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Geological & Geotechnical Consultants

10A Oakhill Avenue, London NW3 7RE

Slope Stability and Ground Movement Assessment

(February 2015)

Prepared for Mr Ian Rosen

Geological & Geotechnical Consultants

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Report Number: 15-061-R-001

Mr Ian Rosen

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(February 2015)

Prepared by:

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I Griffiths BSc CEng MICE ....

Report Distribution List

Name	Copies	Rev.	Date	Copies	Rev.	Date	Copies	Rev.	Date
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1.0 INTRODUCTION

Key GeoSolutions Ltd (KGS) have been commissioned by Mr Ian Rosen to undertake a ground stability assessment in relation to a proposed development at 10A Oakhill Avenue, London NW3 7RE. A Basement Impact Assessment Screening Report has previously been undertaken by Soil Consultants Ltd (SCL), this concluded that it would be necessary to undertake a 'Ground Movement Analysis and Slope Stability Assessment'. The purpose of this report is to provide a review in relation to these two elements.

1.1 Proposed Development

The proposed development will involve the demolition of the existing house and construction of a five-storey block of apartments which includes a basement, the lower floor of which will be at a level of approximately 89.15mAOD. It is proposed that the basement will be constructed using a secant pile wall and top down construction techniques. The construction techniques are discussed further in the Structural Feasibility Report, Ian Harban Consulting Engineers, Reference 214019.100.

1.2 Scope of Work

The aim of the work is to assess if the proposed basement can be constructed without having a detrimental impact on the surroundings with respect to land stability and in particular to assess whether the development will affect the stability of neighbouring properties.

1.3 Qualifications

This assessment has been undertaken by Brian Duthie and Ian Griffiths. Brian holds a BEng in Engineering Geology and Geotechnics, is a chartered geologist and Fellow of the Geological Society with 25 years experience in geotechnical engineering. Ian holds a BSc in Civil Engineering, is a chartered engineer and Member of the Institution of Civil Engineers with 40 years specialist experience in ground engineering. Both assessors satisfy the qualification requirements given in the Camden Planning Guidance 4.

1.4 Limitations

The conclusions and recommendations made in this report are limited to those that can be made on the basis of the research carried out. The results of the research should be viewed in the context of the work that has been carried out and no liability can be accepted for matters outside the stated scope of the research. The assessment is based upon the currently available ground data and is to supplement the Basement Impact Assessment Screening Report previously undertaken by Soil Consultants Ltd (SCL). The assessment does not constitute a detailed structural design for the basement structure, as would be required to allow construction to take place.

This report has been prepared for the information, benefit and use of Mr Ian Rosen only and any liability of Key GeoSolutions Ltd to any third party, whether in contract or in tort, is specifically excluded. Any third party finding themselves in possession of this report may not rely upon it without first obtaining the written authority of Key GeoSolutions Ltd.

2.0 SITE DESCRIPTION

The site 10A Oakhill Avenue in the London Borough of Camden, post code NW3 7RE and National Grid Reference 525690mE, 185720mN. The site is approximately rectangular in plan, being 63m by 23m (the rear garden does narrow to 15m) with the long axis running approximately south-east to north-west.

The general topography of the area slopes down from Parliament Hill 0.5km to the north-east towards the River Westbourne 2.9km to the south-west. The slope is incised with a series of valleys and the site is located on the crest of a spur between two of the valleys The existing house sits on the highest point of the site at an elevation of approximately 96.2mAOD and the ground drops to the front and the rear of the house to an elevation of approximately 93mAOD.

3.0 GROUND CONDITIONS

3.1 Soil Conditions

The Geological Survey map of the area indicates that the site is underlain by the Claygate Member, which is in turn underlain by the London Clay Formation. The geology in this area is generally horizontally bedded such that the boundary between the geological formations approximately follows the ground surface contour lines. Boreholes drilled at the site by SCL indicate that the site lies close to the boundary between the Claygate Member and the London Clay Formation.

Geological cross sections through the proposed basement are shown on Drawing 15-061-D-002, these are based upon the boreholes drilled at the site, borehole information publicly available through the British Geological Survey Geoindex website and the 1:10,560 scale geological map of the area. From the cross-sections it can be seen that the strata are relatively horizontally bedded.

The Claygate Member consists of orange-brown and light orange brown, sandy, silt clay, with partings of silty sand. The strength of the Claygate Member was found to be variable by the boreholes at the site, from soft through to stiff, this variability is probably associated with groundwater within the more sandy horizons. The Claygate Member was found to be of low to intermediate plasticity.

The London Clay Formation comprised stiff, fissured, dark grey-brown, slightly sandy, silty clay, with occasional sand partings. The proportion of sand was less than in the Claygate Member. Whilst the boreholes were terminated at depths of between 5.0 and 7.0m these were below the floor of the basement (89.6mAOD) and it can be expected that the London Clay Formation will continue below this depth.

3.2 Groundwater Conditions

The Claygate Member is classified as a Secondary A aquifer by the Environment Agency. Groundwater was encountered by the boreholes within the Claygate Member, monitoring of the boreholes in May 2013 showed variations in water level from 90.2mAOD to 92.6mAOD across the site. From the ESI Ltd report it is concluded that groundwater flow is in a south-westerly direction.

4.0 SLOPE STABILITY ASSESSMENT

Drawing 15-061-D-001 shows the site location and general topography of the area. The site is located on the crest of a spur between two valleys, the crest of the spur runs approximately north-east to south-west in the direction of Oakhill Avenue. There are no reported incidences of landslides within the Claygate Member in this area.

