

Kirkland Developments Limited

Vine Street, Manchester

Vibration Assessment & Monitoring
Specification

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Document Control Sheet

Project 2664
Vine Street, Manchester
Vibration Assessment & Monitoring Report

Rev.	Details	Date	Author	Checker	Approver
0	Draft for comment	16/06/2025	BS	WF	WF
A	Revised following comment	18/06/2025	BS	WF	WF
B	Revised following comment	09/07/2025	SJ	WF	WF

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1 INTRODUCTION

Kirkland Development Limited (KDL) have appointed Byland Engineering Limited (BEL) in an e-mail dated 26th July 2023 to undertake a slope stability assessment of an existing embankment in the Gorton area of Manchester. A new development supported on piled foundations is to be constructed at the crest of the slope which runs parallel to the Manchester to Sheffield (ELR: HAJ) railway. Network Rail (NwR) have requested that the stability of the slope is assessed to demonstrate that the development will not have a negative impact on the earthwork adjacent to their infrastructure. It is noted that the slope is partially owned by the development and partially owned on NwR land with the area owned by NwR increasing towards the overbridge that carries Vine Street across the railway.

The new development will be located at the crest of the railway embankment. The proposed houses are to be supported by piled foundations. The closest buildings are approximately 2m from the crest. The existing slope is approximately 9m high with an angle of 40° from horizontal at its steepest based on the topographic survey. Proposed changes to the ground level are minimal. A minor increase in height is proposed for east of the site and a minor reduction in the centre.

The following report only considers the temporary works slope stability during the installation of the sheet piles and the impacts of the vibrations on the existing railway embankment.

The analyses have been completed parallel to the existing BEL '2664 - Vine Street, Manchester - Slope Stability Report Rev A' and is in accordance with BS 5228-2:2009 & other best practice guidance.

2 SITE LOCATION & GROUND CONDITIONS

2.1 Site Location

The Site is located in the Gorton area of Manchester approximately 200m east of Gorton Station. Access to the site is off Vine Street at the west of the site. The southern boundary of the site is the back of residential properties on Grapevine Road and the car park of Enterprise Trading Estate. The northern boundary is the crest of the railway embankment along the Manchester Glossop Railway Line. The approximate grid reference of the site is Easting 389289, Northing 396957.

The site is ~140m long and ~45m at its widest. The existing ground gradually slopes from the centre outward. From 82.0mOD in the centre to 81.5mOD in the west and 79.5m OD in the east.

The existing railway embankment runs approximately east to west along the northern boundary of the site. Based off the topographic survey it is approximately 9.0m high at a maximum angle of 40° from horizontal. The slope is vegetated with trees and shrubs. Overbridge HAJ/13 is located at the western end of the site and carries Vine Street across the railway on a north-south alignment. A steel palisade fence is present at the toe of the slope.

2.2 Geological Mapping

Online 1:50,000 scale geological mapping on the British Geological Survey Geo-Index website indicates the site to be underlain by the following strata in order of increasing age:

1. Superficial deposits mapped in the area are recorded as Glacial Till described as unsorted and unstratified drift, generally over consolidated. It consists of a heterogenous mixture of clay, sand, gravel, and boulders varying widely in size and shape.
2. Solid geology is mapped as Manchester Marls Formation – Mudstone. These are described as red marl (calcareous mudstone and siltstone) with thin beds of fossiliferous marine limestone and dolomite; locally green; sandy in places especially in the top part; local breccias and pebbly beds.

2.3 Ground Investigation

For brevity, please refer to detailed ground conditions summary presented in BEL '2664 - Vine Street, Manchester - Slope Stability Report Rev A'.

2.4 Characteristic Geotechnical Parameters

The characteristic geotechnical analysis parameters have been selected based on the soil descriptions, in-situ / laboratory testing and other published data / technical guidance. These are identified in the table below.

Stratum	Unit Weight, γ (kN/m ³)	Effective Cohesion, c' (kPa)	Angle of Friction, Φ' (°)
Made Ground	18	0	32
Glacial – Sand	19	0	36
Glacial - Clay	20	0	28

Table 1 – Characteristic geotechnical parameters

The Glacial Sand and Clay are interbedded with the sand layers being ephemeral in their distribution. It is therefore proposed to model all of the Glacial soil as clay which is a conservative assumption. Glacial soils are located below the toe level of the slope.

3 SLOPE STABILITY ANALYSIS

3.1 Limit Equilibrium Analysis

The temporary stability of the slope due to vibration from pile installation has been assessed using a limit equilibrium analysis. The analysis has been undertaken using the Oasys Slope software implementing Bishops method of analysis for circular slips. The program can check circular and non-circular failures, thereby allowing calculations to be carried out for both soil and rock slopes. The location of circular surfaces is defined using a rectangular grid of centres and a number of different radii, a common point through which all circles must pass or a tangential surface which the circle almost touches.

The following analyses have been undertaken subsequent to the initial slope stability assessment in BEL '2664 - Vine Street, Manchester - Slope Stability Report Rev A':

1. Existing slope analysis – modelling the existing slope to determine the existing factor of safety within the slope.
2. Temporary condition analysis – tracks of the piling rig perpendicular to the slope (ABI TM 20 LR Long Reach for SPW installation) - modelling a construction surcharge of 260kPa over 2.38m, 6.0m back from the crest in combination with a horizontal ground acceleration.

As part of this vibration assessment, design section 2 which has the lowest FOS in the existing condition will be used to assess the impact of sheet pile installation using vibratory techniques on the stability of the slope. The temporary condition analysis on section 2 will be reanalysed with the application of a horizontal ground acceleration to model pile installation vibrations.

To model the vibrations from the installation of the sheet pile wall a horizontal acceleration is applied to the analysis. A Peak Ground Acceleration (PGA) of 0.20g was applied with reference to I.A. Hosking et al. (1988), and R.A.P. Bement (1996) which suggest PGA for installing sheet piles are in the range 0.05-0.20g. PGA is applied to all strata in the model, in reality the effects of the vibrations will be localised to the installation site and will dissipate with distance.

Results are summarised in the table below and graphical outputs are presented in Appendix B.

Condition	Design Section	SLS
Existing	2	0.633
SPW Rig & Vibration	2 (0.2g)	0.695

Table 2 – Slope stability results

The following assumptions have been made in the analysis:

1. 1 No. analysis section have been modelled based on section 2 (lowest FOS) from the existing slope stability assessment – the location of each of this section is indicated on the layout drawing included in Appendix A.
2. The analysis is based on drained soil conditions throughout to model long term conditions. No evidence of previous failure of the slope has been provided and therefore peal soil parameters are considered applicable.
3. The analysis will conservatively assume that ground conditions are Made Ground over Glacial Clay. Refer to the section drawings in Appendix A.
4. A temporary condition surcharge of 260kPa over 2.38m located 6.0m back from the crest of the slope have been modelled for the sheet piling rig (ABI TM 20 LR Long Reach for SPW installation). No other surcharging has been considered as part of this vibration assessment.
5. A conservative ground water level is modelled at 74mOD following the slope down and under the railway lines at 71.5mOD.

The results show that the analysis using moderately conservative soil parameters and an upper bound value for the PGA, the change in factor of safety of slope stability is negligible. It is noted that values of 0.20g are based on good construction practices such as tight control on verticality in order to avoid vibratory motions in the horizontal plane.

As noted in the existing BEL slope stability assessment, these analyses are reporting relatively low factors of safety there is at present no evidence that the slope has failed. Potential reasons for this are as follows:

1. As the critical failure surfaces are relatively shallow the existing vegetation on the slope may be having a significant stabilising effect on the slope.
2. The operative angle of friction within the soils forming the slope is higher than assumed. It is noted that the single shear box test undertaken on soils from the site records an angle of friction of 36 degrees, however there is only a single test.
3. It is possible that due to the dense vegetation on the slope the topographic survey is not providing an accurate representation of the geometry of the slope and it is possible that in reality the slope is less steep than assumed in the model.

