DESCRIPTION	BY	CHECKED

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W www.akt-uk.com

CLIENT

M&G / PRUDENTIAL UK REAL ESTATE LP

PROJECT

247 TOTTENHAM COURT ROAD

TITLE

SITE CONSTRAINTS
EXISTING SERVICES

RT	11.08.20	KT	A1
DRAWN BY	DRAWN DATE	CHECKED BY	SHEET SIZE
4190	STAGE 2	S4	1:100
PROJECT No.	PROJECT STAGE	SUITABILITY CODE	SCALE

STAGE 2

4190	AKT	XX	XX	DR	S	00101
PROJECT ID	ORIGINATOR	ZONE	LEVEL	TYPE	ROLE	DRAWING No.	REVISION