A-squared Studio

Harrington Square

Northern Line Ground Movement Assessment

September 2023

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Project Name	Harrington Square
Project Number	2874
Client	Salboy (Mornington Crescent) Limited
Document Name	Northern Line Ground Movement Assessment

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Appendices

1. Introduction

A-squared Studio Engineers Ltd has been appointed by Salboy (Mornington Crescent) Limited to undertake a Ground Movement Assessment (GMA) of London Underground Limited (LUL) tunnels within the zone of influence of the proposed development at the land adjacent to Hurdwick House, Harrington Square, Camden, London, NW1 2JE (herein called the 'site').

The A-squared scope comprises an assessment of the potential impact of the proposed development works on selected LUL assets (i.e. railway tunnels) located in the vicinity of the proposed development site.

1.1. Study Aims and Objectives

A ground movement and impact assessment has been carried out in order to estimate the potential damage induced by the proposed Harrington Square development on a number of nearby LUL assets.

The assessment encompasses nearby LUL assets (Northern Line running tunnels) running adjacent to the site at approximately 21 meters below ground level (mbgl) (i.e. approximately 3mOD). The GMA assessment is based on *greenfield* ground movements and *unlikely to be exceeded* ground movements. The adopted assessment methodology provides a robust and conservative assessment representative of current industry best practice, as detailed in Section 5.

The assessment carried out and described herein aims to:

- Assess the impact of ground movements induced by the proposed works on the LUL assets in the proximity of the development under consideration.
- Provide performance criteria and inform aspects of substructure construction and design.

This report provides a detailed description of the:

- Site and proposed development.
- Modelling parameters and input.
- Analyses and results.

2. The Site & Development

2.1. Site Location and Proposed Development

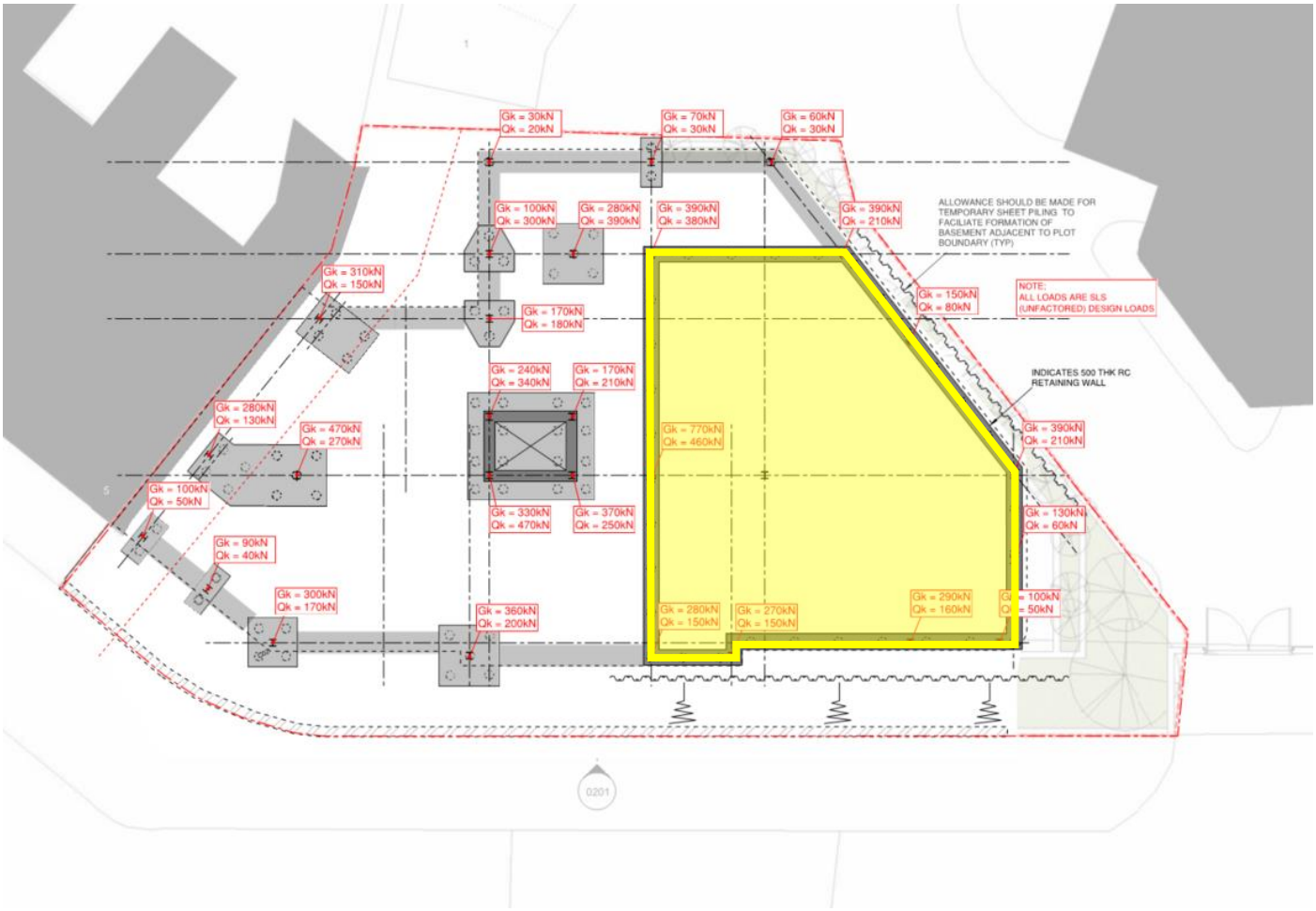
The proposed development is located at the land adjacent to Hurdwick House, Harrington Square, Camden, London, NW1 2JE (see Figure 2.1). The site is currently occupied by a private car park with soft landscaping. The proposed scheme comprises the construction of a multi-storey residential building including the excavation of a single-storey basement level (over part of the footprint of the structure). The excavation will be supported by reinforced concrete retaining walls and temporary sheet piling. The new structure will be founded on piled foundations.

Key dimensions and levels assumed in the analysis, based on the information provided by Renaissance Associates Ltd (Renaissance) are as follows:

- The proposed basement formation level is +20.425mOD, based on a 500mm thick basement slab.
- The piled foundations have an assumed toe level of +9.00mOD for both the ground floor and basement level.
- A proposed dead load of 6300kN at basement level and 6960kN at ground floor level has been assumed. The arrangement of the proposed basement footprint in relation to the proposed building is presented in Figure 2.2.

Approximate site boundary marked in red. Source: Google Earth.