4 VIBRATION ANALYSIS

4.1 Preamble

Drawings by Kirkland Developments identify the sheet pile wall to be a 1.0m offset from the existing slope at its closest point. As a result, consideration is given to the magnitude of vibrations and their impact on the existing slope. Vibration will dissipate as the distance between the slope and the sheet piles increases and as such only vibrations at the minimum offset point are considered.

The sheet pile wall will be installed with a long reach leader rig using vibratory installation techniques.

4.2 Peak Particle Velocity Calculation

Peak particle velocity (PPV) measurements, which are typically used to describe vibration, from vibratory piling methods are presented within case history data in Annex D of BS 5228-2:2009 + A1:2014. The following table summarizes the relevant data from table D.10 of BS 5228-2:2009 + A1:2014,

Reference Number	Soil Conditions	Construction Summary	Distance from Source (m)	PPV (mm/s)
C44	4m to 5m soft saturated sand over soft to firm clay	Sheet steel piling – driving or extracting	6	2.6
C47	Not Recorded	Resonant Pile Driver	2	10 – 15
C48	4m clay / 8m peat / 2.5m clay / 1m sandy silt with gravel / 6m stiff clay / mudstone and siltstone	Resonant Pile Driver	6	2.5
C53	Gravel / London Clay	Driving Sheets	5	4.3
C56	Gravel	Driving Sheets	3	42

Table 3 – Key data from BS 5228-2:2009 + A1:2014 Table D.10

Alternatively for vibratory piling, PPV (v_{res}) can be estimated based on the following equation from Table E.1 of BS 5228-2:2009 + A1:2014.

$$v_{res} = \frac{k_v}{x^\delta}$$

Where,

k_v is a scaling factor based on the probability of the predicted PPV being exceeded (probability in brackets)

$k_v =$ 60 (50%)
126 (33.3%)

$x =$ distance measured along the ground surface in meters = 1.0m (slope crest) OR 6.0m (midslope) OR 12.0m (palisade fence)

$\delta =$ 1.3 (all operations)
1.2 (start up and rundown)
1.4 (steady state operation)

Therefore,

$$v_{res} = \frac{k_v}{x^{1.4}}$$

PPV is calculated as follows for each respective exceedance probability,

PPV (mm/sec)	Distance from Source (m)	Probability of exceedance
60	1.0 (Crest)	50%
5	6.0 (Midslope)	
2	12.0 (Palisade Fence)	
126	1.0 (Crest)	33.3%
10	6.0 (Midslope)	
4	12.0 (Palisade Fence)	

Table 4 – Estimates of PPV

Based on all the information and calculations above it is expected that the PPV will be less than 60mm/s and less than 10 mm/s at the palisade fence.

4.3 Peak Particle Velocity Limits

BS7385-2:1993 states that 'the risk to [slope] stability is dependent on the extent to which the factor of safety under static loading is reduced by the vibrations, and hence on the intensity, characteristics and duration of the vibration and the soil response'.

Based on the slope stability analyses undertaken in section 3.1 with a horizontal ground acceleration of 0.2g, it is found that there is negligible effect on slope stability due to low level vibrations arising from vibratory piling techniques.

It is proposed to use the following limits on vibration at the Network Rail boundary:

Trigger Level	PPV Limit (mm/s)	Response
Green	< 5mm/s	Work may proceed
Amber	5 – 10mm/s	Increase frequency of monitoring, review working practices & consult the designer
Red	> 10mm/s	Halt operations immediately if this limit is exceeded until the reason for reaching the limit has been identified. Review movement monitoring.

Table 5 – PPV Limits

2 No. vibrographs to be positioned at the crest, and the mid height of the slope or Network Rail Boundary will be moved parallel to the slope as piling progresses.

The above table is replicated on drawing 2664/DWG/001 presented in Appendix D which also details the proposed general arrangement for monitoring locations.

In the event that the above limits are exceeded the movement monitoring should be reviewed. If no movement is recorded, then works may recommence.

5 MOVEMENT MONITORING

It is proposed to use the below monitoring limits on movement of the slope:

Trigger Level	Ground Movement (mm)	Response
Green	< 5mm	Work may proceed
Amber	5 – 10mm	Increase frequency of monitoring, review working practices & consult the designer
Red	> 10mm	Halt operations immediately if this limit is exceeded until the reason for reaching the limit has been identified.

Table 6 – Slope ground movement limits

The above table is replicated on drawing 2664/DWG/001 presented in Appendix D which also details the proposed general arrangement for monitoring locations. Suitable movement monitoring survey points are to be provided at the proposed locations.

It is proposed to monitor movement of the slope at the following frequency both during and immediately following installation of the sheet pile wall,

- Daily monitoring to be undertaken for 1 week before works commence and during installation of the sheet pile wall.
- Weekly monitoring to be undertaken in the 4 weeks following installation of the sheet pile wall.

6 CONCLUSIONS & RECOMMENDATIONS

This report assesses the impact of vibrations arising from sheet pile installation on the overall stability of an existing railway “embankment” (note the slope is filled ground rather than cutting) on the Manchester to Glossop Railway Line in the Gorton area of Manchester.

- Ground conditions are Made Ground over Glacial Clay. Refer to the section drawings in Appendix A.
- Slope stability analyses have been completed using the software Oasys Slope implementing the Bishops method of slices, which considers a series of hypothetical circular failure surfaces of increasing radius about a grid of centres specified by the user.
- Vibrations from the installation of the sheet piles have been modelled as a 0.20g horizontal acceleration.
- The analyses are carried out using unfactored (SLS) parameters in order to assess the relative changes in factor of safety (FoS) and do not aim to assess the slope in accordance with current British Standards / Eurocodes.
- This report has been completed parallel to the existing BEL ‘2664 - Vine Street, Manchester - Slope Stability Report Rev A’.
 - a. Design Section 2 (critical FOS) from the existing slope stability report has been used to assess the impact of sheet pile installation using vibratory techniques on the stability of the slope
- The results identify that the calculated factor of safety is decreased by 0.5% due to vibrations, which is considered to be negligible.
- Estimates of peak particles velocity (PPV) have been assessed using empirical data within Annex D of BS 5228-2:2009 + A1:2014. These identified a likely PPV of <60mm/s 1.0m from the sheet pile wall.
- The following limits for monitoring of slope movement and ground borne PPV are proposed
- Proposed slope movement limits are as follows:

Trigger Level	Ground Movement (mm)	Response
Green	< 5mm	Work may proceed
Amber	5 – 10mm	Increase frequency of monitoring, review working practices & consult the designer
Red	> 10mm	Halt operations immediately if this limit is exceeded until the reason for reaching the limit has been identified.

- Proposed PPV limits are as follows:

Trigger Level	PPV Limit (mm/s)	Response
Green	< 5mm/s	Work may proceed
Amber	5 – 10mm/s	Increase frequency of monitoring, review working practices & consult the designer
Red	> 10mm/s	Halt operations immediately if this limit is exceeded until the reason for reaching the limit has been identified. Review movement monitoring.

- 2 No. vibrographs to be positioned at the crest and the mid height of the slope will be moved parallel to the slope as piling progresses.
- Suitable movement monitoring survey points are to be provided at the proposed locations.
- It is proposed to monitor movement of the slope at the following frequency both during and immediately following installation of the sheet pile wall,
 - Daily monitoring to be undertaken during installation of the sheet pile wall.
 - Weekly monitoring to be undertaken in the 4 weeks following installation of the sheet pile wall.
- Drawing 2664/DWG/001 detailing the proposed monitoring general arrangement and specification is presented in Appendix D.

Assumptions

The following assumptions have been made as part of this vibration assessment:

- 1 No. analysis section have been modelled based on section 2 (lowest FOS) from the existing slope stability assessment – the location of each of this section is indicated on the layout drawing included in Appendix A.
- The analysis is based on drained soil conditions throughout to model long term conditions. No evidence of previous failure of the slope has been provided and therefore peal soil parameters are considered applicable.
- The analysis will conservatively assume that ground conditions are Made Ground over Glacial Clay. Refer to the section drawings in Appendix A.
- A temporary condition surcharge of 260kPa over 2.38m located 6.0m back from the crest of the slope have been modelled for the sheet piling rig (ABI TM 20 LR Long Reach for SPW installation). No other surcharging has been considered as part of this vibration assessment.
- A conservative ground water level is modelled at 74mOD following the slope down and under the railway lines at 71.5mOD.