Cross-sections showing the position of the basement in relation to the surrounding topography and expected geological conditions in the area are given on Drawing 15-061-D-002. The site can be seen to be located close to the boundary of the Claygate Member and the London Clay Formation.

From the cross-sections it can be seen that the topography to the south-west and south of the site is gently sloping, with gradients of the order of 3 - 5° (Sections 2-2' and 3-3'). To the north-west of the site, beyond the garden boundary, which is over 20m from the proposed development, the land is on the side of the valley to the north and gradients can be seen to steeper. Section 1-1' shows an overall slope gradient of 8° within the Claygate Member.

It is proposed that the piles that will form the basement and support the building will penetrate a significant distance into the London Clay Formation. The basement will be at least 20m away from change in ground slope to the north.

Hydrogeological modelling undertaken by ESI Ltd suggests that the basement will have minimal impact on the groundwater regime and that the changes can be expected to be within the natural seasonal fluctuations that would occur. The changes to groundwater will predominantly be up slope of the proposed basement, which will have a damming effect on the groundwater flow. Down slope of the basement there will be a negligible impact on the groundwater levels and hence there should be no impact on the slope stability.

Given that there will be negligible change to the groundwater regime down slope of the basement and that the piles forming the basement will penetrate a significant distance into the London Clay Formation it is concluded that the construction of the proposed basement will have no significant impact on the slope stability of the ground within the area.

5.0 GROUND MOVEMENT ANALYSIS

A ground movement analysis has been undertaken to evaluate the potential movement that may occur, with particular regard to the adjacent properties due to the construction of the basement.

The following assumptions have been made when undertaking the analysis;

- The construction technique employed will be a secant piled wall to form the perimeter of the basement, with top down construction of the basement.
- Maximum depth of basement approximately 6.0m.
- Each floor in the basement will be constructed prior to the removal of the ground below and will provide lateral stability to the secant pile wall.
- The secant piles will have a minimum diameter of 600mm and will penetrate at least 10m beyond the floor of the basement.
- Parameters for the soil have been taken from published literature.
- Groundwater levels have been taken as those modelled by ESI.
- It has been assumed that, given their age, the properties located either side of the site are constructed on traditional strip footings.

The analysis has been undertaken using the Rocscience Phase2 software, which is an elasto-plastic finite element stress analysis program. Detailed outputs of the analyses undertaken are given in Appendix 1. The results of the analyses are presented as contoured plots of predicted total displacements.

The analyses show potential for heave within the floor of the basement, during excavation down to the first basement level a maximum movement of 25mm is predicted. At this point it is predicted that there will be no movement of the ground beneath the adjacent properties. During excavation down to the second basement level a maximum movement of approximately 50mm is predicted within the basement. The impact upon the adjacent properties is shown to be less than 10mm (c. 7.5mm) at the closest point to the basement. Across the width of the adjacent properties this would equate to a maximum gradient of less than 1 in 1000.

A summary of the results of the final stage of basement construction, showing predicted total displacements is presented as Figure 1 overleaf.

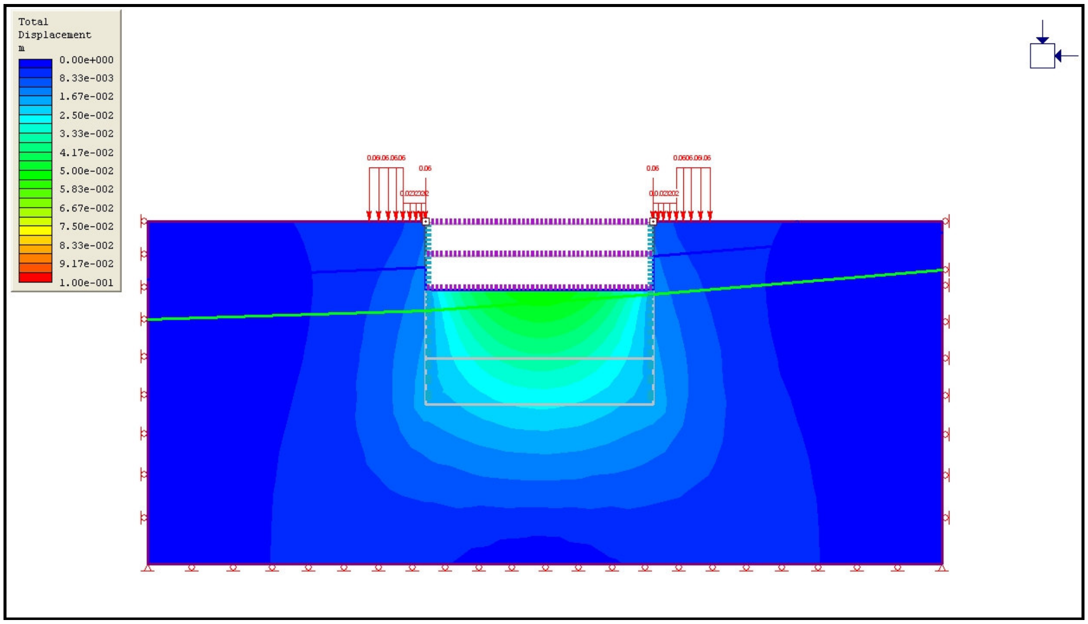


Figure 1. Basement Completion - Potential Total Displacements

Burland (1995) proposed a three stage approach to assessing the risk of damage due to excavation and tunnelling. Given the predicted maximum movement and the expected gradient then the adjacent properties would fall into Stage 1 of this approach, i.e. preliminary assessment, where according to Rankin (1988) a building experiencing a maximum gradient of 1 in 500 and a movement of less than 10mm has negligible risk.