Figure 2.1 Location of the proposed development



Site boundary marked in red. Basement footprint outlined in yellow

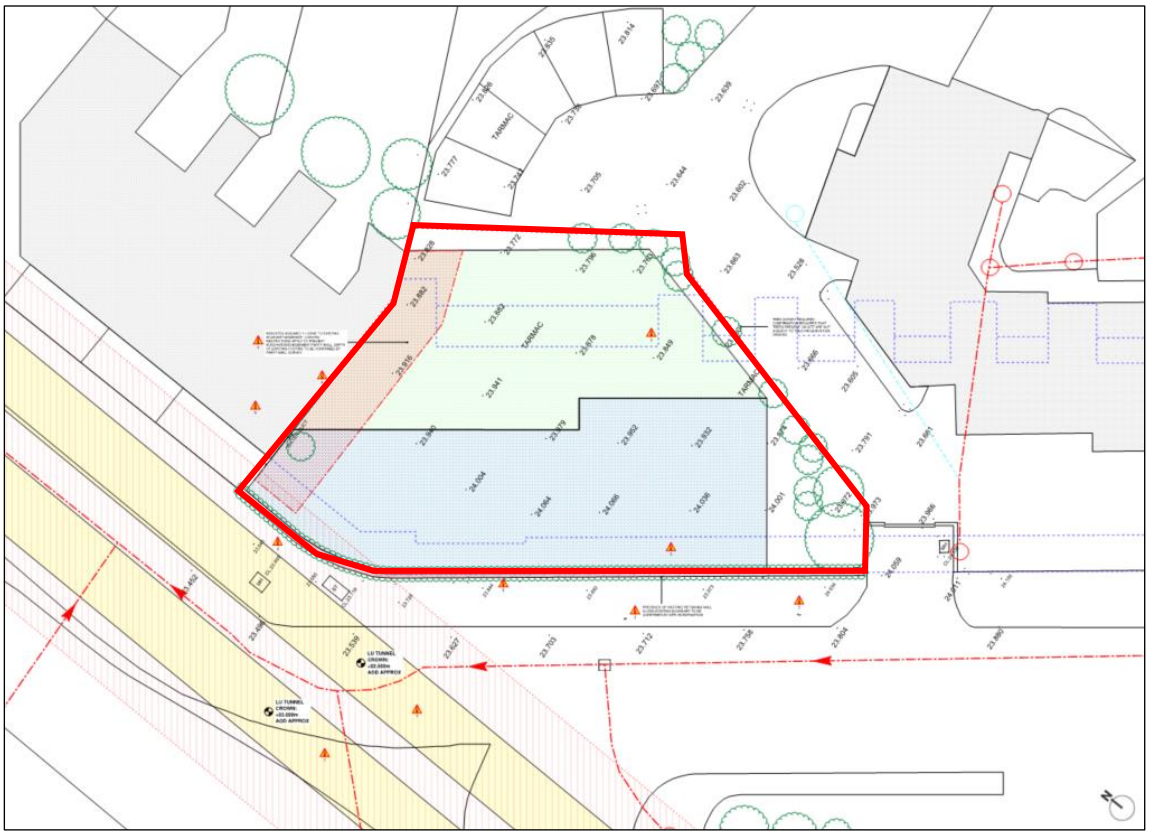
Figure 2.2 Proposed basement arrangement

3. London Underground Assets

Two London Underground Limited (LUL) Northern Line running tunnels are present in close proximity to the site. The southbound tunnel is approximately 1.5m west of the site boundary with a crown level of 2.5mOD, while the northbound tunnel is approximately located 7.0m west of the site boundary with a crown level of 3.0mOD. In line with the early 20th century construction period, these have an assumed internal diameter of approximately 3.5m. The tunnel alignment in relation to the development is presented in Figure 3.1.

Based on A-squared's experience on previous Ground Movement Assessments for LUL assets, the findings of the analysis will be compared with the following acceptance criteria:

- Minimum radius of curvature of 10km.
- Maximum tunnel ovalisation of 0.1% of the as-built tunnel diameter.



KEY

- INDICATES APPROXIMATE LINE OF SITE BOUNDARY. REFER TO ARCHITECTS AND LEGAL BOUNDARY DRAWINGS FOR EXACT LOCATION
- INDICATES ASSUMED 1:1 ZONE TO EXISTING ADJACENT BASEMENT.
- INDICATES APPROXIMATE AREA OF PROPOSED BUILDING GROUND FLOOR. REFER TO ARCHITECT INFORMATION FOR SETTING OUT.
- INDICATES APPROXIMATE AREA OF PROPOSED BUILDING BASEMENT. REFER TO ARCHITECT INFORMATION FOR SETTING OUT.
- INDICATES APPROXIMATE LOCATION OF TRANSPORT FOR LONDON UNDERGROUND TUNNELS BELOW.
- INDICATES APPROXIMATE LOCATION OF UNITED UTILITIES COMBINED SEWER.
- INDICATES APPROXIMATE LOCATION OF SURFACE WATER SEWER.
- INDICATES APPROXIMATE LOCATION OF ONSITE TREES & VEGETATION.
- INDICATES ASSUMED LOCATION OF EXISTING HISTORIC RETAINING WALL.
- INDICATES APPROXIMATE LOCATION OF EXISTING BUILDINGS.
- INDICATES APPROXIMATE AREA OF TRANSPORT FOR LONDON UNDERGROUND TUNNEL PILING EXCLUSION ZONE BELOW.
- INDICATES APPROXIMATE EXTENT OF HISTORIC HOUSING NOW DEMOLISHED

Approximate site boundary marked in red. LUL tunnels marked in yellow.

Figure 3.1 Northern Line tunnel alignment in relation to the proposed development

4. Ground Model

The ground model and soil parameters adopted as part of this study presented herein are based on site-specific ground investigation undertaken in June 2023 as presented in the *Factual Report* by A2 Site Investigation Limited (ref: 33023-A2SI-XX-XX-RP-X-0001-01). An interpretation of the findings of the ground investigation is presented in the A2 Site Investigation Geotechnical Interpretive Report (ref. 33023-A2SI-XX-XX-RP-Y-0002-00). This is summarised in Table 4.1.

Table 4.1 Ground model and geotechnical parameters

Stratum	Top of stratum (mOD)	Thickness (m)	Unit Weight, γ_b (kN/m^3)	Undrained Young's Modulus, E_u (kPa)	Drained Young's Modulus, E' (kPa)
Made Ground	24.70	2.50	19	-	14,000
London Clay	22.20	22.50	20	26,000 + 3,600z[1]	20,800 + 2,900z[1]

1. z refers to depth below top of stratum

5. Impact Assessment Methodology

The impact assessment has been carried out using the commercially available software Oasys PDisp.

Ground movement will arise due to the excavation of the new basement level and subsequent associated loading of the proposed structure. The permanent loading condition will partially reinstate and exceed the excavation unloading, yielding settlements over the footprint of the load and a given zone of influence surrounding the footprint.

The analysis strategy can be summarised as follows:

1. Model the short-term excavation (unloading) effects on-site in Oasys PDisp.
2. Model the long-term proposed loading on-site in Oasys PDisp.

A uniform value of 83kPa has been used to model the proposed unloading resulting from ground excavation, derived from the soil unit weight presented in Section 6 (i.e. an excavation depth of 4.3mbgl).

To simulate the proposed building construction in Oasys PDisp, the loads have been applied using the "equivalent raft" approach (i.e. as a uniformly distributed load at a level equivalent to two-thirds the foundation pile-toe depth, with a 1H-in-4V lateral load spread). This approach results in applied pressures of 19.4kPa at +13.5mOD and 47.9kPa at +12.8mOD for the ground floor and basement respectively.

An indicative view of the PDisp model is presented in Figure 5.1.

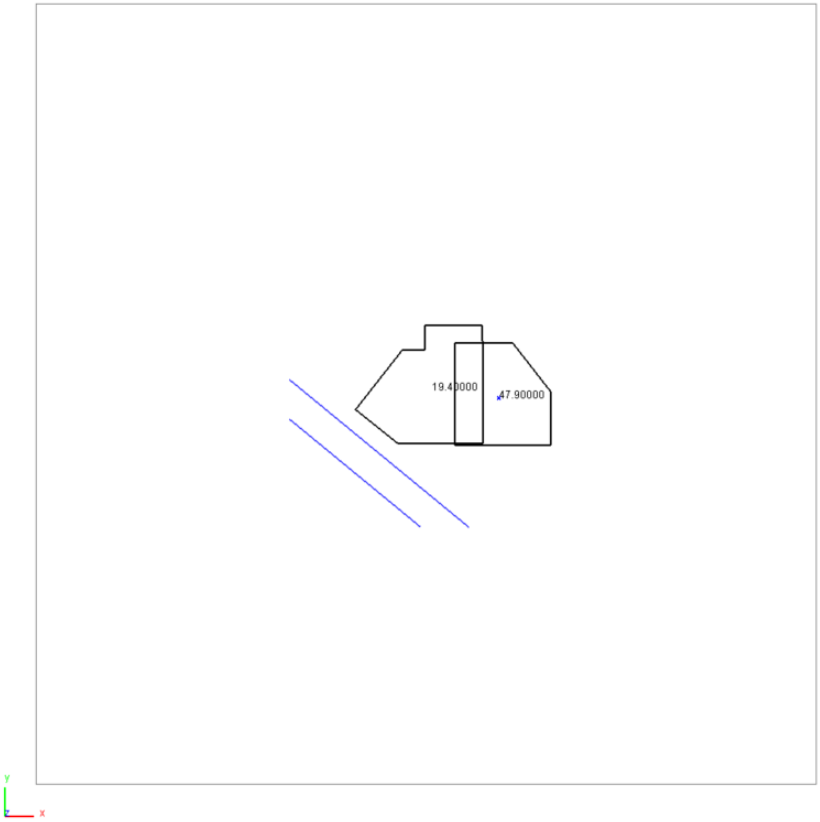


Figure 5.1 PDisp model (proposed loading arrangement)