The following points are replicated from the existing BEL slope stability report with regard to the existing factors of safety which may suggest a higher factor of safety is actually present within the slope:

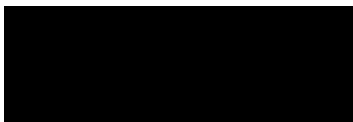
- There have been no reports of failures affecting the slope.

- b. Critical failure surfaces are relatively shallow and generally arise from the existing slope being overstep. Failure surfaces with adequate factors of safety generally occur 2 to 3m behind the face of the slope.
- c. The analysis is based on conservative parameters due to the limited amount of geotechnical testing that has been carried out. It is possible that the angle of friction within the slope is considerably higher than that adopted. It is noted that increasing the angle of friction to 36 degrees (as determined by the single shear box test) would increase the critical factors of to 0.7 to 1.2 for the 3 No. sections in their existing conditions.
- d. There is a significant amount of vegetation on the face of the slope which may be assisting in stabilising the slope face.
- e. It is noted that the topographic survey provided may potentially be artificially steepening the slope due to difficulties in surveying densely vegetated slopes.

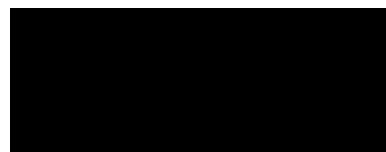
Recommendations

The following recommendations apply to further mitigate the risks associated with the slope:

- a. No other plant should be in use between the piling rig and the slope while piling operations are ongoing.
- b. For other works only light plant should be operated near the slope and this should be positioned no closer than 5m to the crest of the slope based on a 10kPa construction surcharge. Again once final plant loadings are known this should be reviewed. It should also be noted that no large loads should be placed in the garden areas e.g. sheds etc. post construction where these are located within 5m of the crest of the slope.
- c. Under no circumstance should water be discharged into the ground near to the slope. All rain water from the proposed structures should be run into the sewerage system. Additionally falls should be set such that water flows away from the slope and is not concentrated at the crest.



Billy Sturdy MEng GMICE



Will Frampton BSc MSc GMICE FGS CGeol

7 REFERENCES

1. BS 8002 (2015) – Earth Retaining Structures, BSI, London
2. BS EN 1997-1 (2004) + A1 (2013) – Eurocode 7: Geotechnical design – Part 1 General rules, BSI, London
3. NA +A1 (2014) to BS EN 1997-1 (2004) + A1 (2013) – UK National Annex to Eurocode 7: Geotechnical design – Part 1: General rules, BSI, London
4. BS EN ISO 14688-2:2018 – Geotechnical Investigation and Testing – Identification and Classification of Soils - Part 2: Principles for a classification, BSI, London

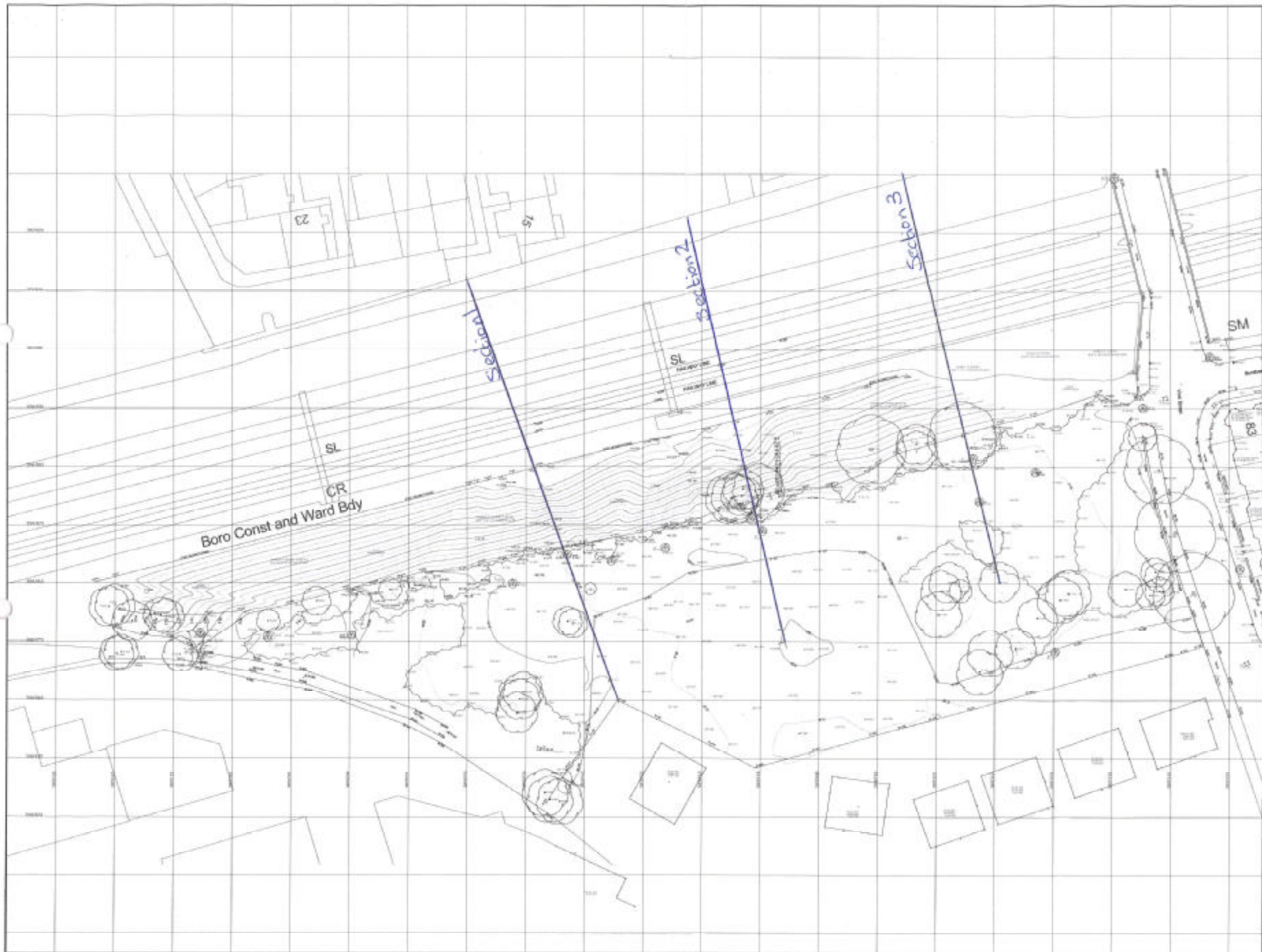
Provided Information

The following documentation has been provided for the assessment:

- e3p Limited - Phase II Geoenvironmental Site Assessment – 14-944-R1-2 dated 11th January 2022
- JLP Surveying Limited – Topographical Land Survey – S18-442 dated 29th May 2018
- Ridge Limited Drawings
 - o Proposed Finished Levels – VSG-RDG-XX-XX-DR-C-0001-PO2 dated 14TH April 2023
 - o Proposed Drainage GA - VSG-RDG-XX-XX-DR-C-0101-PO3 dated 9th June 2023
- JIG Consulting Engineers Limited – Embankment Retaining Wall Proposal – 23042-001 dated 5th July 2023
- Byland Engineering Limited – 2664 – Vine Street, Manchester – Slope Stability Assessment Report – Rev. A – dated 04/09/2023

Appendix A

Design Sections



SHRIFT ORIENTED TO REAL TIME GPS

NOTES AND AMENDMENTS
 1. All measurements were taken at the time of the survey.
 2. All measurements were taken at the time of the survey.
 3. All measurements were taken at the time of the survey.
 4. All measurements were taken at the time of the survey.
 5. All measurements were taken at the time of the survey.

