



**METRO NORTH
ORAL HEARING**

**Stage 1 Preliminary Ground
Movement Assessment Report
Rev 3_Part16**

CALCULATION SHEET

JACOBS

Project Title: Dublin Metro North			Sheet No: 4	
Subject: Stop Boxes Settlement-St. Stephen's Green Stop –Chainage 18800 to 18880			Calc No: 17	
Job No: B0307000		File:		
Made By: AL	Date: 26/11/08	Revised By:	Date:	
Checked By:LR	Date:26/11/08	Checked By:	Date:	

are excavated no further below the ticket hall level. As this level is only about 1.67m below the assumed head rock level (included the 2m factor of safety), the entire height of the wall has been considered as height of the wall in the settlement calculation (Table 2).

INPUT PARAMETERS

The assessment parameters pertaining to the geological conditions and proposed structures for the area under consideration are presented below.

Table 1

Soil Type	Made Ground	Glacial Till	Glacial Sand & Gravel
Top Level of Strata (mOD)	12.00	9.5	7.00
Base Level of Strata (mOD)	9.50	7	3.00
Thickness (m)	2.50	2.50	4.00
Drained Elastic Modulus - E (KPa) (Soil strata)	8.00	60.00	50.00
Permeability (k) m/s (Soil strata)	0.0001	0.0005	0.00002
SPT Value (Soil strata)	50.0	-	50.0

Table 2

Stop:	Ground Level (moD)	Basement Excavation Level (moD)	Design Water Level (moD)	Drawdown Water Level (moD)	Wall Height (m)
St. Stephen's Green Ticket Hall Level Excavation*	12.00	-0.67	7.00	3.00	12.67
St. Stephen's Green Deep Wall Excavation	12.00	1.00	7.00	3.00	11.00

OUTPUT

The results of the analysis have been plotted manually on Topographical Survey or Ordnance Survey backgrounds.

CALCULATION SHEET



Project Title: Dublin Metro North		Sheet No: 1	
Subject: Running Tunnel Settlement- Chainage 18840 to 19080- Track Loop and Siding Tunnels		Calc No:18	
Job No: B0307000		File: Airport	
Made By: AL	Date: 26/11/08	Revised By:	Date:
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St Stephens Green Loop

INTRODUCTION

The objective of this calculation is to predict ground movements induced by construction of the system of mined tunnels south of St Stephen's Green stop between Chainage 18840 and 19080 (loop and siding tunnels section). The results of this calculation will be presented as settlement contours and will be used to identify existing buildings, structures, utilities and infrastructure that lie within the zone of influence, as per the design requirements specified Technical Note 12 'Strategy for Assessing and Managing Building, Infrastructure and Utility Response to Ground Movements Generated by Underground Excavation' September 2007, Ref: B0307000-010\Geo.360\001\1.

REFERENCES

Document/Drawing Ref	Rev	Title
B0307000-010\Geo.02\001	0	Design Input Statement for Predicting Ground Movements and the Response of Buildings, Infrastructure and Utilities Generated by Underground Excavation
B0307000-010\Geo.360\001\1	0	Technical Note 12 'Strategy for Assessing and Managing Building, Infrastructure and Utility Response to Ground Movements Generated by Underground Excavation'
BMN/0000/GE/234	A01	Exploratory Hole Location Plan and Inferred Geological Section (incl. MGI data) Sheet 14 of 14
BMN/0000/TU/7046	B01	Loop and Siding Tunnels Plan – St. Stephen's Green-South
BMN/0000/TU/7243	B01	Loop and Siding Tunnel details – St. Stephen's Green-South
BMN/0000/TU/7244	B01	Loop and Siding Tunnels - Cavern for Loop Turnout – St. Stephen's Green-South
BMN/0000/TU/7245	B01	Loop and Siding Tunnels - Crossing and TBM Chambers, Sheet 1/2 – St. Stephen's Green-South
BMN/0000/TU/7246	B01	Loop and Siding Tunnels - Crossing and TBM Chambers, Sheet 2/2 – St. Stephen's Green-South
BMN/0000/TU/7247	B01	Loop and Siding Tunnels - Tunnel Vent Bypass – St. Stephen's Green-South
BMN/0000/TU/7348	B01	Loop and Siding Tunnels - Loop Escape Stair Tunnel details – St. Stephen's Green-South
BMN/0000/ML.200/7215	B03	Track Vertical Alignment 1:500 St Stephens Green Loop 0-750
BMN/0000/ML.200/7214	B03	Track Vertical Alignment 1:500 St Stephens Green Stop 18540-End