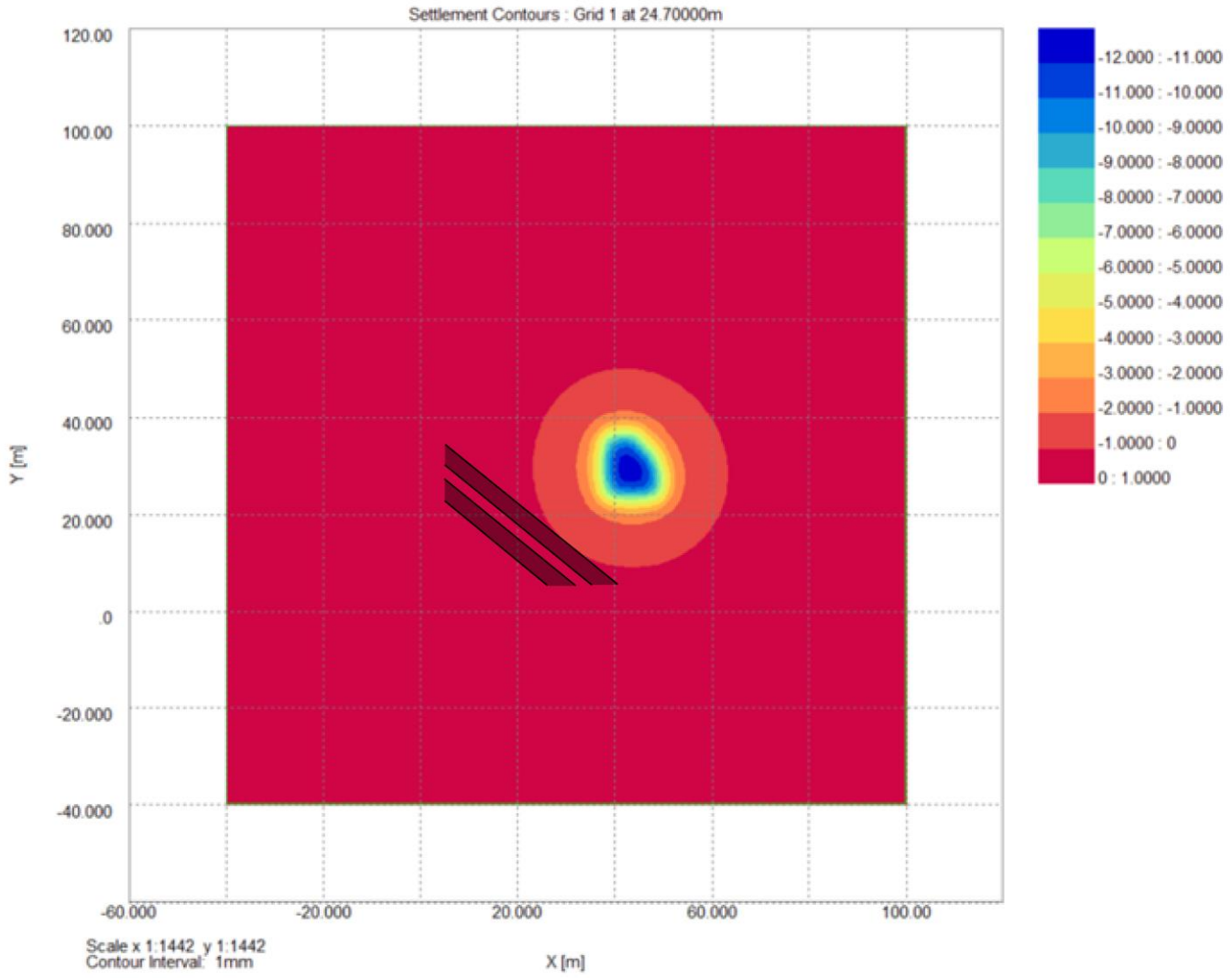
6. Impact Assessment Results

The ground movements have been estimated for both the short and long-term conditions, as outlined in Section 5. The results outlined in the following section present the predicted ground displacements and associated potential impacts on the LUL tunnel assets determined as part of this ground movement assessment. Considering the nature of the assumptions adopted in these analyses, the displacements presented below are considered to be a moderately conservative estimate and represent an upper bound range of movements (i.e. unlikely to be exceeded).

Maximum tunnel deflections from the assessed scenarios have been calculated along with the associated ovalisation and radius of curvature. The results are presented in Table 6.1. A maximum displacement of 0.2mm has been calculated. The calculated ovalisation and radius of curvature have been found to be within the adopted damage criteria. The settlement contours are presented in Figure 6.2. Detailed results for each tunnel can be found in Appendix A.

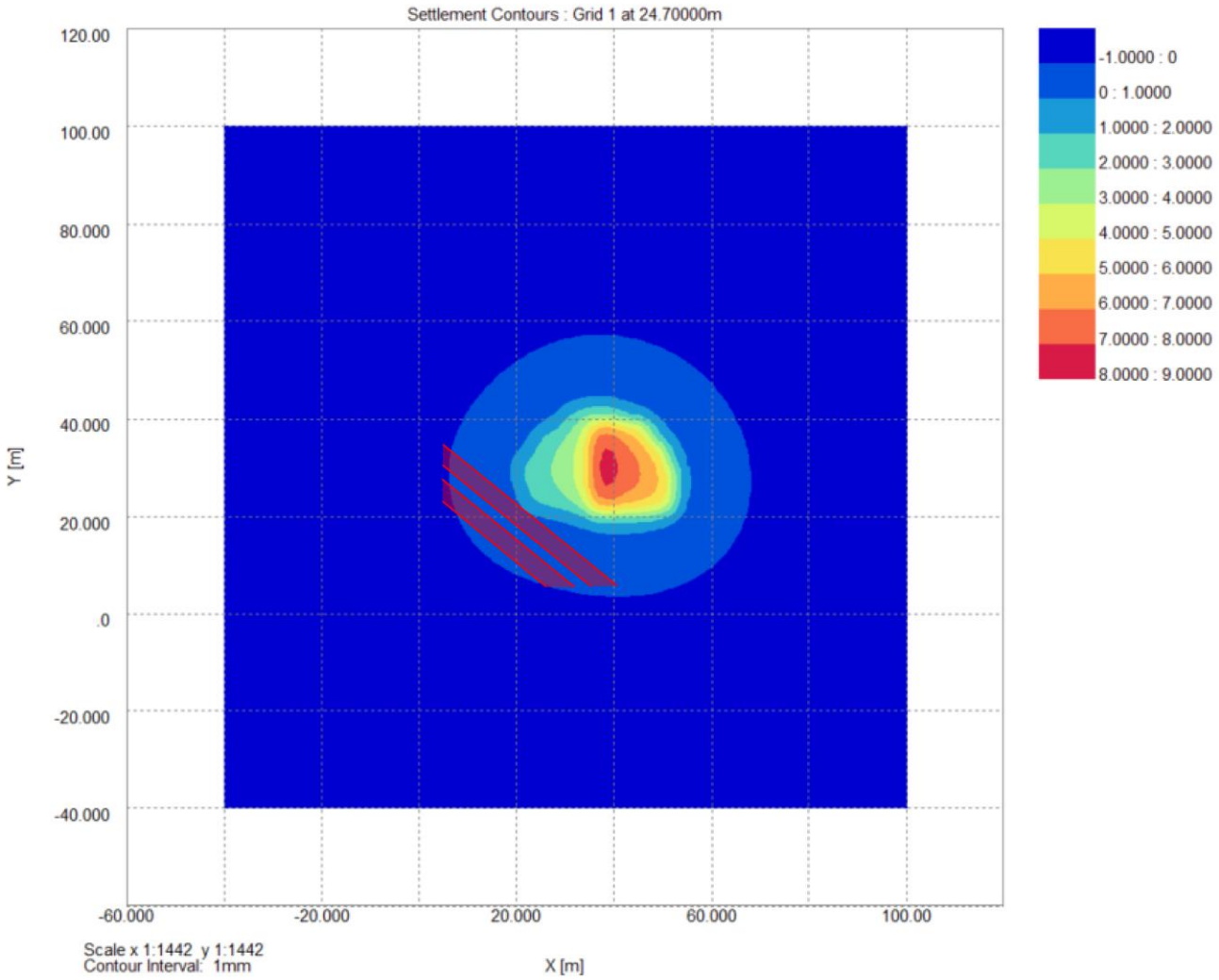
Table 6.1 Summary of Ground Movement Assessment results