REVISIONS

NO.	DATE	DESCRIPTION
1	10/10/2010	Initial Survey
2	10/10/2010	Initial Survey
3	10/10/2010	Initial Survey
4	10/10/2010	Initial Survey
5	10/10/2010	Initial Survey

Topographic Survey Legend

Symbol	Description
1	10/10/2010
2	10/10/2010
3	10/10/2010
4	10/10/2010
5	10/10/2010
6	10/10/2010
7	10/10/2010
8	10/10/2010
9	10/10/2010
10	10/10/2010

GENERAL INFORMATION
 1. All measurements were taken at the time of the survey.
 2. All measurements were taken at the time of the survey.
 3. All measurements were taken at the time of the survey.
 4. All measurements were taken at the time of the survey.
 5. All measurements were taken at the time of the survey.

PROPERTY DATA

NO.	DATE	DESCRIPTION
1	10/10/2010	Initial Survey
2	10/10/2010	Initial Survey
3	10/10/2010	Initial Survey
4	10/10/2010	Initial Survey
5	10/10/2010	Initial Survey

JLP Surveying

PROJECT DATA

NO.	DATE	DESCRIPTION
1	10/10/2010	Initial Survey
2	10/10/2010	Initial Survey
3	10/10/2010	Initial Survey
4	10/10/2010	Initial Survey
5	10/10/2010	Initial Survey

Topographic Survey Data

NO.	DATE	DESCRIPTION
1	10/10/2010	Initial Survey
2	10/10/2010	Initial Survey
3	10/10/2010	Initial Survey
4	10/10/2010	Initial Survey
5	10/10/2010	Initial Survey

Byland

Calculations

Job No. 2664

Originator SJ

Date 02-08-23

Job Name Vine Street, Manchester

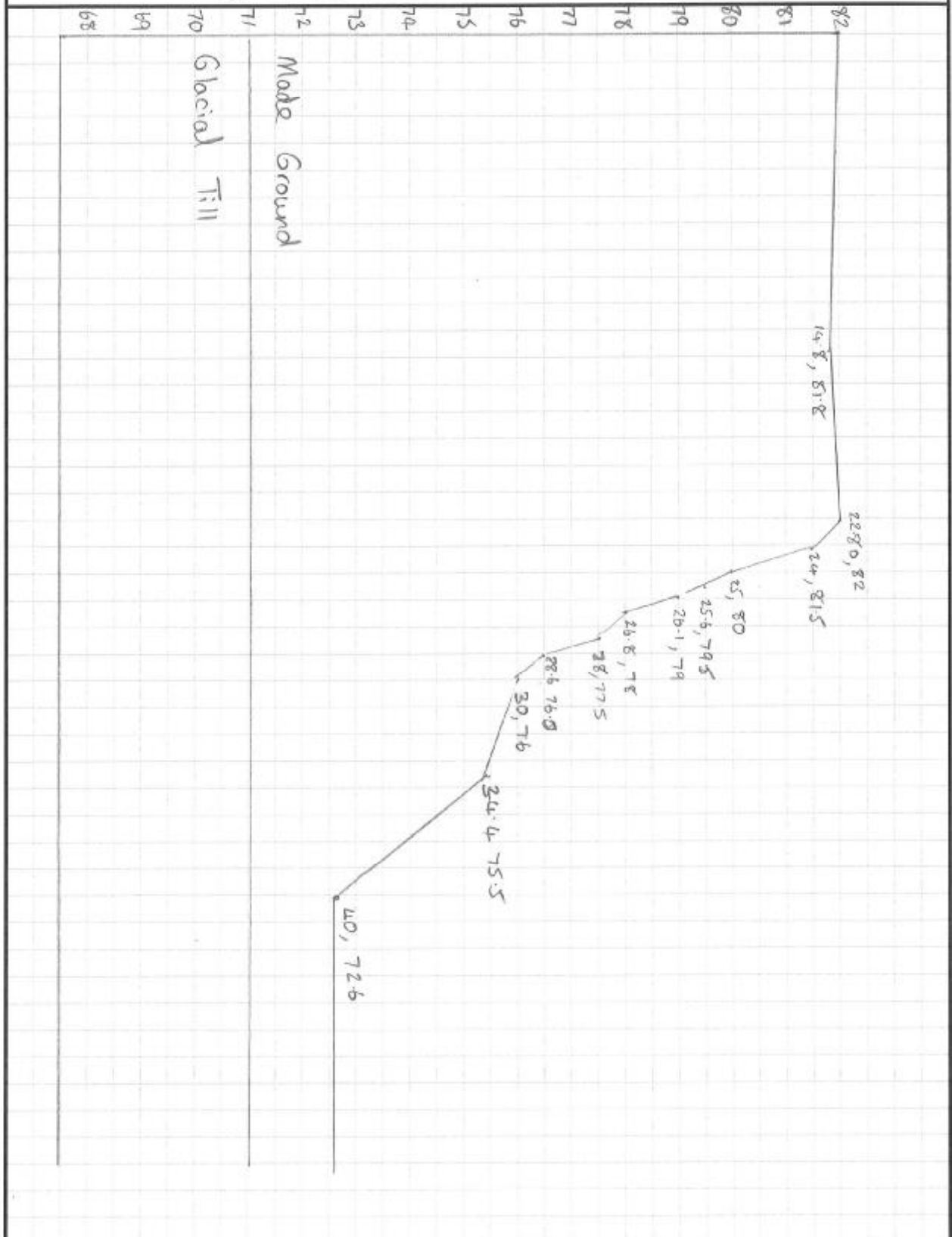
Checker

Date

Section Existing Slope - Section 2

Revision

Page



Appendix B

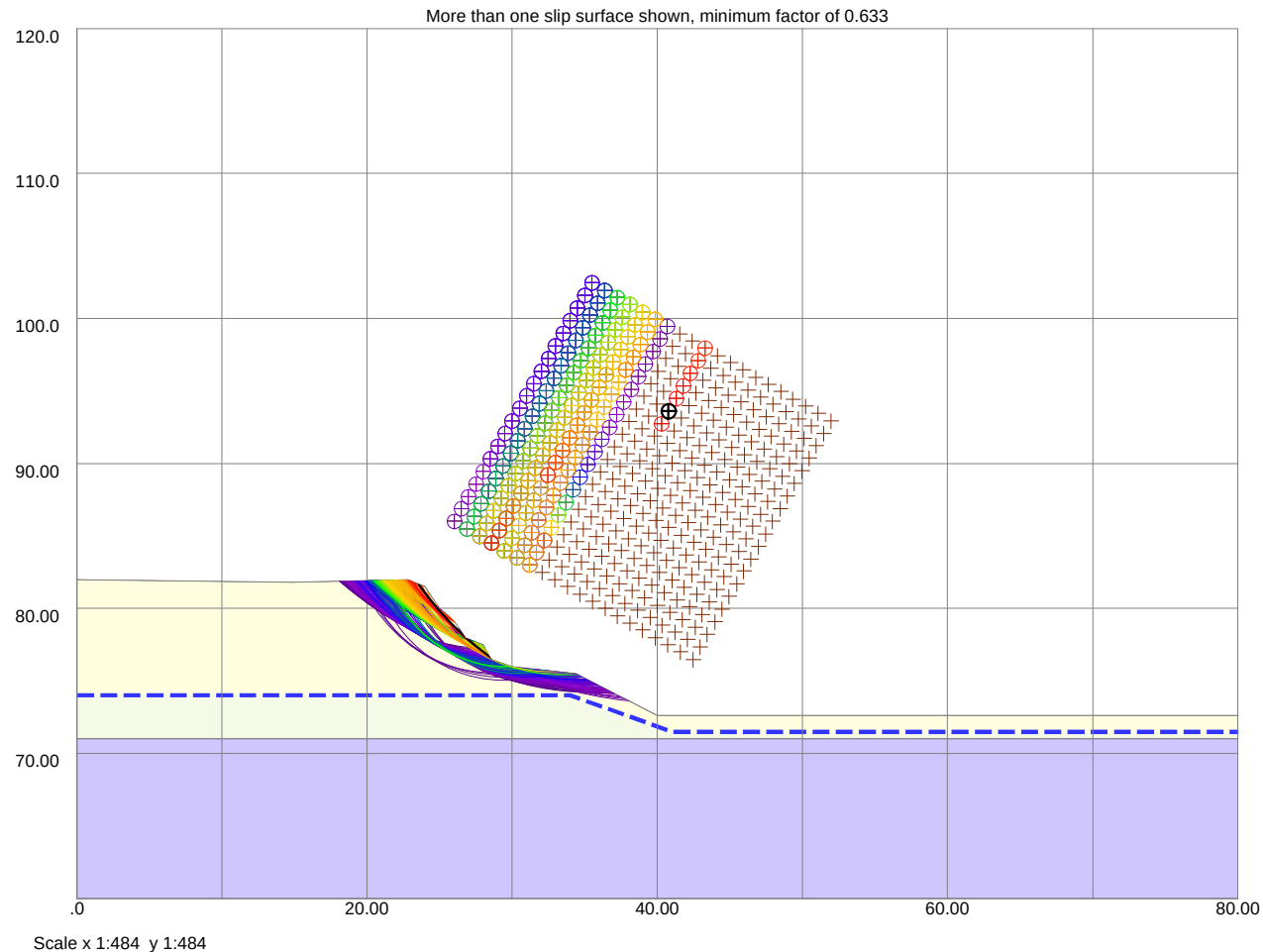
Oasys Slope input/output for Design Section 2 in existing condition