ANALYTICAL TOOLS

The following analytical tools were used in this analysis

Project Title: Dublin Metro North		Sheet No: 2	
Subject: Running Tunnel Settlement- Chainage 18840 to 19080- Track Loop and Siding Tunnels		Calc No:18	
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- TunDisp (Jacobs in-house programme): used to calculate predicted ground movement Jacobs in-house programme.
- Surfer (Ver 6): used to generate settlement contours at ground level.

Verification of ground movement predictions will be undertaken using hand calculations for specific areas along the alignment.

METHODOLOGY

1. Analysis in TunDisp

Tunnel alignment coordinates (X, Y and Z) retrieved from the relevant alignment drawings have been collated at 10m increments along the alignment. The corresponding ground level and geological sequence associated with each incremental section of the proposed development has been determined from the inferred geological long sections referenced above.

All elements generating ground movement (mined tunnels, including cross passages, tunnel intersection caverns, TBM reception chambers and turnout tunnels) were considered together in the TunDisp analysis. The output file contains the total settlement values corresponding to the combined effect of the ground excavation elements.

2. Contouring of settlement at Ground Level

The TunDisp output files (.dat) have been converted to a .sin or .txt file and then imported into Surfer (ver 6 or 8) to generate contour maps for the discrete sections analysed. The contour map was then exported from Surfer into a .dxf file to be opened by a CAD program. The spacing option of the Grid Line Geometry in Surfer was left as default from the program and a Triangulation grid with Linear Interpolation chosen.

Contours were plotted for 2mm and 5mm settlements and for every 5mm above the 5mm settlement mark.

ASSUMPTIONS

- For tunnels, hard ground parameters were utilised where there is a minimum of half tunnel diameter cover to the crown of the tunnel. For the tunnel intersection caverns a minimum cover of 4m was taken.
- The completed tunnel elements are considered to be watertight and therefore long-term settlement due to consolidation is considered negligible.
- The predicted area or zone of influence affected by excavation activities has been established in the ground movement analysis. For bored and mined tunnels the zone of influence is defined as 30m each side of the tunnels centreline, or the 2mm contour line whichever is greatest. For cut and cover and retained sections the zone of influence is defined as the horizontal distance from the façade of the wall to a distance equal to the height of the wall, or to the 2mm contour line whichever is greatest.

CALCULATION SHEET

Project Title: Dublin Metro North		Sheet No: 3	
Subject: Running Tunnel Settlement- Chainage 18840 to 19080- Track Loop and Siding Tunnels		Calc No:18	
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- The geology above the ventilation tunnels is characterised by a combination of Glacial Till with Glacial Sand and Gravels for this tunnel section. Assuming that the Glacial Sand/Glacial Till analogy is 4:7, a value of 0.5 for the K parameter was estimated by interpolation. Volume loss was considered to be equal to the Glacial sand's characteristic value of $V_L=2.25\%$ for mined tunnels.

INPUT PARAMETERS

General

The assessment parameters pertaining the geological conditions and proposed structures for the area under consideration are presented below.

Structure Type	Excavation Geology	Volume Loss (* % related to excavation depth)	Dimensions	Notes
Running tunnels (Bored)	Fluvio – Glacial Deposits	1.5%	N/A	N/A
	Glacial Till	0.6%	6.75m Dia.	Based on dimensions of TBM
	Limestone Bedrock	0.20%	N/A	N/A
Cross Passage tunnels (SEM*)	Fluvio – Glacial Deposits	2.25%	N/A	N/A
	Glacial Till	0.9%	5.5m Dia.	Cross Passage Entrance enlarged Sections, distance from tunnel axis to end of enlarged section = 5.5m
	Limestone Bedrock	0.30%	4.0m Dia	Based on OD plus 0.15m overcut.
Cross Passages with Drainage Sumps (SEM*)	Fluvio – Glacial Deposits	2.25%	N/A	N/A
	Glacial Till	0.9%	5.9m	Cross passage tunnel dimensions, based on OD plus 0.15m overcut.
	Limestone Bedrock	0.30%	7.86m	Cross passage and sump dimensions, based on equivalent circular area plus 0.15m overcut.
Crossovers (SEM*)	Fluvio – Glacial Deposits	2.25%	N/A	N/A
	Glacial Till	0.9%	N/A	N/A
	Limestone Bedrock	0.30%	N/A	N/A

*Sequential Excavation Method.