For the Damage Categories after Burland 1995 the adjacent buildings would fall into Category 0 or 1, with the degree of severity being negligible to very slight, which in relation to damage to the buildings would equate to fine cracks which are easily treated in normal decoration. A scheme of monitoring should be installed prior to commencement of construction in order that the actual movements be measured.

6.0 CONCLUSIONS AND RECOMMENDATIONS

An assessment has been made of the potential impacts of the proposed basement construction at 10A Oakhill Avenue with respect to slope stability and ground movement. This assessment does not constitute a detailed structural design for the basement; assumptions have been made with regards to the proposed structure under the guidance of the instructed structural engineer.

Given that there will be negligible change to the groundwater regime down slope of the basement and that the piles forming the basement will penetrate a significant distance into the London Clay Formation it is concluded that the construction of the proposed basement will have no significant impact on the slope stability of the ground within the area.

With regard to impact on the adjacent properties it is concluded that the risk of any damage will fall into Category 0 or 1 of the Damage Categories after Burland 1995, with the degree of severity being negligible to very slight, which in relation to damage to the buildings would equate to fine cracks which are easily treated in normal decoration.

Hence, it is concluded, based upon the information currently available, that the proposed basement can be constructed employing secant pile wall and top down construction techniques without any significant impact on either the slope stability within the area or on the adjacent properties.

7.0 REFERENCES

7.1 Interim Basement Impact Assessment Screening Report: ‘Land Stability’, Soil Consultants Ltd, report reference 9374C/MC/AW, April 2014

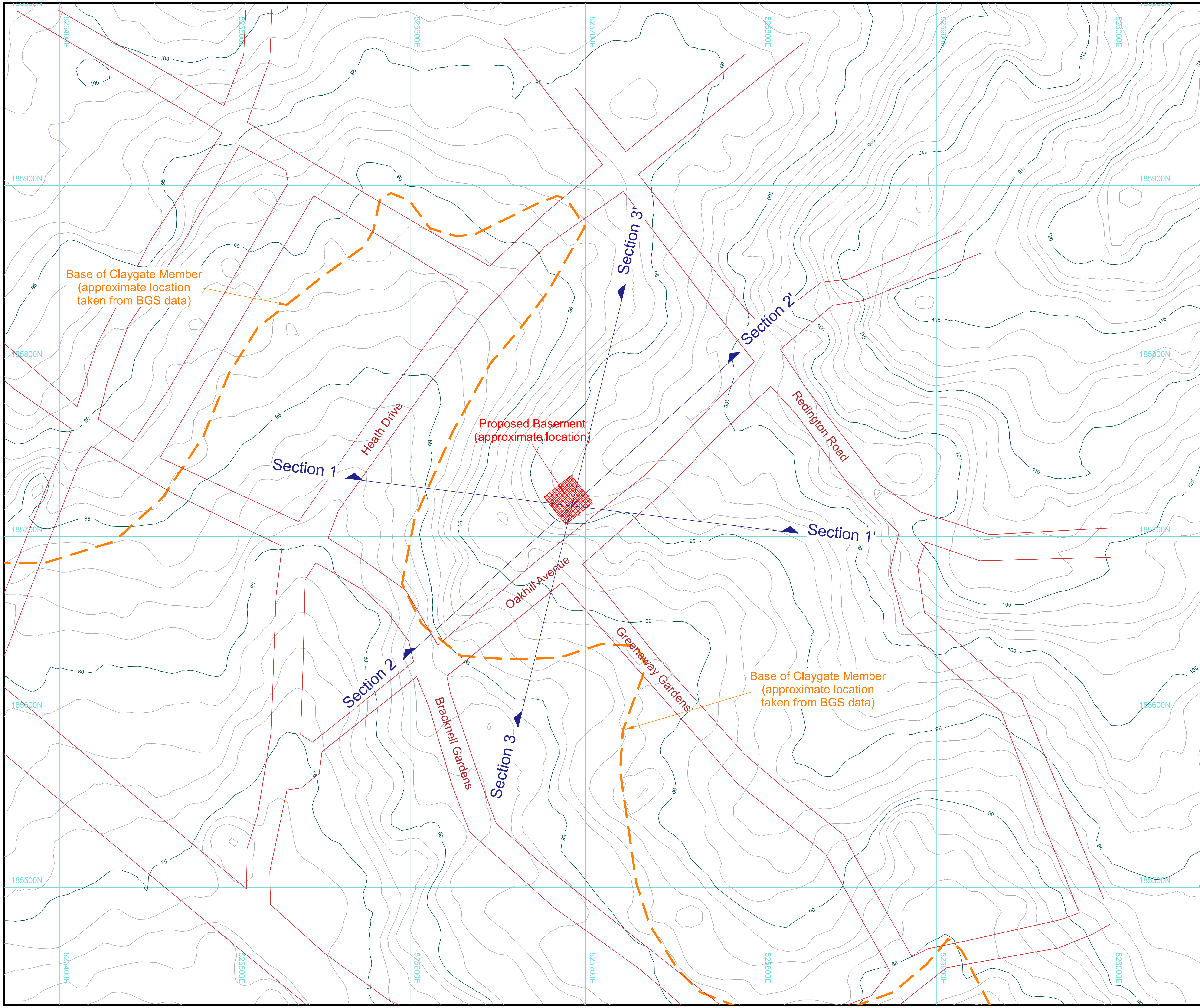
7.2 Basement impact assessment: hydrology and hydrogeology. 10a Oakhill Avenue, ESI Ltd, report reference 61458R2Rev1, April 2014

7.3 Structural feasibility report for Basement Construction for Apartment Scheme, Ian Harban Consulting Engineers, April 2014

7.4 Assessment of risk of damage to buildings due to tunnelling and excavation, Burland J B, 1995

7.5 Ground movements resulting from urban tunnelling: predictions and effects, Rankin W J, 1988

DRAWINGS



Note: Contours produced from DTM survey data.