	Tunnel	Maximum displacements (mm)			Ovalisation (%) Limit: 0.1%	Minimum radius of curvature (km) Limit: 10km
		Axis	Crown	Invert		
Short-term	Southbound	<0.1	<0.1	<0.1	<0.01	3240
	Northbound	<0.1	<0.1	<0.1	<0.01	7490
Long-term	Southbound	0.1	0.2	0.1	<0.01	820
	Northbound	0.1	0.1	<0.1	<0.01	1930



North and southbound tunnel alignment outlined in black.

Figure 6.1 Short-term vertical surface settlement contours



North and southbound tunnel alignment outlined in red.

Figure 6.2 Long-term vertical surface settlement contours

7. Conclusions and Closing Remarks

A-squared Studio Engineers Ltd has been appointed by Salboy (Mornington Crescent) Limited to undertake a Ground Movement Assessment (GMA) of London Underground Limited (LUL) tunnels within the zone of influence of the proposed development at the land adjacent to Hurdwick House, Harrington Square, Camden, London, NW1 2JE.

The proposed scheme comprises the construction of a multi-storey residential building including the excavation of a single-storey basement level and the installation of reinforced concrete retaining walls and temporary sheet piling in order to support the excavation.

The underlying soil has been proven through site-specific ground investigation to comprise Made Ground overlying the London Clay Formation.

Two London Underground Limited (LUL) Northern Line running tunnels are present in close proximity to the site. The tunnels have an approximate internal diameter of 3.5m and a crown elevation of 2.5 and 3.0mOD.

A ground movement assessment has been carried out on the two LUL tunnels using Oasys PDisp. The GMA assessment is based on *greenfield* ground movements and *unlikely to be exceeded* ground movements.

The results indicate that maximum asset deflections are less than 1mm. The predicted radii of curvature are greater than the 10km limiting criterion outlined in Section 3 and the radial distortion (ovalisation) is consistently within the criterion of 0.1%.

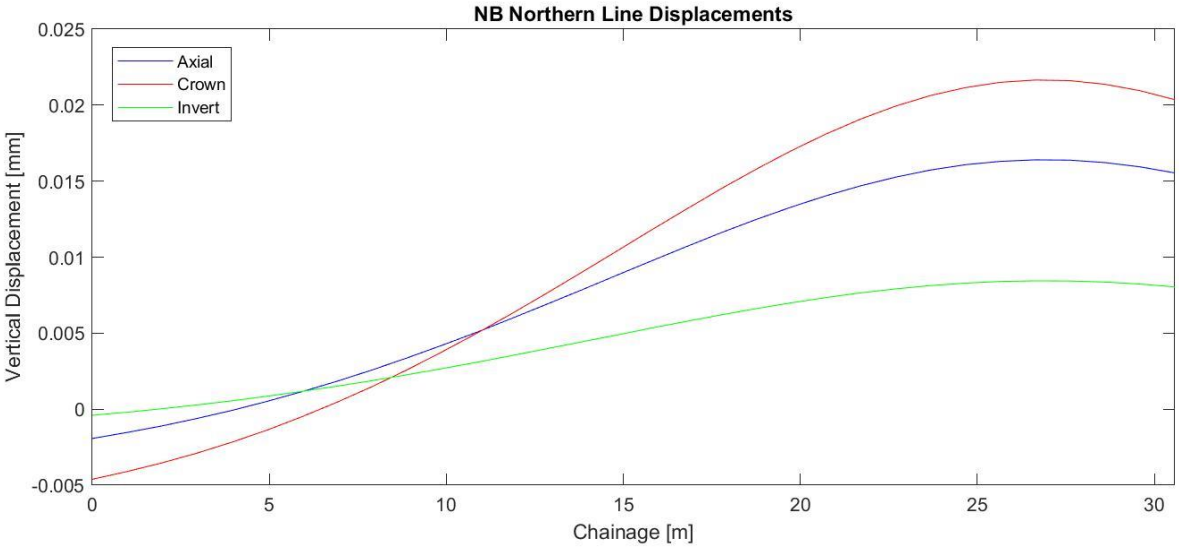
It is considered that the evaluated ground movements represent a conservative evaluation of the potential impact on the assets concerned (i.e. representative of an unlikely to be exceeded scenario) due to the full greenfield conditions simulation in the ground movement assessment presented in this report. Hence, it is considered that the scope and approach presented herein has provided a robust means of verification at this stage of the project.

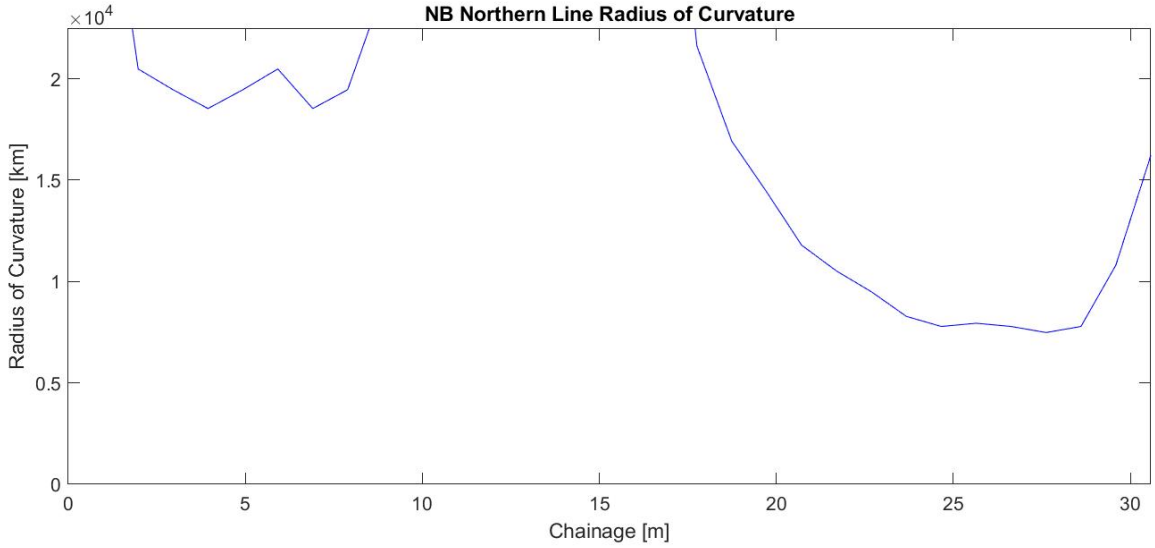
The assessment presented herein assumes that the works will be undertaken by an experienced contractor, with high quality workmanship and appropriate supervision of construction means and methods by experienced personnel.