Geology	'K' Value
Fluvio – Glacial Deposits	0.3
Glacial Till	0.6
Limestone Bedrock	0.4

CALCULATION SHEET

JACOBS

Project Title: Dublin Metro North		Sheet No: 4	
Subject: Running Tunnel Settlement- Chainage 18840 to 19080- Track Loop and Siding Tunnels		Calc No:18	
Job No: B0307000		File: Airport	
Made By: AL	Date: 26/11/08	Revised By:	Date:
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Notes:

- The itkp value in TunDisp defines the rate of change in the trough width parameter with depth. This should be set to '0' i.e. constant value as per the Design Input Statement. Hand calculation indicate that for the Loop and Siding tunnels section the ground movement predictions are only slightly influenced by this parameter.
- All tunnels in the loop section are going to be constructed by using the shotcrete tunnelling method. Therefore the mined tunnel parameters apply for all the tunnels of this section.
- For the siding tunnels, tunnel axis levels were interpolated at 10m intervals assuming a constant slope over the total length of the tunnels.
- Where ground levels were not available, these were extracted from the relevant geological long section drawing (BMN/0000/GE/234/A01).

Chainage 18840 to 19050

Area of Interest: (315888.6 E, 233476.3 N)
(316112.4 E, 233215.6 N)

Chainages: Element 1: Cross Passage with sump
Element 2: Cross Passage
Element 3: Turnout Southbound
Element 4: Turnout Northbound
Element 5: Ventilation Tunnel Southbound
Loop and Siding tunnels section spans from Ch. 18840 to Ch. 19080
Element 6: Ventilation Tunnel Northbound
Element 7: Escape Stair Tunnel
Element 8: TBM Reception Chamber Northbound
Element 9: TBM Reception Chamber Southbound
Element 10: Tunnel Intersection Cavern Southbound
Element 11: Tunnel Intersection Cavern Northbound
Element 12: Siding Tunnel Southbound
Element 13: Siding Tunnel Northbound
Element 14: Track Loop, Loop Ch.: 0 to 190m
Element 15: Track Loop, Loop Ch.: 155 to 315m
Element 16: Track Loop, Loop Ch.: 280 to 470m

Tunnel Alignment Data - File Location: P:\B0307000 Dublin Metro North\Design\Alignment\track loop\South of St Stephen's underground structures\trackloop-Definitive.xls

Analysis directory (settlements): P:\B0307000 Dublin Metro North\Design\Settlement Analysis - building Damage Assessment\Tundisp Analysis\final\track loop\settlement analysis

TunDisp Input File: loop.inp

Geology: Glacial Till topping Glacial Sand and Gravels, Limestone

Cross Passage with Diameters: 5.9m, 7.86m, 5.9m

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Project Title: Dublin Metro North		Sheet No: 5	
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Made By: AL	Date: 26/11/08	Revised By:	Date:
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sump:
 VL= 0.003 (0.3%)
 K value at surface, K=0.4
 K variable with depth , itkp =0
 z, depth to plane of interest = 0m (surface settlement)
 No. of increments n=5,4,5
 Vertical offset=0m
 Horizontal offset=0m

Cross passage:
 Diameter: 3.67m
 VL= 0.003 (0.3%)
 K value at surface, K=0.4
 K variable with depth , itkp =0
 z, depth to plane of interest = 0m (surface settlement)
 No. of increments n=11
 Vertical offset=0m
 Horizontal offset=0m