Rev	Revision Detail	Drawn	Date

CLIENT:

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PROJECT: 10A Oakhill Avenue

TITLE: Site Topography

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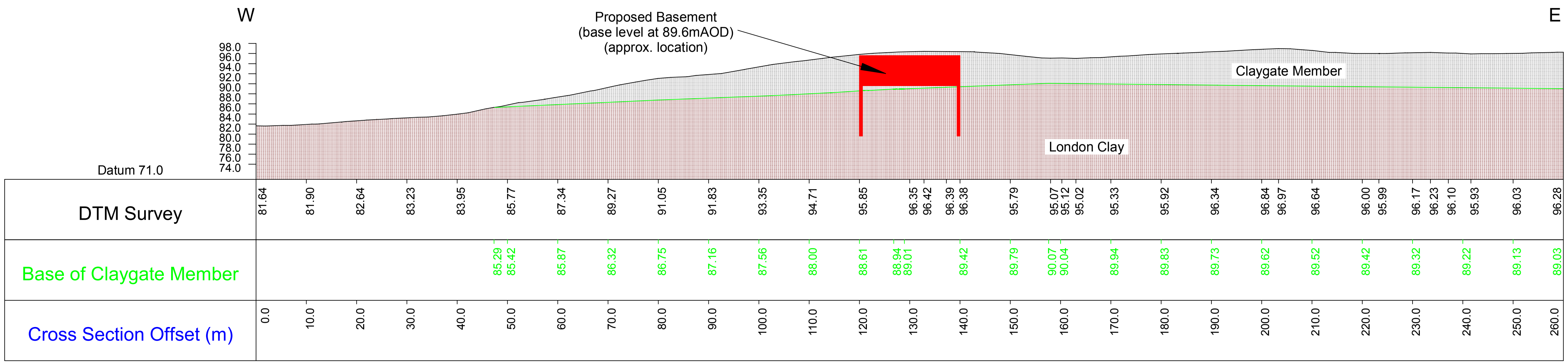
Drawn	Checked	Date	Scale @ A3
WR	BD	Feb '15	1:2000

Drawing No.	Revision
15-061-D-001	



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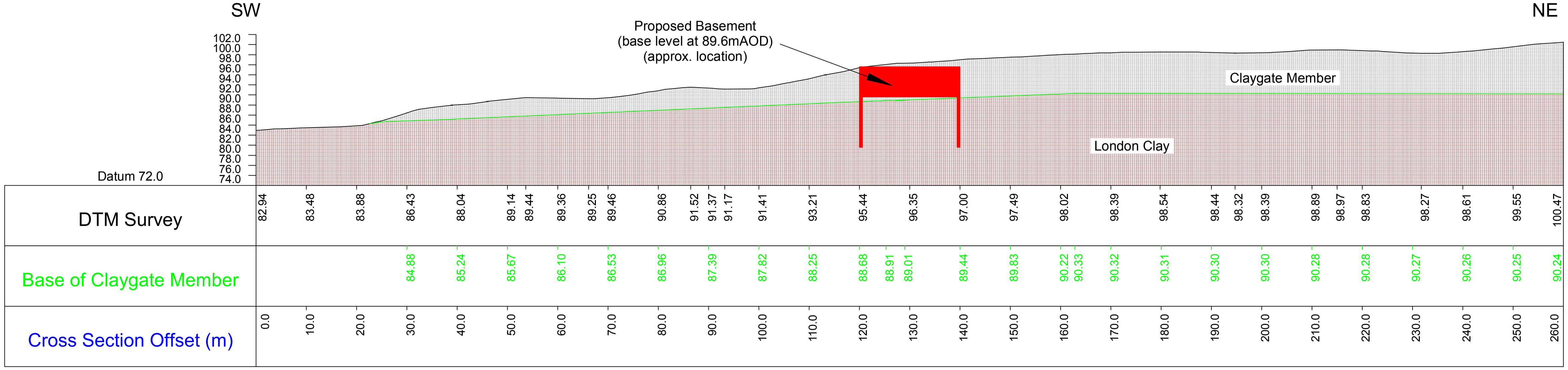