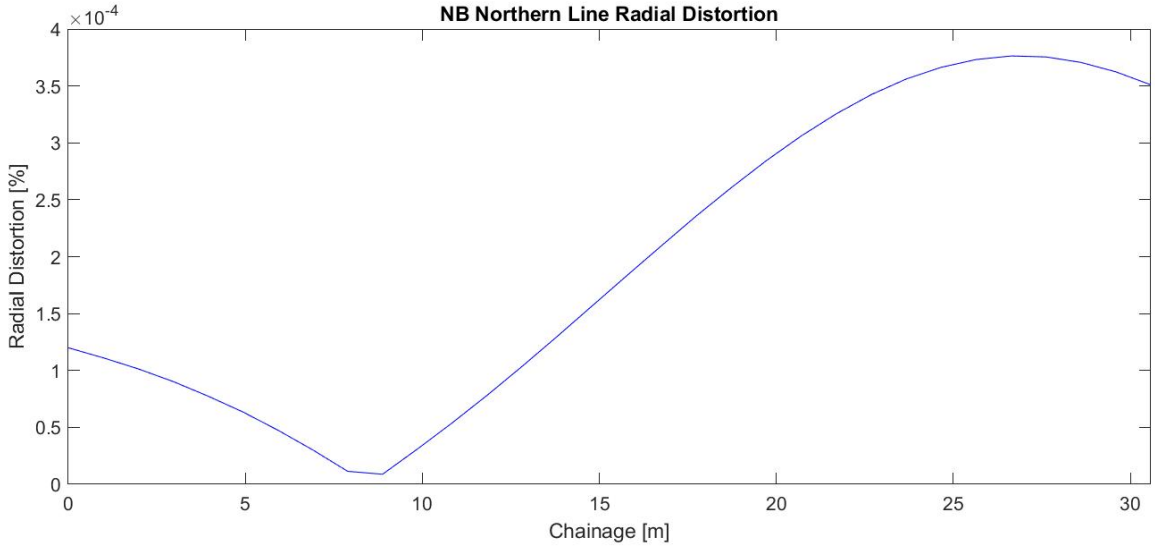
Where significant changes are made to items such as construction sequencing and scheme design, the engineer should review the departure from the current design intent and evaluate any potential impacts on ground movements and the LUL shafts and service tunnels. If necessary, the ground movement assessment results should be re-evaluated.