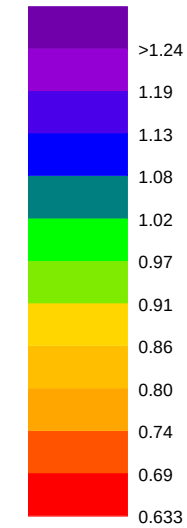
Vine Street, Manchester
Section 2 Existing Slope
SLS

BYLAND
ENGINEERING LIMITED

Job No.	Sheet No.	Rev.
2664		
Drg. Ref.		
Made by SJ	Date	Checked



Factors of Safety



NOTE: plotted range is
a sub-set of the results



Vine Street, Manchester
Section 2 Existing Slope
SLS

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ENGINEERING LIMITED

Job No.	Sheet No.	Rev.
2664		
Drg. Ref.		
Made by SJ	Date	Checked

General Parameters

Direction of slip: Increasing x
Minimum slip weight [kN/m] : 20.00000
Type of analysis : STATIC

Analysis Options

Factor of safety on : SHEAR STRENGTH
Minimum number of slices: 25
Method: Bishop (Variably inclined interslice forces)
Maximum number of iterations: 300
Reinforcement: ACTIVE

Material properties

No	Description	Unit Weight Above GWL	Unit Weight Below GWL	Shear Strength Parameters Condition	Phi
or c or c0'					
Phi0					
		[kN/m3]	[kN/m3]		
[°]	[kN/m²]				
1	Made Ground	18.000	19.000	Drained - linear strength	
32.000	0.0				
2	Glacial Clay	20.000	21.000	Drained - linear strength	
28.000	0.0				

Coordinates of top of soil strata

The units of the following coordinates are in m

Stratum	X -->						
	0.0	14.800	22.800	24.000	25.000	25.600	26.100
1	82.000	81.800	82.000	81.500	80.000	79.500	79.000
2	71.000	.	.	.	.	.	.
GW Profile 1	74.000	.	.	.	.	.	.
Stratum	X -->						
	26.800	28.000	28.600	30.000	34.000	34.400	40.000
1	78.000	77.500	76.500	76.000	.	75.500	72.600
2	.	.	.	.	.	.	.
GW Profile 1	.	.	.	.	74.000	.	.
Stratum	X -->						
	41.000	80.000					
1	.	72.600					
2	.	71.000					
GW Profile 1	71.500	71.500					

Piezometers

Stratum-linked data

No.	Material	Water table	Piezo Set/ Ru value
1	Made Ground	GW Profile 1	-
2	Glacial Clay	GW Profile 1	-

Slip Surface Specification

Circle centre specification: GRID
Bottom left of grid: x = 26.00000 m y = 86.00000 m
Inclination of grid: -30.00000 deg
(positive anticlockwise direction about bottom left of grid)
Centres on grid: 20 in x direction at 1.00000m spacing
20 in y direction at 1.00000m spacing
Grid extended to find minimum FoS
Initial radius of circle 1.00000 m
Incremented by 1.00000 m until all possible circles considered

WORST CASE

Centre at (40.794m,93.624m) Radius 21.000m
Iterations: 5 Horiz acceleration [%g]: 0.0
Net vertical force [kN/m]: 368.60E-6 Slip weight [kN/m] 27.114
Net horiz force [kN/m]: 361.93E-6 Disturbing moment [kN/m]: 401.97
Restoring moment [kNm/m]: 254.44
Reinf.Rest.Moment [kNm/m]: 0.0
Factor of Safety: 0.63298



Vine Street, Manchester
Section 2 Existing Slope
SLS

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No. Material Water table Piezo Set/ Ru value

The system of interslice and base forces are in equilibrium when the strengths available at the bases are divided by the computed factor of safety. The interslice forces shown in the following table are in equilibrium with the factored strengths of the soil at the bases of slices.

Slip surface coordinates			Pore Pressure		Interslice forces [kN/m]		E(u)
Point	x [m]	y [m]	L	R	T	E	
			[kN/m ²]	[kN/m ²]			
1	23.503	81.707	-	-77.069	0.0	0.0	0.0
2	23.600	81.567	-75.673	-75.673	0.0077936	0.014707	0.0
3	23.699	81.428	-74.284	-74.284	0.049820	0.053876	0.0
4	23.798	81.290	-72.904	-72.904	0.12281	0.11599	0.0
5	23.898	81.153	-71.531	-71.531	0.22346	0.19942	0.0
6	24.000	81.017	-70.167	-70.167	0.34850	0.30241	0.0
7	24.120	80.859	-68.586	-68.586	0.49830	0.42776	0.0
8	24.241	80.702	-67.016	-67.016	0.63051	0.54195	0.0
9	24.364	80.546	-65.458	-65.458	0.74487	0.64430	0.0
10	24.488	80.391	-63.911	-63.911	0.84149	0.73437	0.0
11	24.614	80.238	-62.377	-62.377	0.92067	0.81188	0.0
12	24.741	80.085	-60.854	-60.854	0.98303	0.87680	0.0
13	24.870	79.934	-59.343	-59.343	1.0294	0.92932	0.0
14	25.000	79.784	-57.845	-57.845	1.0609	0.96992	0.0
15	25.118	79.651	-56.512	-56.512	1.0836	1.0021	0.0
16	25.237	79.519	-55.190	-55.190	1.1064	1.0348	0.0
17	25.357	79.388	-53.877	-53.877	1.1278	1.0668	0.0
18	25.478	79.257	-52.575	-52.575	1.1464	1.0967	0.0
19	25.600	79.128	-51.283	-51.283	1.1609	1.1232	0.0
20	25.723	79.000	-50.001	-50.001	1.1694	1.1443	0.0
21	25.848	78.873	-48.729	-48.729	1.1709	1.1589	0.0
22	25.973	78.747	-47.468	-47.468	1.1652	1.1665	0.0
23	26.100	78.622	-46.217	-46.217	1.1521	1.1667	0.0
24	26.238	78.488	-44.882	-44.882	1.1306	1.1592	0.0
25	26.376	78.356	-43.559	-43.559	1.1042	1.1463	0.0
26	26.516	78.225	-42.249	-42.249	1.0758	1.1311	0.0
27	26.658	78.095	-40.952	-40.952	1.0488	1.1169	0.0
28	26.800	77.967	-39.667	-39.667	1.0266	1.1078	0.0
29	26.946	77.838	-38.375	-38.375	1.0028	1.0969	0.0
30	27.093	77.710	-37.097	-37.097	0.96709	1.0719	0.0
31	27.241	77.583	-35.832	-35.832	0.91676	1.0292	0.0
32	27.391	77.458	-34.581	-34.581	0.84936	0.96512	0.0
33	27.541	77.334	-33.344	-33.344	0.76259	0.87618	0.0
34	27.693	77.212	-32.121	-32.121	0.65434	0.75873	0.0
35	27.846	77.091	-30.913	-30.913	0.52264	0.60925	0.0
36	28.000	76.972	-29.718	-29.718	0.36576	0.42427	0.0
37	28.141	76.864	-28.641	-28.641	0.22385	0.25386	0.0
38	28.284	76.758	-27.576	-27.576	0.11213	0.12064	0.0
39	28.427	76.652	-26.523	-26.523	0.035887	0.033156	0.0
40	28.571	76.548	-25.482	-	368.60E-6	361.93E-6	0.0