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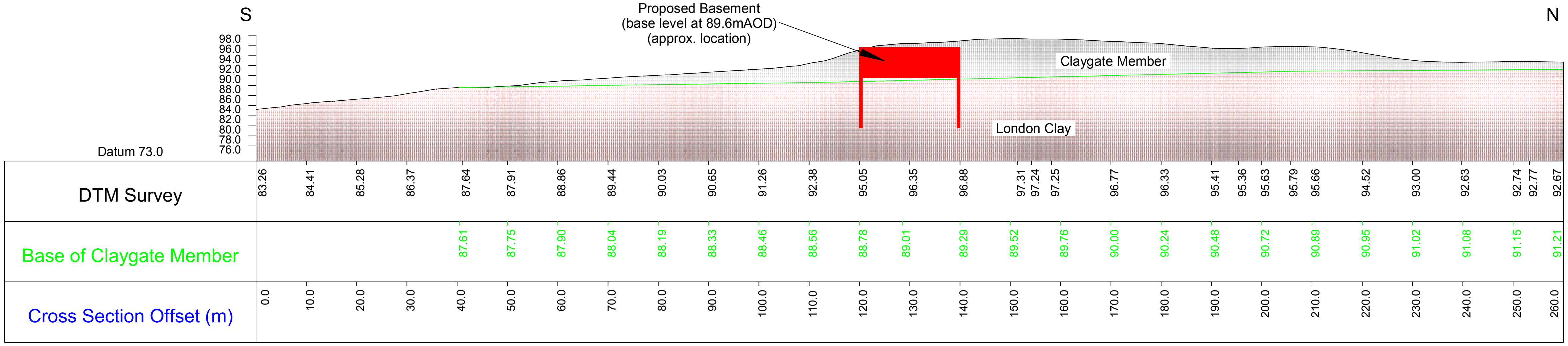

Section 3 - 3'

Rev	Revision Detail	Drawn	Date

CLIENT:

Mr Ian Rosen

PROJECT: 10A Oakhill Avenue

TITLE: Cross Sections

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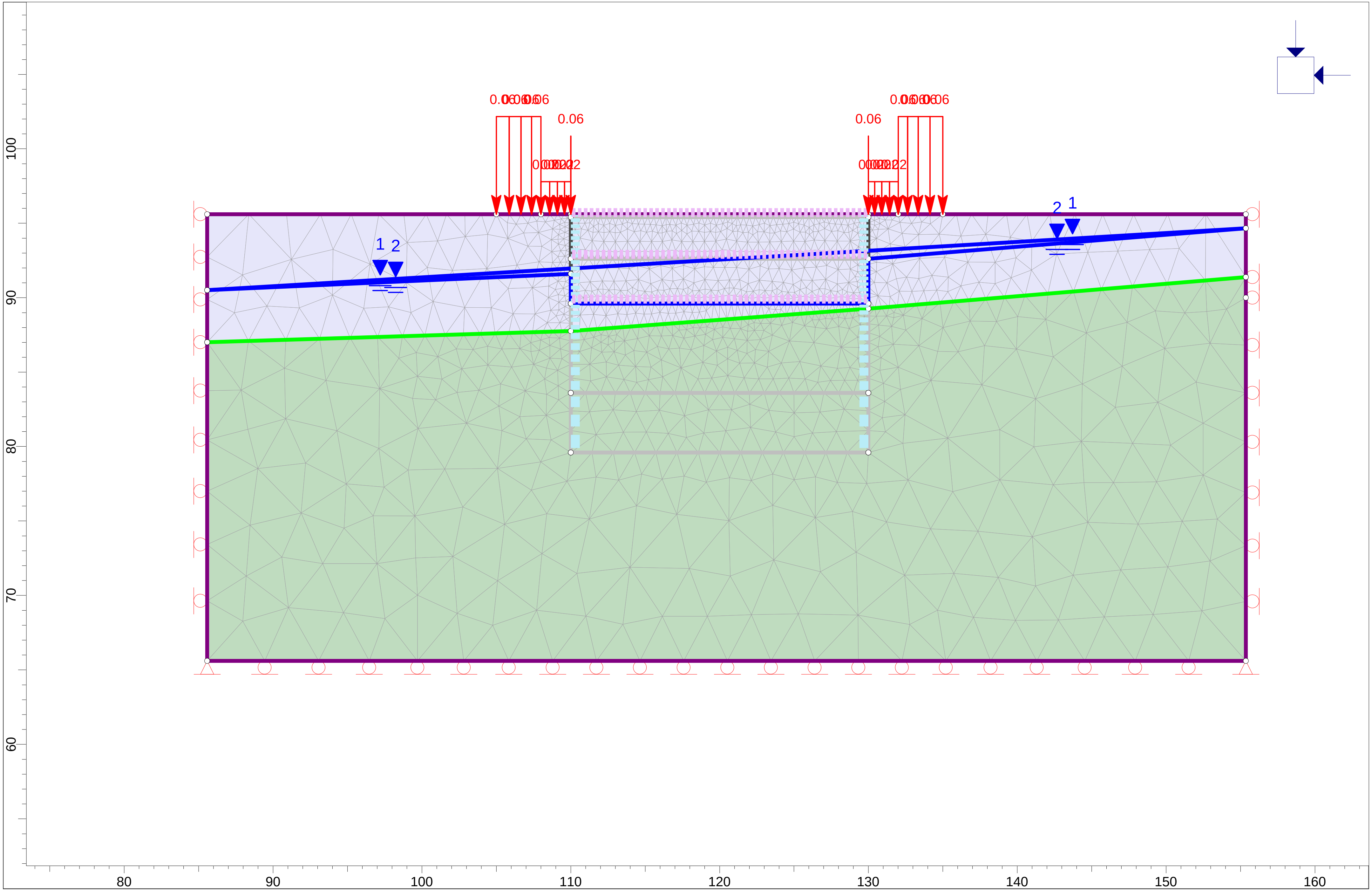
Drawn	Checked	Date	Scale @ A3
WR	BD	Feb '15	1:1000