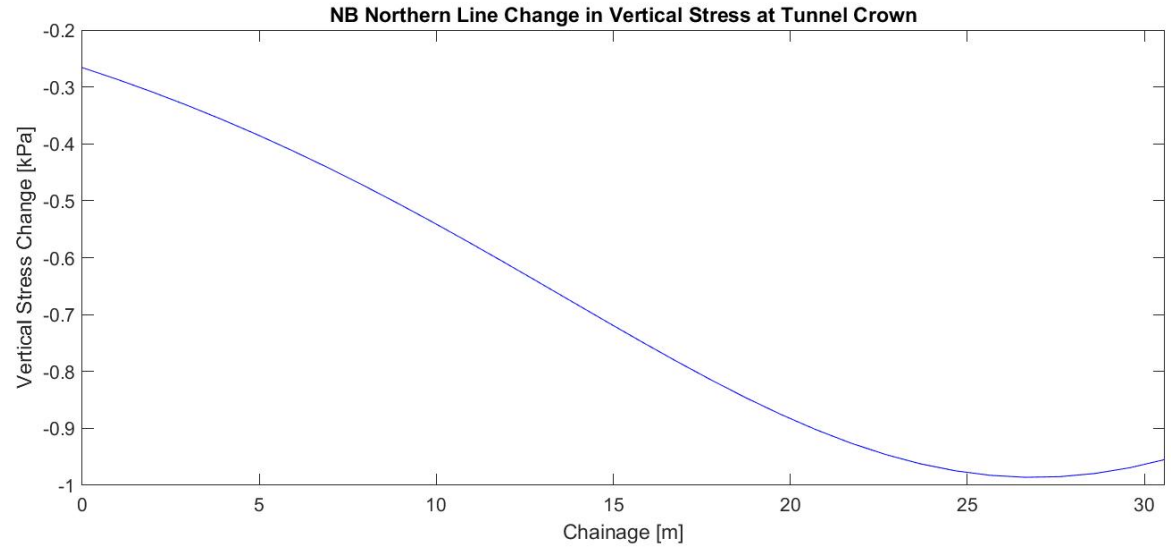
Appendix A: Oasys PDisp Output

Short-term





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Vertical Stress Change [kPa]
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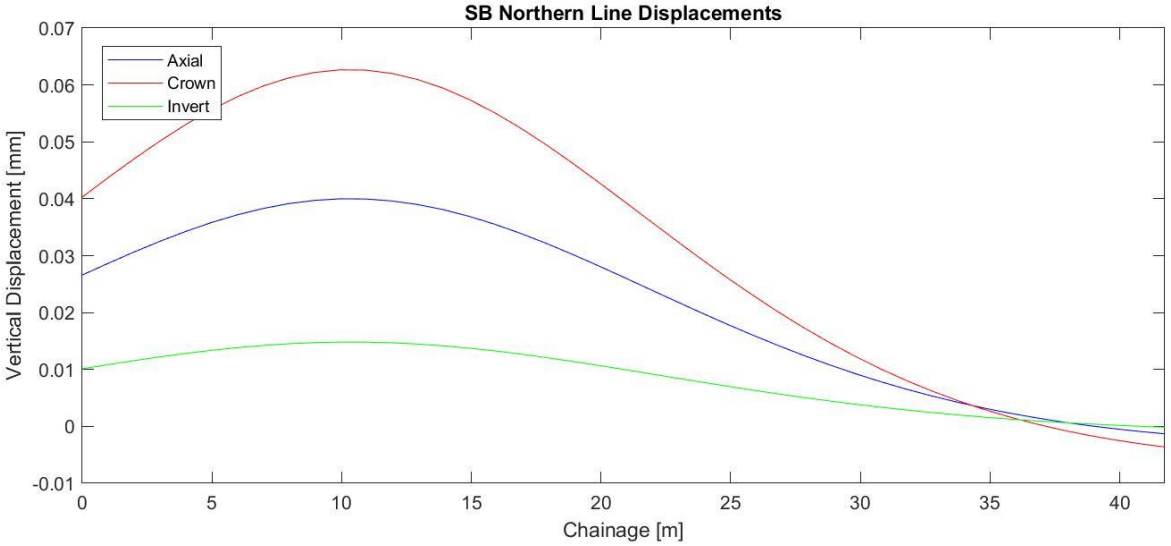
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
0
5
10
15
20
25
30
Chainage [m]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Axial
Crown
Invert
Vertical Displacement [mm]
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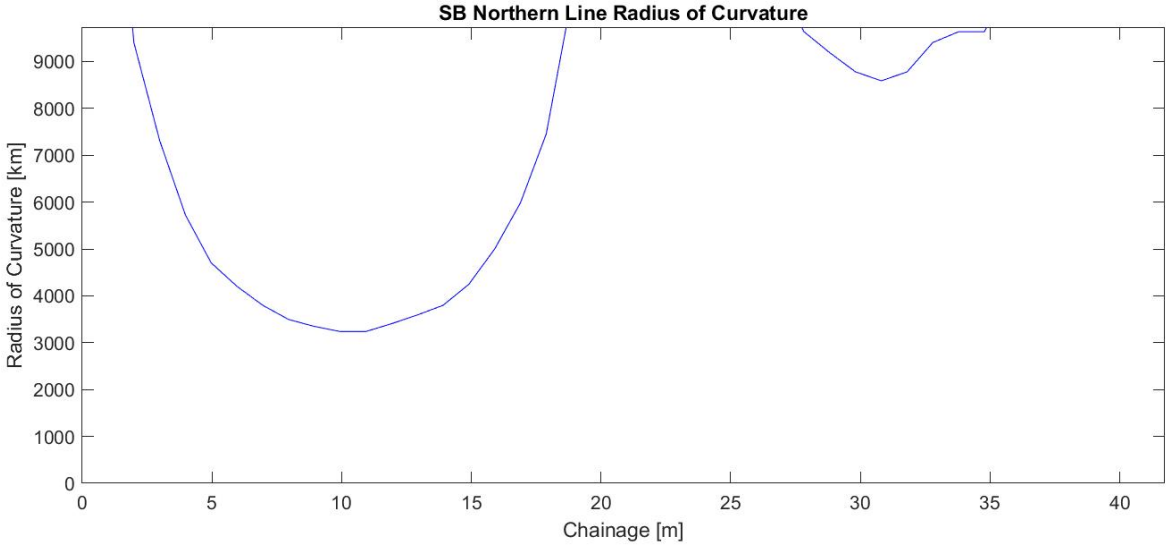
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
0
5
10
15
20
25
30
35
40
Chainage [m]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Radius of Curvature [km]
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7000
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5000
4000
3000
2000
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0
0
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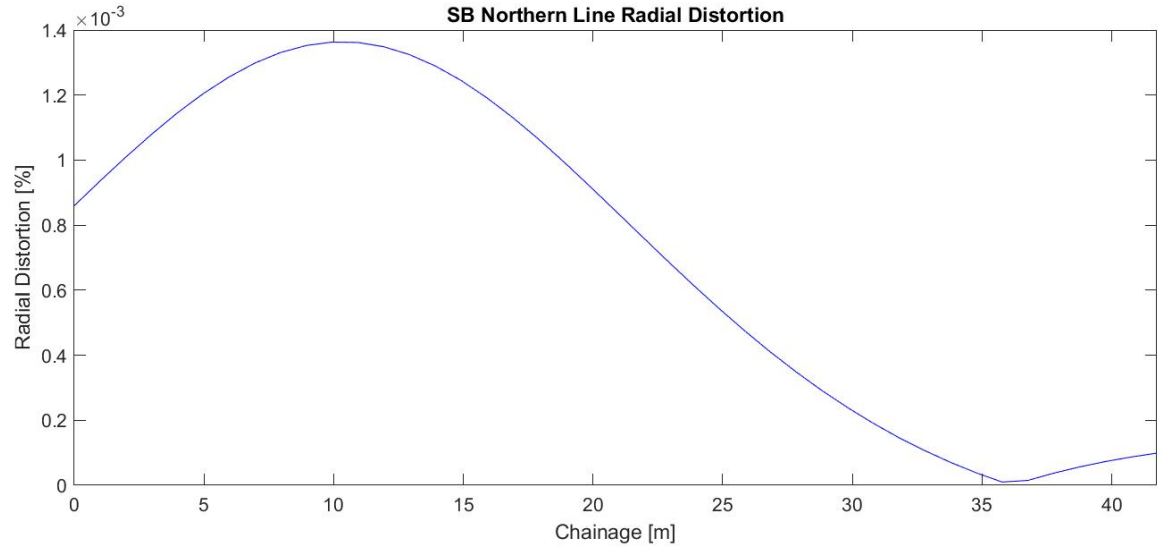
10
15
20
25
30
35
40
Chainage [m]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Radial Distortion [%]
Chainage [m]
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10
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20
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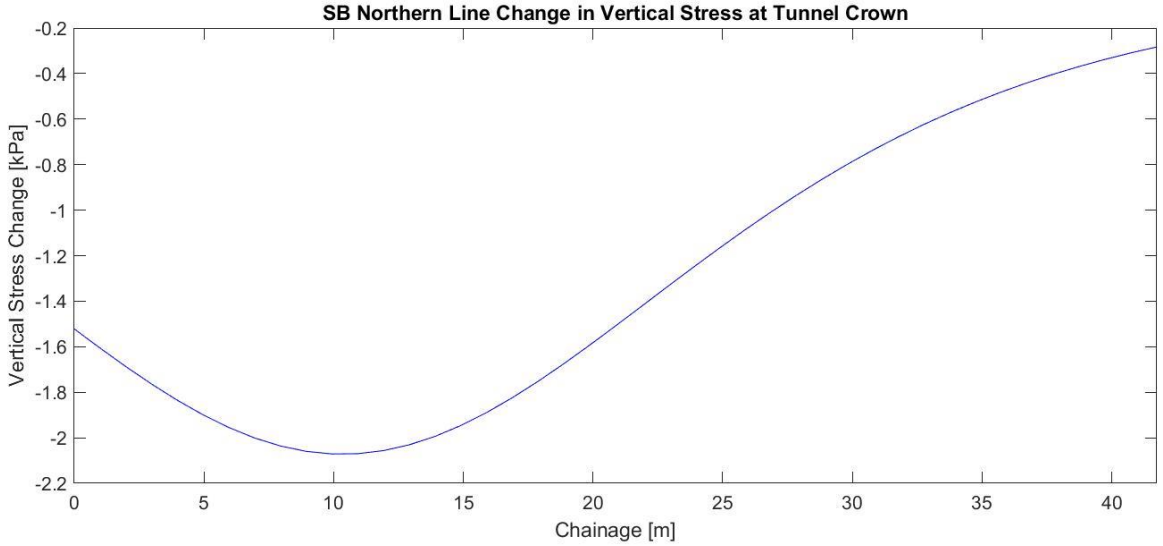
30
35
40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Vertical Stress Change [kPa]
Chainage [m]
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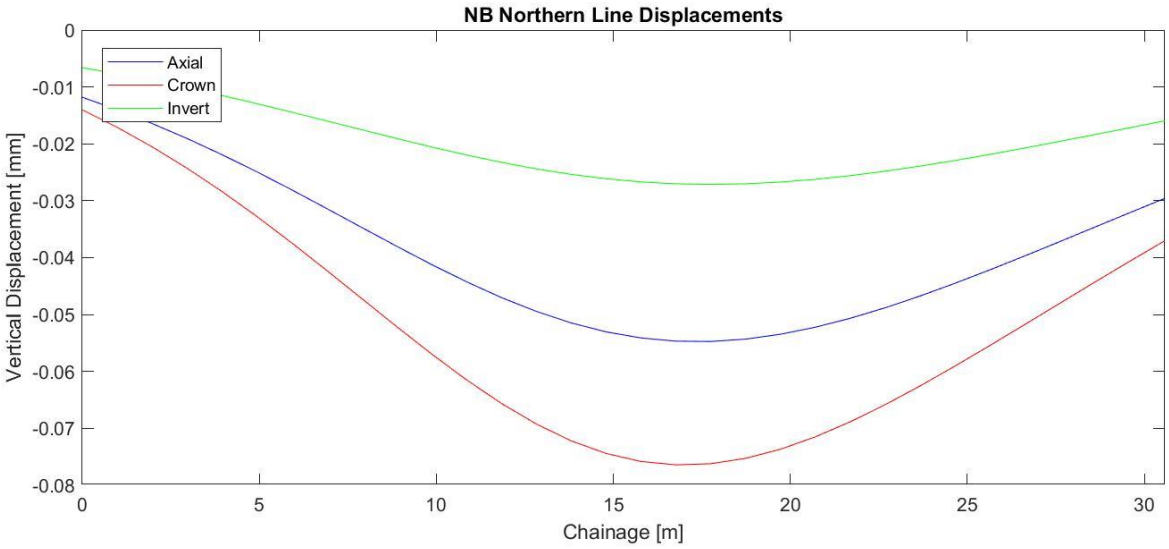
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
-2.2
0
5
10
15
20
25
30
35
40