Turnout Southbound
 Diameters: 9.7, 10.97, 12.4, 14.76m
 VL= 0.003 (0.3%)
 K value at surface, K=0.4
 K variable with depth , itkp =0
 z, depth to plane of interest = 0m (surface settlement)
 No. of increments n=6,6,6,7
 Vertical offset=0m
 Horizontal offset=0m

Turnout Northbound
 Diameters: 9.7, 10.97, 12.4, 14.76m
 VL= 0.003 (0.3%)
 K value at surface, K=0.4
 K variable with depth , itkp =0
 z, depth to plane of interest = 0m (surface settlement)
 No. of increments n=6,6,6,7
 Vertical offset=0m
 Horizontal offset=0m

Ventilation Tunnel Southbound
 Diameters: 5, 6.7m
 VL= 0.0225 (2.25%)
 K value at surface, K=0.5
 K variable with depth , itkp =0
 z, depth to plane of interest = 0m (surface settlement)
 No. of increments n=5,7
 Vertical offset=0m
 Horizontal offset=0m

CALCULATION SHEET

Project Title: Dublin Metro North		Sheet No: 6	
Subject: Running Tunnel Settlement- Chainage 18840 to 19080- Track Loop and Siding Tunnels		Calc No:18	
Job No: B0307000		File: Airport	
Made By: AL	Date: 26/11/08	Revised By:	Date:
Checked By:LR	Date:26/11/08	Checked By:	Date:

Ventilation Tunnel Northbound

Diameters: 5, 6.7m
 VL= 0.0225 (2.25%)
 K value at surface, K=0.5
 K variable with depth , itkp =0
 z, depth to plane of interest = 0m (surface settlement)
 No. of increments n=5,7
 Vertical offset=0m
 Horizontal offset=0m

Escape Stair Tunnel

Diameter: 4.57m
 VL= 0.003 (0.3%)
 K value at surface, K=0.4
 K variable with depth , itkp =0
 z, depth to plane of interest = 0m (surface settlement)
 No. of increments n=2
 Vertical offset=0m
 Horizontal offset=0m

TBM Reception Chamber Northbound

Diameters: 9, 11.24m
 VL= 0.003 (0.3%)
 K value at surface, K=0.4
 K variable with depth , itkp =0
 z, depth to plane of interest = 0m (surface settlement)
 No. of increments n=4,9
 Vertical offset=0m
 Horizontal offset=0m

TBM Reception Chamber Southbound

Diameters: 9, 11.24m
 VL= 0.003 (0.3%)
 K value at surface, K=0.4
 K variable with depth , itkp =0
 z, depth to plane of interest = 0m (surface settlement)
 No. of increments n=4,9
 Vertical offset=0m
 Horizontal offset=0m

Tunnel Intersection Cavern Southbound

Diameter: 13.8m
 VL= 0.003 (0.3%)
 K value at surface, K=0.4
 K variable with depth , itkp =0
 z, depth to plane of interest = 0m (surface settlement)
 No. of increments n=2
 Vertical offset=0m
 Horizontal offset=0m

CALCULATION SHEET

Project Title: Dublin Metro North		Sheet No: 7	
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Made By: AL	Date: 26/11/08	Revised By:	Date:
Checked By:LR	Date:26/11/08	Checked By:	Date:

**Tunnel Intersection
Cavern Northbound**

Diameter: 13.8m
 VL= 0.003 (0.3%)
 K value at surface, K=0.4
 K variable with depth , itkp =0
 z, depth to plane of interest = 0m (surface settlement)
 No. of increments n=2
 Vertical offset=0m
 Horizontal offset=0m

**Siding Tunnel
Southbound**

Diameter: 6.92m
 VL= 0.003 (0.3%)
 K value at surface, K=0.4
 K variable with depth , itkp =0
 z, depth to plane of interest = 0m (surface settlement)
 No. of increments n=2
 Vertical offset=0m
 Horizontal offset=0m

**Siding Tunnel
Northbound**

Diameter: 6.92m
 VL= 0.003 (0.3%)
 K value at surface, K=0.4
 K variable with depth , itkp =0
 z, depth to plane of interest = 0m (surface settlement)
 No. of increments n=2
 Vertical offset=0m
 Horizontal offset=0m