Drawing No. 15-061-D-002
Revision

APPENDIX 1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150
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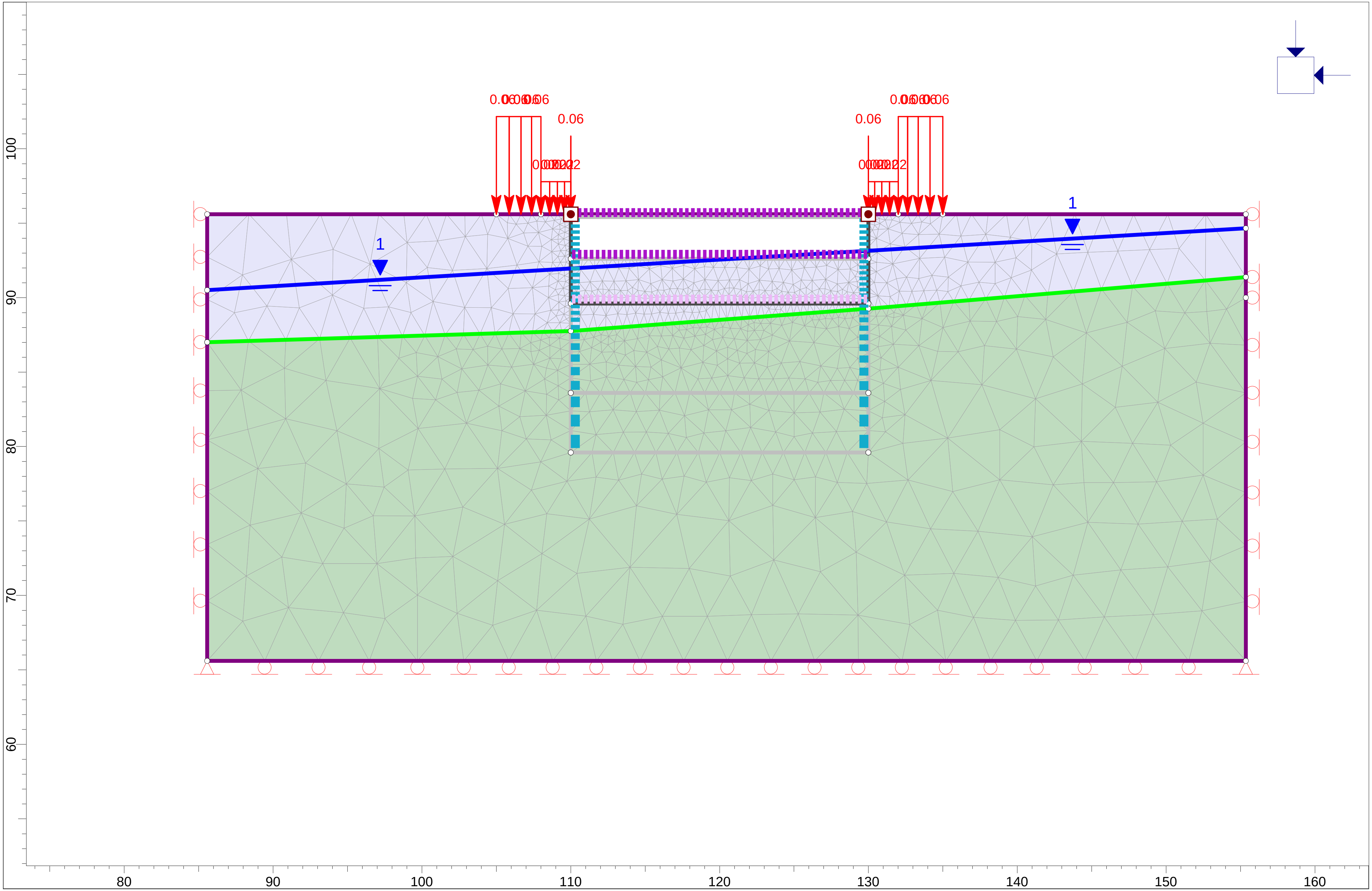
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100