Slice Strength Parameters			Average Pore Pressure	Slice Weight	Forces on base [kN/m]		
No.	c' [kN/m ²]	Tan phi	[kN/m ²]	[kN/m]	Normal	Shear (capacity)	Shear (mobilised)
1	0.0	0.62487	0.0	0.086681	0.057107	0.035684	0.056375
2	0.0	0.62487	0.0	0.26196	0.15898	0.099341	0.15694
3	0.0	0.62487	0.0	0.43897	0.26418	0.16508	0.26080
4	0.0	0.62487	0.0	0.61753	0.37260	0.23282	0.36782
5	0.0	0.62487	0.0	0.79758	0.48419	0.30256	0.47799
6	0.0	0.62487	0.0	1.0194	0.62528	0.39072	0.61726
7	0.0	0.62487	0.0	0.98104	0.60951	0.38087	0.60171
8	0.0	0.62487	0.0	0.93385	0.58772	0.36725	0.58019
9	0.0	0.62487	0.0	0.87760	0.55947	0.34960	0.55231
10	0.0	0.62487	0.0	0.81207	0.52447	0.32772	0.51775
11	0.0	0.62487	0.0	0.73704	0.48236	0.30141	0.47618
12	0.0	0.62487	0.0	0.65227	0.43282	0.27046	0.42727
13	0.0	0.62487	0.0	0.55749	0.37545	0.23460	0.37064
14	0.0	0.62487	0.0	0.49409	0.33624	0.21011	0.33194
15	0.0	0.62487	0.0	0.57188	0.39143	0.24459	0.38642
16	0.0	0.62487	0.0	0.64682	0.44565	0.27847	0.43994
17	0.0	0.62487	0.0	0.71878	0.49874	0.31165	0.49235
18	0.0	0.62487	0.0	0.78758	0.55051	0.34400	0.54346
19	0.0	0.62487	0.0	0.83091	0.58542	0.36581	0.57792



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Section 2 Existing Slope
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Slice No.	Strength Parameters	Average Base	Slice Weight	Forces on base [kN/m]		
20	0.0 0.62487	0.0	0.84664	0.60154	0.37588	0.59383
21	0.0 0.62487	0.0	0.85769	0.61447	0.38397	0.60660
22	0.0 0.62487	0.0	0.86385	0.62404	0.38994	0.61604
23	0.0 0.62487	0.0	0.85890	0.62656	0.39152	0.61853
24	0.0 0.62487	0.0	0.70526	0.52082	0.32544	0.51415
25	0.0 0.62487	0.0	0.54121	0.40549	0.25338	0.40029
26	0.0 0.62487	0.0	0.36662	0.28031	0.17516	0.27672
27	0.0 0.62487	0.0	0.18135	0.14502	0.090616	0.14316
28	0.0 0.62487	0.0	0.17723	0.14323	0.089503	0.14140
29	0.0 0.62487	0.0	0.35734	0.28029	0.17515	0.27670
30	0.0 0.62487	0.0	0.53535	0.41790	0.26114	0.41255
31	0.0 0.62487	0.0	0.71104	0.55585	0.34734	0.54873
32	0.0 0.62487	0.0	0.88431	0.69396	0.43363	0.68506
33	0.0 0.62487	0.0	1.0549	0.83197	0.51987	0.82131
34	0.0 0.62487	0.0	1.2227	0.96972	0.60595	0.95729
35	0.0 0.62487	0.0	1.3875	1.1069	0.69168	1.0927
36	0.0 0.62487	0.0	1.1816	0.94966	0.59341	0.93749
37	0.0 0.62487	0.0	0.85786	0.69649	0.43521	0.68756
38	0.0 0.62487	0.0	0.52283	0.43085	0.26923	0.42533
39	0.0 0.62487	0.0	0.17652	0.15269	0.095411	0.15073

Slice No.	Surface Load [kN/m_hor/m]		Point Load [kN/m]		Water Pressure on ground surface [kN/m_hor/m]		
	Vert	Horiz	Vert	Horiz	Vert	Horiz	
1	0.0		0.0	0.0	0.0	0.0	0.0
2	0.0		0.0	0.0	0.0	0.0	0.0
3	0.0		0.0	0.0	0.0	0.0	0.0
4	0.0		0.0	0.0	0.0	0.0	0.0
5	0.0		0.0	0.0	0.0	0.0	0.0
6	0.0		0.0	0.0	0.0	0.0	0.0
7	0.0		0.0	0.0	0.0	0.0	0.0
8	0.0		0.0	0.0	0.0	0.0	0.0
9	0.0		0.0	0.0	0.0	0.0	0.0
10	0.0		0.0	0.0	0.0	0.0	0.0
11	0.0		0.0	0.0	0.0	0.0	0.0
12	0.0		0.0	0.0	0.0	0.0	0.0
13	0.0		0.0	0.0	0.0	0.0	0.0
14	0.0		0.0	0.0	0.0	0.0	0.0
15	0.0		0.0	0.0	0.0	0.0	0.0
16	0.0		0.0	0.0	0.0	0.0	0.0
17	0.0		0.0	0.0	0.0	0.0	0.0
18	0.0		0.0	0.0	0.0	0.0	0.0
19	0.0		0.0	0.0	0.0	0.0	0.0
20	0.0		0.0	0.0	0.0	0.0	0.0
21	0.0		0.0	0.0	0.0	0.0	0.0
22	0.0		0.0	0.0	0.0	0.0	0.0
23	0.0		0.0	0.0	0.0	0.0	0.0
24	0.0		0.0	0.0	0.0	0.0	0.0
25	0.0		0.0	0.0	0.0	0.0	0.0
26	0.0		0.0	0.0	0.0	0.0	0.0
27	0.0		0.0	0.0	0.0	0.0	0.0
28	0.0		0.0	0.0	0.0	0.0	0.0
29	0.0		0.0	0.0	0.0	0.0	0.0
30	0.0		0.0	0.0	0.0	0.0	0.0
31	0.0		0.0	0.0	0.0	0.0	0.0
32	0.0		0.0	0.0	0.0	0.0	0.0
33	0.0		0.0	0.0	0.0	0.0	0.0
34	0.0		0.0	0.0	0.0	0.0	0.0
35	0.0		0.0	0.0	0.0	0.0	0.0
36	0.0		0.0	0.0	0.0	0.0	0.0
37	0.0		0.0	0.0	0.0	0.0	0.0
38	0.0		0.0	0.0	0.0	0.0	0.0
39	0.0		0.0	0.0	0.0	0.0	0.0