Track Loop

Diameter: 6.66 m
 VL= 0.003 (0.3%)
 K value at surface, K=0.4
 K variable with depth , itkp =0
 z, depth to plane of interest = 0m (surface settlement)
 No. of increments n=39, 33, 39
 Vertical offset=0m
 Horizontal offset=0m

CALCULATION SHEET



Project Title: Dublin Metro North		Sheet No: 8	
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Made By: AL	Date: 26/11/08	Revised By:	Date:
Checked By:LR	Date:26/11/08	Checked By:	Date:

OUTPUT FILE NAMES AND LOCATIONS

Chainage 18840 to 19050

Output file – tunnels: loop3.dat

Contour plot file: Loop.srf

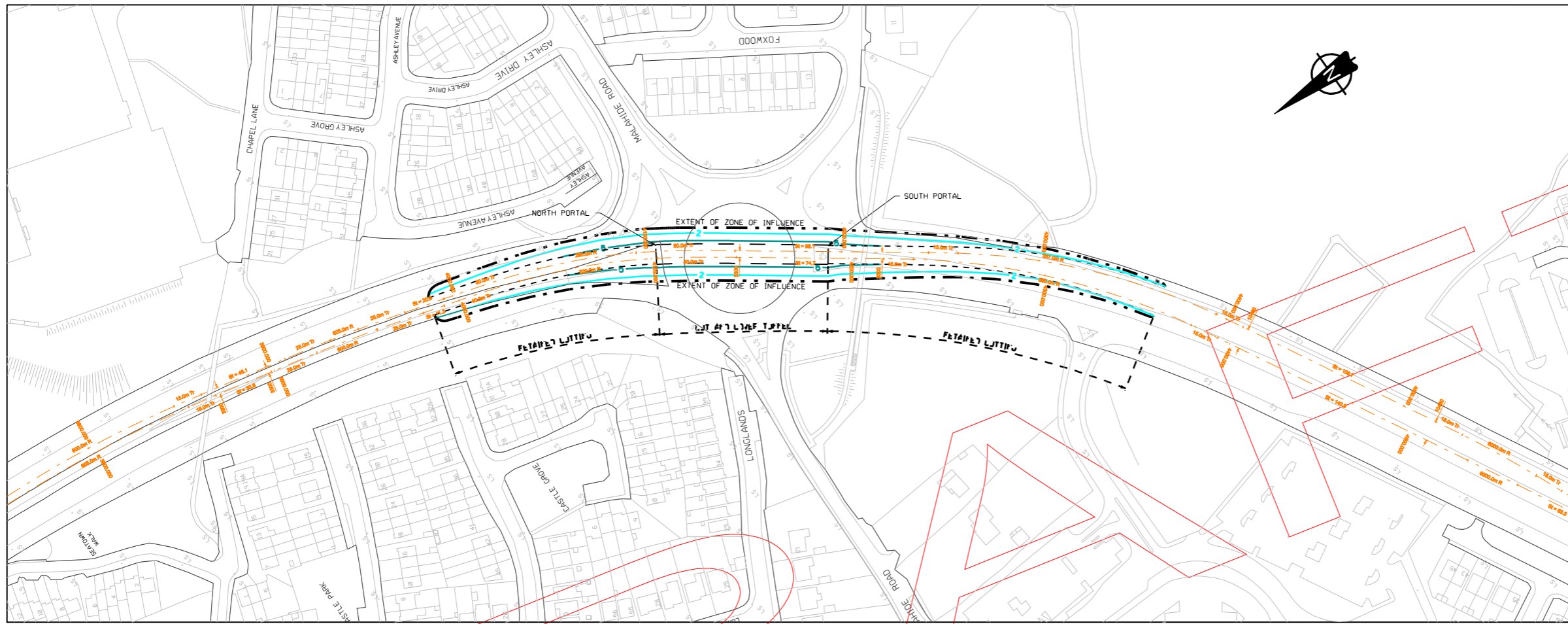
Contour file for use in CAD: Loop.dxf

Appendix D Predicted Settlement Contour Drawings

Included within this Appendix are the following predicted settlement contour drawings:

DRAWINGS Reference table				
	Element	Number	Revision	Name
BMN0000	TU	2050	B03	Malahide Underpass
BMN0000	TU	2051	B03	Fosterstown Underpass
BMN0000	TU	3050	B03	Dublin Airport (Sheet 1 of 2)
BMN0000	TU	3051	B03	Dublin Airport (Sheet 2 of 2)
BMN0000	TU	5050	B03	Northwood to South of Ballymun
BMN0000	TU	5051	B04	South of Ballymun to South of DCU
BMN0000	TU	6050	B04	Griffith Avenue
BMN0000	TU	6051	B04	South of Griffith Ave. To Drumcondra
BMN0000	TU	6052	B03	South of Drumcondra to South of Mater
BMN0000	TU	7050	B05	South of Mater to O'Connell Bridge
BMN0000	TU	7051	B05	O'Connell Bridge to St Stephen's Green

Refer to Section 2.3, regarding chainages presented within this Stage 1 Preliminary Ground Movement Report.



PLAN - MALAHIDE UNDERPASS
SCALE 1:1250

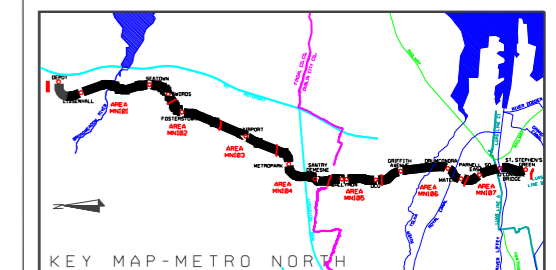
- STANDARD NOTES:**
- DO NOT SCALE FROM THIS DRAWING. USE WRITTEN DIMENSIONS ONLY.
 - DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE STATED.
 - FOR LEGEND REFER TO DRAWING BMN000000001.
 - ALL LEVELS ARE TO MALIN HEAD AS DEFINED BY OSGM02.
 - CHAINAGES ARE IN METRES RELATIVE TO THE NORTHBOUND TRACK ALIGNMENT UNLESS OTHERWISE STATED.
 - EXTERNAL GROUND LEVELS ARE APPROXIMATE.
- NOTES:**
- THE HORIZONTAL ALIGNMENT SHOWN ON THIS DRAWING IS THE TWIN TRACK ALIGNMENT REVISION ISSUED ON 14 MAY 2008.
 - CONTOURS SHOWN FOR PREDICTED SETTLEMENTS OF 2mm, 5mm AND 10mm THEN AT INTERVALS OF 5mm.
 - ZONE OF INFLUENCE DEFINED: DEPTH OF EXCAVATION FROM WALL OF CUT & COVER/RETAINED CUT - DEPTH OF EXCAVATION FROM WALL OF CUT & COVER/RETAINED CUT.
 - GROUND MOVEMENTS PREDICTED USING CLOUGH & O'ROURKE (1990) AND BRANGAN AND LONG (2001).

DRAFT

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B02 5 Feb 2008 ISSUED FOR RPA PRELIMINARY REVIEW

REV	DATE	DESCRIPTION	BY	CHK	APD



RPA
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METRO

JACOBS

CONTRACT NO	AREA	CHAINAGE
MN-0000	MN102	

LOCATION
MALAHIDE UNDERPASS

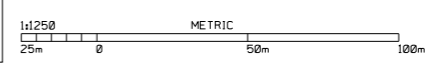
DRAWING TITLE
PREDICTED SETTLEMENT CONTOURS

DESIGNED BY	DESIGNED BY	APPROVED BY
CHECKED	CHECKED	AS BUILT BY
DATE: 5 Feb 2008	SCALE: 1:1250	SHEET SIZE: A1

STAGE	LINE	CONTROL	ELEMENT	DRW NO	DRW REV
B	MN	0000	TU	2050	B03

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SETTLEMENT KEY:		20mm CONTOUR		25mm CONTOUR		30mm CONTOUR		35mm CONTOUR		40mm CONTOUR		45mm CONTOUR		50mm CONTOUR		55mm CONTOUR		60mm CONTOUR		65mm CONTOUR		MAX. SPOT SETTLEMENT	
2mm	CONTOUR	2	20mm	25	25mm	30	30mm	35	35mm	40	40mm	45	45mm	50	50mm	55	55mm	60	60mm	65	65mm	+	



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