Long-term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Axial
Crown
Invert
Vertical Displacement [mm]
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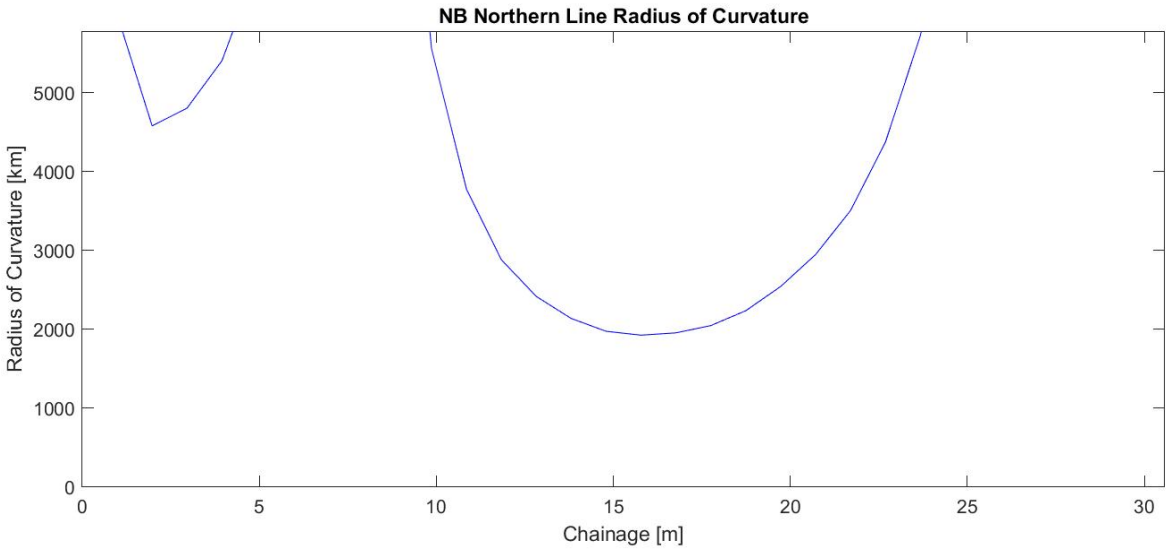
-0.08
0
5
10
15
20
25
30
Chainage [m]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Radius of Curvature [km]
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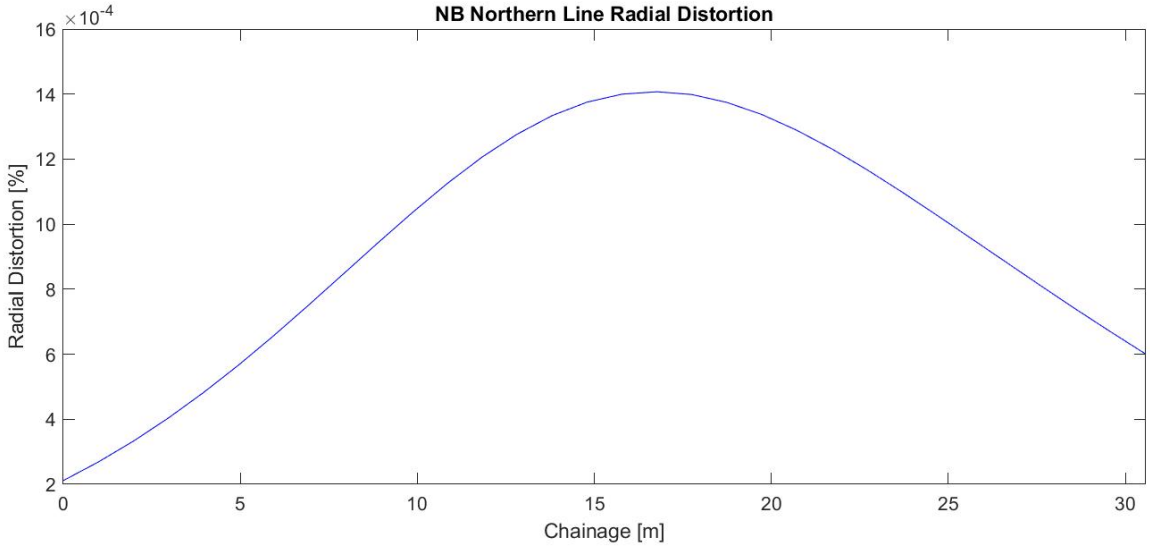
Chainage [m]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Radial Distortion [%]
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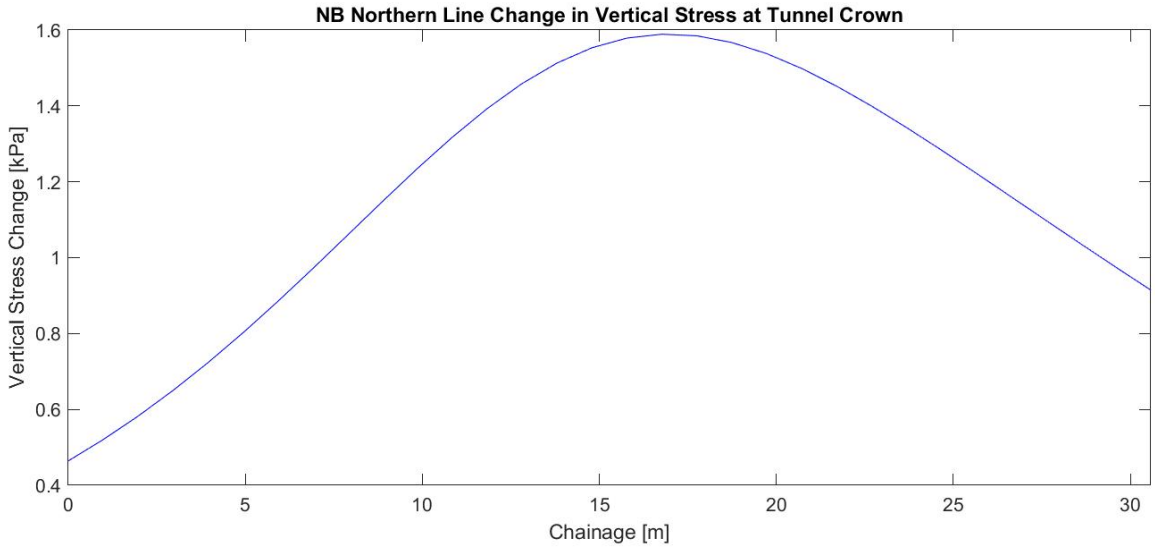
Chainage [m]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Vertical Stress Change [kPa]
Chainage [m]
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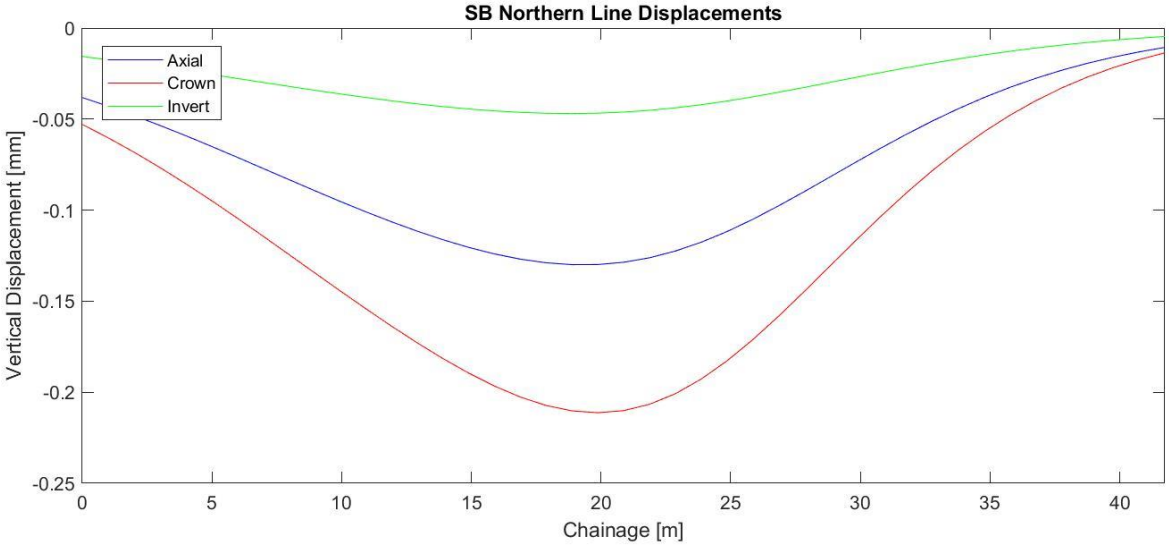
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Crown
Invert
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Chainage [m]