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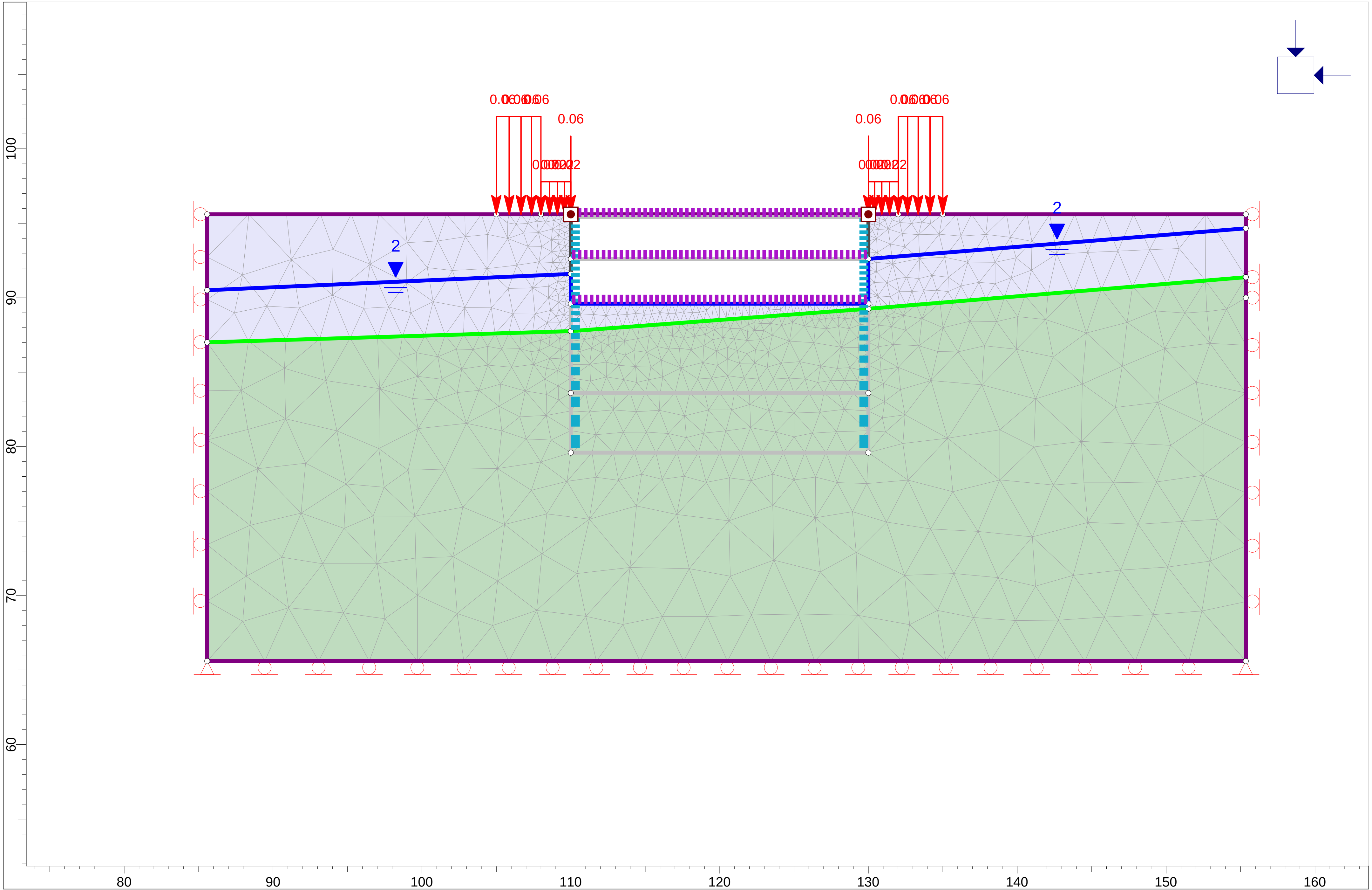
130
140
150
160
1
1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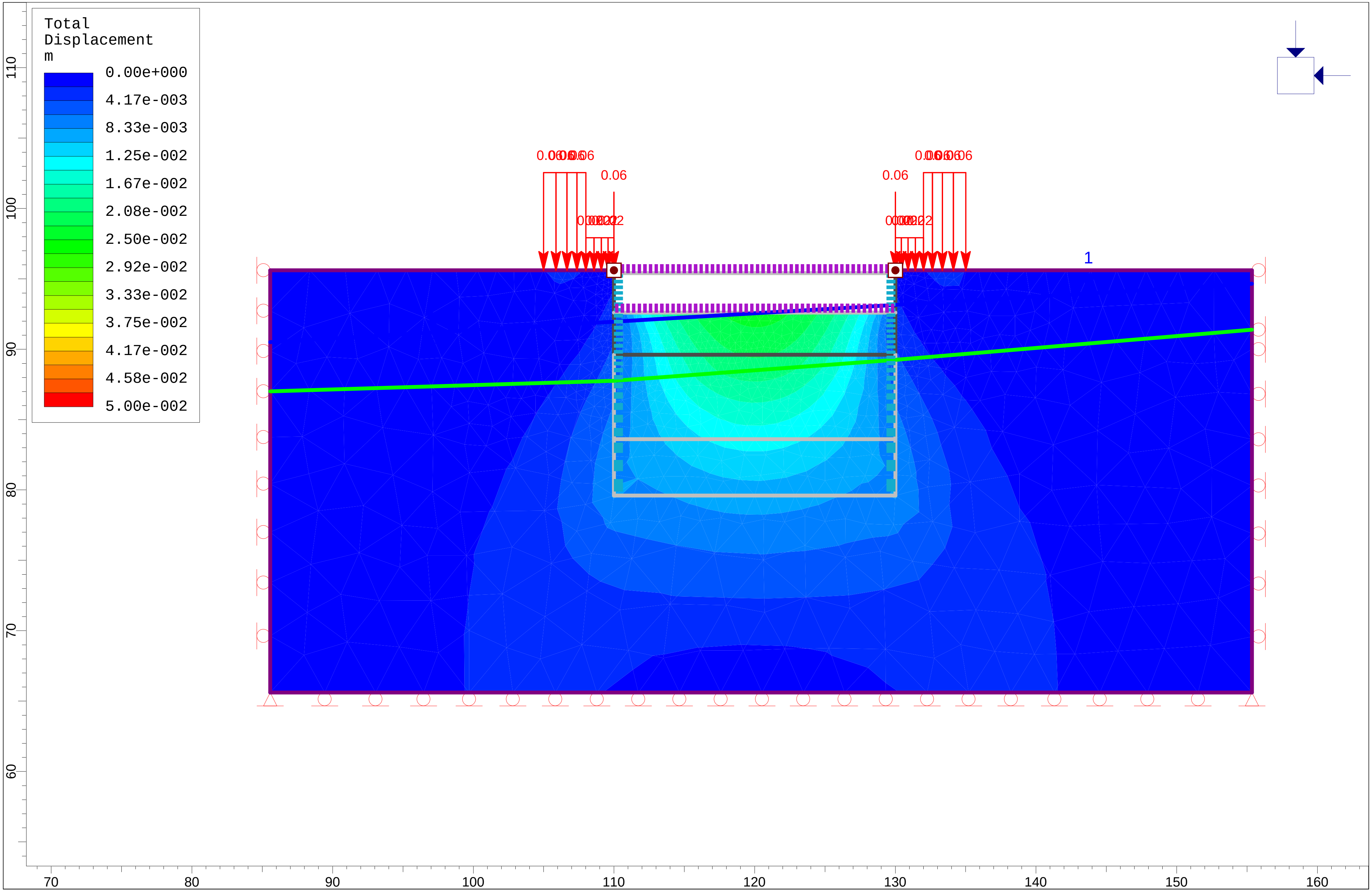
90
100
110
120
130
140
150
160