Appendix C

Oasys Slope input/output for Design Section 2 in temporary condition

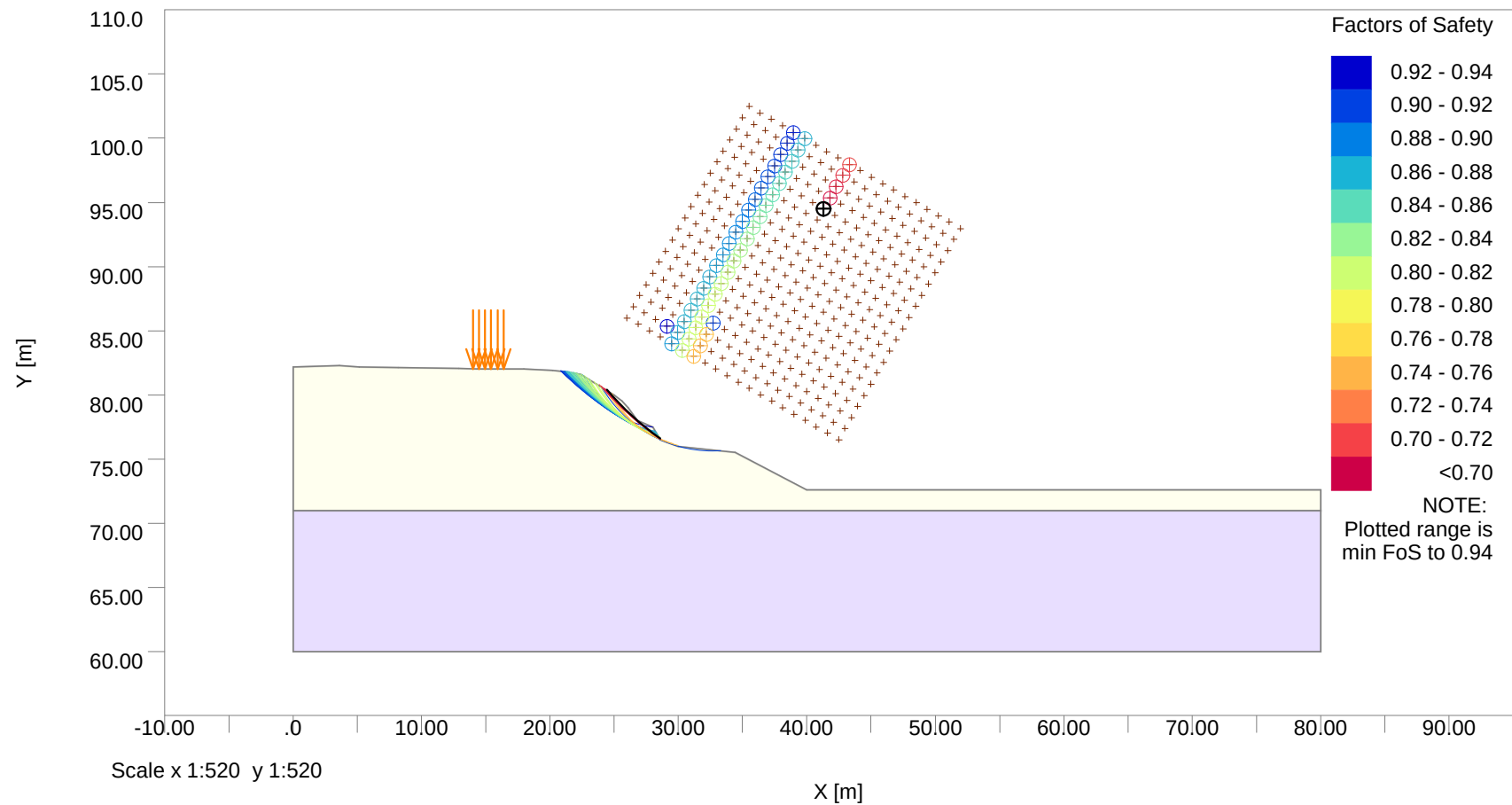


Vine Street, Manchester
Section 2 Temporary Slope
SLS

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More than one slip surface shown, minimum factor of 0.695





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Specification
Slip Type: CIRCULAR
Direction of slip: Increasing x
Minimum slip weight [kN/m] :20.00000
Type of analysis: Increasing x
Factor of safety on: SHEAR STRENGTH
Minimum number of slices 25
Method: Bishop(Variably inclined interslice forces)
Maximum number of iterations: 300
Reinforcement: NONE

Material Properties

No	Description	Unit Weight Above GWL	Unit Weight Below GWL	Shear Strength Parameters Condition	Phi
or	c or c0'				
Phi0		[kN/m3]	[kN/m3]		
[°]	[kN/m²]				
1	Made Ground	18.000	18.000	Drained	
32.000	0.0				
2	Glacial Clay	20.000	20.000	Drained	
28.000	0.0				

Surface loads

No.	Limits of loaded area	Distributed load	Permanent / Variable load	Favourable / Unfavourable load	Use in pull-out calc
	X1 [m]	X2 [m]	Vert [kN/m²]	Horiz [kN/m²]	
1	14.020	16.400	260.00	0.0	Variable
					N/A
					No

Slip Surface Specification
Circle centre specification:
Bottom left of grid: x = 26.00000 m y = 86.00000 m
Inclination of grid: -30.00000 deg
(positive anticlockwise direction about bottom left of grid)
Centres on grid: 20 in x direction at 1.00000m spacing
20 in y direction at 1.00000m spacing
Grid extended to find minimum FoS
Initial radius of circle 1.00000 m
Incremented by 1.00000 m until all possible circles considered

WORST CASE

Centre at (41.294m,94.490m)	Radius 22.000m
Iterations: 5	Horiz acceleration [%g]: 0.20000
Net vertical force [kN/m]: 461.59E-6	Slip weight [kN/m] 21.852
Net horiz force [kN/m]: 501.60E-6	Disturbing moment [kN/m]: 322.17
	Restoring moment [kNm/m]: 223.92
	Reinf.Rest.Moment [kNm/m]: 0.0
	Factor of Safety: 0.69505

The system of interslice and base forces are in equilibrium when the strengths available at the bases are divided by the computed factor of safety. The interslice forces shown in the following table are in equilibrium with the factored strengths of the soil at the bases of slices.

Slip surface coordinates		Pore Pressure		Interslice forces [kN/m]		
Point	x [m] y [m]	L	R	T	E	E(u)
		[kN/m²]	[kN/m²]			
1	24.450 80.338	-	-63.380	0.0	0.0	0.0
2	24.587 80.177	-61.770	-61.770	0.0063804	0.011967	0.0
3	24.725 80.018	-60.180	-60.180	0.036272	0.044359	0.0
4	24.862 79.862	-58.620	-58.620	0.084679	0.093604	0.0
5	25.000 79.709	-57.090	-57.090	0.14694	0.15618	0.0
6	25.150 79.545	-55.450	-55.450	0.22256	0.23260	0.0
7	25.300 79.385	-53.850	-53.850	0.29573	0.30850	0.0
8	25.450 79.227	-52.270	-52.270	0.36997	0.38632	0.0
9	25.600 79.073	-50.730	-50.730	0.43607	0.45808	0.0



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SLS

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Slip surface coordinates		Pore Pressure		Interslice forces [kN/m]		
Point	x [m] y [m]	L	R	T	E	E(u)
		[kN/m ²]	[kN/m ²]			
10	25.725	78.947	-49.470	-49.470	0.48442	0.51223 0.0
11	25.850	78.823	-48.230	-48.230	0.52507	0.55943 0.0
12	25.975	78.700	-47.000	-47.000	0.56173	0.60291 0.0
13	26.100	78.580	-45.800	-45.800	0.58663	0.63511 0.0
14	26.240	78.448	-44.480	-44.480	0.60320	0.65974 0.0
15	26.380	78.317	-43.170	-43.170	0.61282	0.67709 0.0
16	26.520	78.189	-41.890	-41.890	0.61223	0.68356 0.0
17	26.660	78.064	-40.640	-40.640	0.60527	0.68291 0.0
18	26.800	77.940	-39.400	-39.400	0.59769	0.68152 0.0
19	26.950	77.810	-38.100	-38.100	0.58727	0.67722 0.0
20	27.100	77.682	-36.820	-36.820	0.57149	0.66648 0.0
21	27.250	77.556	-35.560	-35.560	0.54816	0.64648 0.0
22	27.400	77.433	-34.330	-34.330	0.51280	0.61117 0.0
23	27.550	77.312	-33.120	-33.120	0.46554	0.56043 0.0
24	27.700	77.193	-31.930	-31.930	0.40465	0.49156 0.0
25	27.850	77.076	-30.760	-30.760	0.32857	0.40192 0.0
26	28.000	76.961	-29.610	-29.610	0.23583	0.28890 0.0
27	28.144	76.853	-28.530	-28.530	0.14307	0.17267 0.0
28	28.288	76.746	-27.460	-27.460	0.071927	0.084442 0.0
29	28.433	76.642	-26.420	-26.420	0.021757	0.022583 0.0
30	28.577	76.539	-25.390	-	461.59E-6	501.60E-6 0.0