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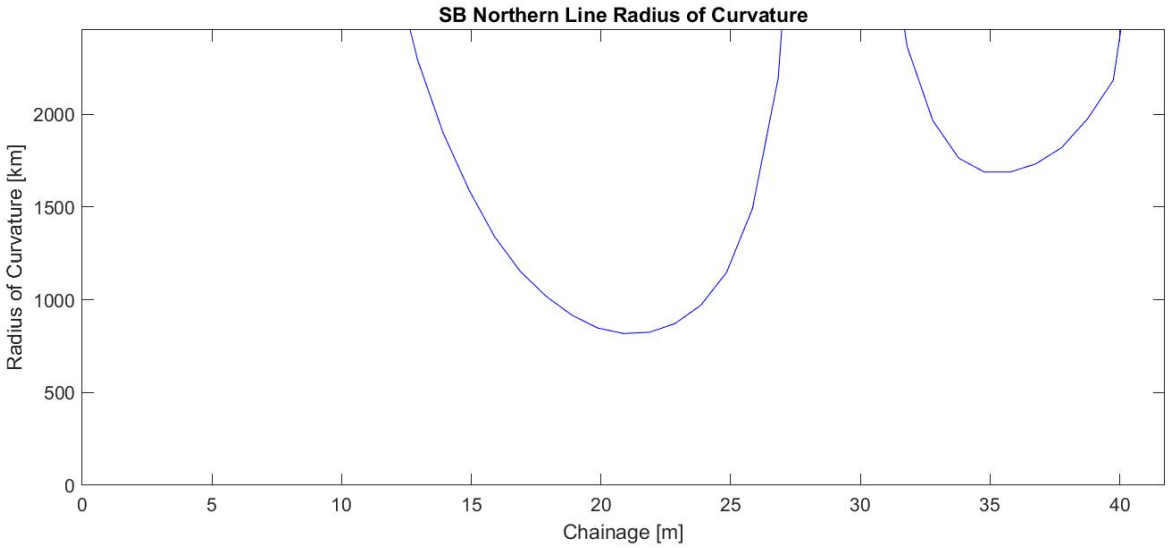
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Radius of Curvature [km]
Chainage [m]
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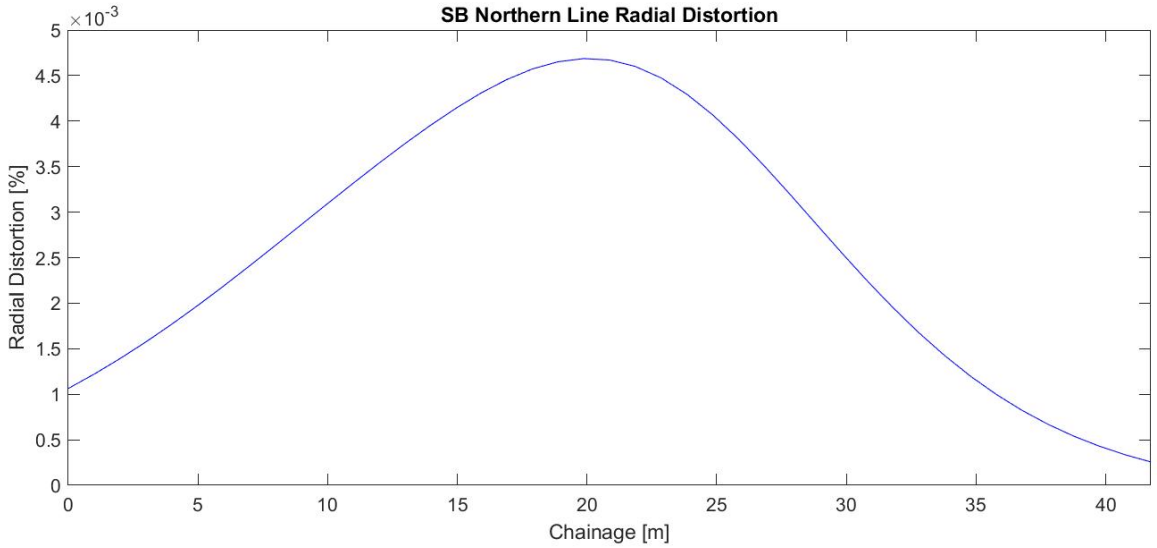
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Radial Distortion [%]
Chainage [m]
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4
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5
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25
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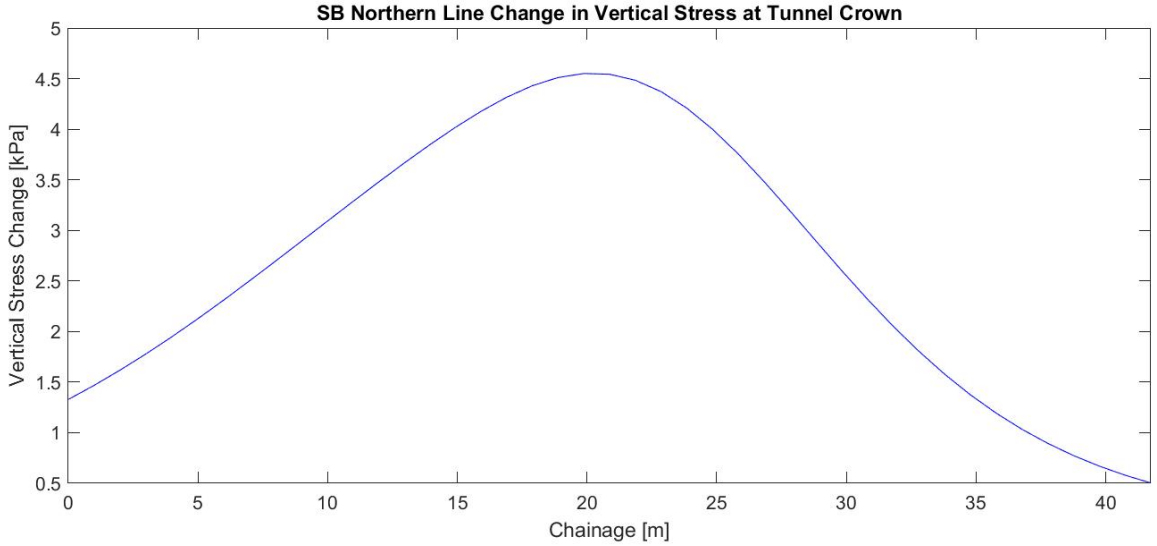
35
40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Vertical Stress Change [kPa]
Chainage [m]
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1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
35
40

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