Slice No.	Strength Parameters		Average Pore Pressure	Slice Weight	Forces on base [kN/m]		
	c' [kN/m ²]	Tan phi	[kN/m ²]	[kN/m]	Normal	Shear (capacity)	Shear (mobilised)
1	0.0	0.62487	0.0	0.095288	0.066694	0.041675	0.059959
2	0.0	0.62487	0.0	0.28215	0.18908	0.11815	0.16999
3	0.0	0.62487	0.0	0.46283	0.31027	0.19388	0.27894
4	0.0	0.62487	0.0	0.63608	0.42915	0.26816	0.38581
5	0.0	0.62487	0.0	0.83835	0.56993	0.35613	0.51238
6	0.0	0.62487	0.0	0.93825	0.64567	0.40346	0.58047
7	0.0	0.62487	0.0	1.0301	0.71302	0.44555	0.64102
8	0.0	0.62487	0.0	1.1138	0.78081	0.48790	0.70196
9	0.0	0.62487	0.0	0.96188	0.68046	0.42520	0.61175
10	0.0	0.62487	0.0	0.96188	0.68590	0.42860	0.61664
11	0.0	0.62487	0.0	0.95850	0.68623	0.42880	0.61694
12	0.0	0.62487	0.0	0.95063	0.68879	0.43041	0.61924
13	0.0	0.62487	0.0	0.97272	0.71125	0.44444	0.63943
14	0.0	0.62487	0.0	0.80010	0.58796	0.36740	0.52859
15	0.0	0.62487	0.0	0.62244	0.46334	0.28952	0.41655
16	0.0	0.62487	0.0	0.43722	0.33032	0.20641	0.29697
17	0.0	0.62487	0.0	0.24696	0.18930	0.11828	0.17018
18	0.0	0.62487	0.0	0.25380	0.19652	0.12280	0.17667
19	0.0	0.62487	0.0	0.43335	0.33411	0.20877	0.30037
20	0.0	0.62487	0.0	0.60750	0.46939	0.29330	0.42199
21	0.0	0.62487	0.0	0.77490	0.60318	0.37691	0.54227
22	0.0	0.62487	0.0	0.93555	0.73192	0.45735	0.65801
23	0.0	0.62487	0.0	1.0908	0.85808	0.53619	0.77144
24	0.0	0.62487	0.0	1.2407	0.98159	0.61337	0.88247
25	0.0	0.62487	0.0	1.3851	1.1024	0.68884	0.99105
26	0.0	0.62487	0.0	1.2281	0.98625	0.61628	0.88666
27	0.0	0.62487	0.0	0.88281	0.71257	0.44526	0.64061
28	0.0	0.62487	0.0	0.53228	0.43566	0.27223	0.39167
29	0.0	0.62487	0.0	0.17786	0.14904	0.093131	0.13399

Slice No.	Surface Load [kN/m_hor/m]		Point Load [kN/m]		Water Pressure on ground surface [kN/m_hor/m]		
	Vert	Horiz	Vert	Horiz	Vert	Horiz	
1	0.0		0.0	0.0	0.0	0.0	0.0
2	0.0		0.0	0.0	0.0	0.0	0.0
3	0.0		0.0	0.0	0.0	0.0	0.0
4	0.0		0.0	0.0	0.0	0.0	0.0
5	0.0		0.0	0.0	0.0	0.0	0.0
6	0.0		0.0	0.0	0.0	0.0	0.0
7	0.0		0.0	0.0	0.0	0.0	0.0
8	0.0		0.0	0.0	0.0	0.0	0.0
9	0.0		0.0	0.0	0.0	0.0	0.0
10	0.0		0.0	0.0	0.0	0.0	0.0

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				Made by BS	Date	Checked	Date
Slice No.	Surface Load [kN/m_hor/m]		Point Load [kN/m]		Water Pressure on ground surface [kN/m_hor/m]		
	Vert	Horiz	Vert	Horiz	Vert	Horiz	
11	0.0		0.0	0.0	0.0	0.0	
12	0.0		0.0	0.0	0.0	0.0	
13	0.0		0.0	0.0	0.0	0.0	
14	0.0		0.0	0.0	0.0	0.0	
15	0.0		0.0	0.0	0.0	0.0	
16	0.0		0.0	0.0	0.0	0.0	
17	0.0		0.0	0.0	0.0	0.0	
18	0.0		0.0	0.0	0.0	0.0	
19	0.0		0.0	0.0	0.0	0.0	
20	0.0		0.0	0.0	0.0	0.0	
21	0.0		0.0	0.0	0.0	0.0	
22	0.0		0.0	0.0	0.0	0.0	
23	0.0		0.0	0.0	0.0	0.0	
24	0.0		0.0	0.0	0.0	0.0	
25	0.0		0.0	0.0	0.0	0.0	
26	0.0		0.0	0.0	0.0	0.0	
27	0.0		0.0	0.0	0.0	0.0	
28	0.0		0.0	0.0	0.0	0.0	
29	0.0		0.0	0.0	0.0	0.0	

Appendix D
Monitoring General Arrangement and Specification Drawing



Monitoring Setting Out
General Arrangement
Scale 1:125

Monitoring Setting Out Data			
Ref.	Easting (m)	Northing (m)	Monitoring Purpose
VIB-01	389207.503	396960.876	Vibration
VIB-02	389205.679	396966.243	Vibration
VIB-03	389241.357	396967.883	Vibration
VIB-04	389240.241	396973.042	Vibration
VIB-05	389294.355	396983.350	Vibration
VIB-06	389292.435	396988.655	Vibration
MOV-01	389202.348	396959.808	Slope Movement
MOV-02	389200.998	396964.924	Slope Movement
MOV-03	389199.268	396970.650	Slope Movement
MOV-04	389245.836	396968.317	Slope Movement
MOV-05	389244.894	396974.577	Slope Movement
MOV-06	389244.207	396980.637	Slope Movement
MOV-07	389291.423	396982.102	Slope Movement
MOV-08	389289.327	396987.257	Slope Movement
MOV-09	389287.042	396992.430	Slope Movement

Slope Movement Monitoring Trigger Levels		
Trigger Level	Ground Movement	Action
Green	<5mm	Work may proceed
Amber	5-10mm	Increase frequency of monitoring, review working practices & consult the designer
Red	>10mm	Halt operations immediately if this limit is exceeded until the reason for reaching the limit has been identified.

Vibration Monitoring Trigger Levels		
Trigger Level	PPV Limit	Action
Green	<5mm/s	Work may proceed
Amber	5-10mm/s	Increase frequency of monitoring, review working practices & consult the designer
Red	>10mm/s	Halt operations immediately if this limit is exceeded until the reason for reaching the limit has been identified.

NOTES :

General

All dimensions mm UNO

All elevations mOD UNO

Do not scale, use figured dimensions only

2 No. vibrographs to be positioned at the crest and the mid height of the slope OR the Network Rail Boundary will be moved parallel to the slope as piling progresses. Setting out points for vibration monitoring shown nominally for reference.

Vibrographs to be offset a minimum of 1.5m from the sheet pile wall line.

Suitable movement monitoring survey points are to be provided at the proposed locations.

It is proposed to monitor movement of the slope at the following frequency both during and immediately following installation of the sheet pile wall,

- Daily monitoring to be undertaken during installation of the sheet pile wall.
- Weekly monitoring to be undertaken in the 4 weeks following installation of the sheet pile wall.

Key

VIB-XX
● Vibration Monitoring Point

MOV-XX
● Movement Monitoring Point

B	Revised following comment	SJ	WF	09/07/25
A	Revised following comment	BS	WF	10/06/25
REV	AMENDMENTS	DRAWN	CHECK	DATE



Client:
Kirkland Developments Limited

Project :
Vine Street, Manchester

Title :
Monitoring General Arrangement & Specification

Drawing Status :
FOR INFORMATION

	INITIALS	DATE	SCALE	DRAWING NUMBER
DRAWN	BS	17/06/25	1:125	2664/DWG/001
CHECKED	WF	17/06/25		
DATE : June 2025		ORIGINAL SHEET SIZE	A3	REVISION : B