Total Displacement m
0.00e+000
4.17e-003
8.33e-003
1.25e-002
1.67e-002
2.08e-002
2.50e-002
2.92e-002
3.33e-002
3.75e-002
4.17e-002
4.58e-002
5.00e-002
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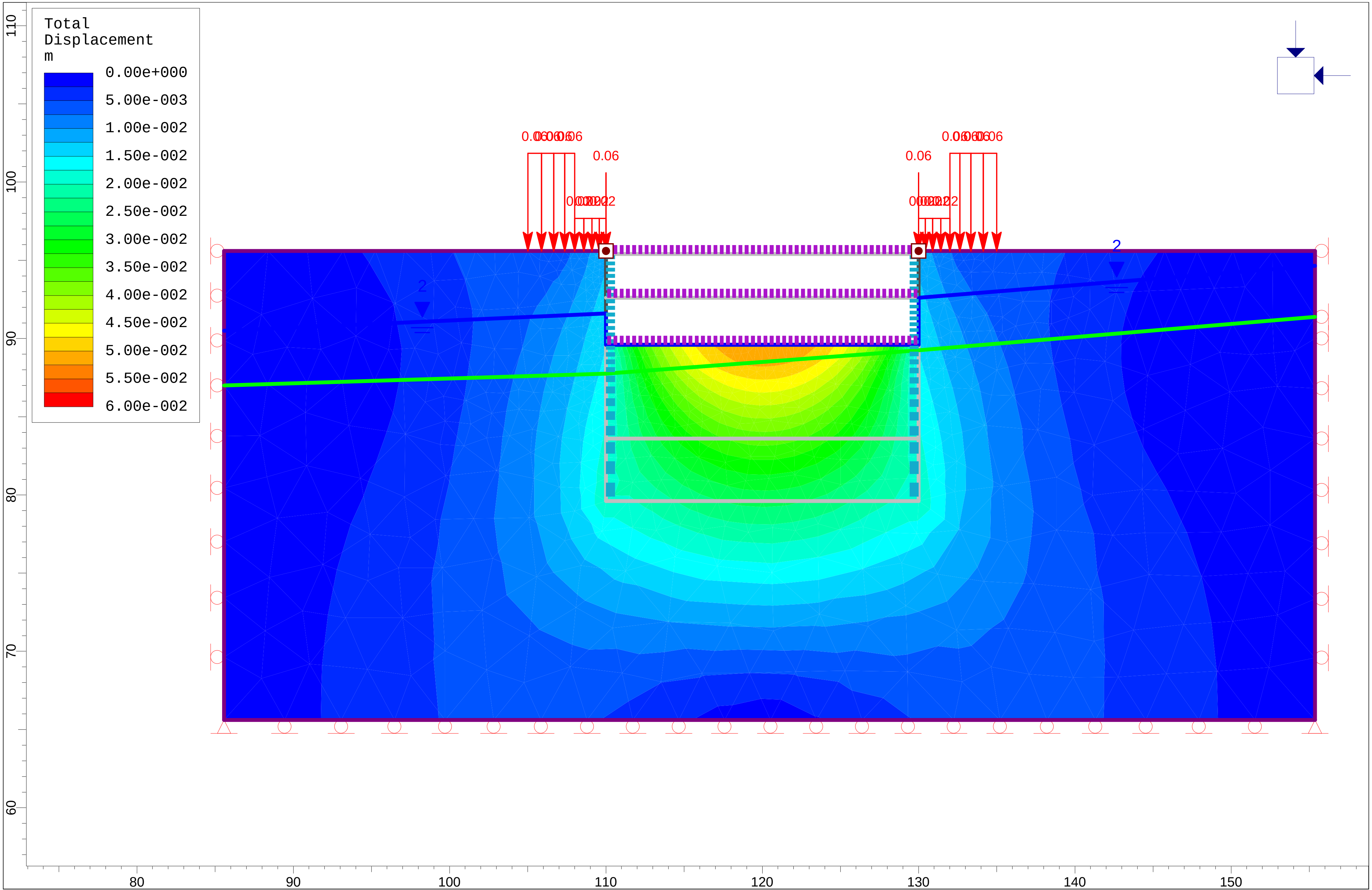
80
70
60
70
80
90
100
110
120
130
140
150
160


Total Displacement
m
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1.00e-002
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2.00e-002
2.50e-002
3.00e-002
3.50e-002
4.00e-002
4.50e-002
5.00e-002
5.50e-002
6.00e-002
0.06
0.06
110
100
90
80
70
60
80
90
100
110
120
130
140
150

Phase2 Analysis Information

Document Name

Section 1 Boundaries 1F.fez

Project Settings

General
  Project Title: Project1
  Number of Stages: 6
  Analysis Type: Plane Strain
  Solver Type: Gaussian Elimination
  Units: Metric, stress as MPa
Stress Analysis
  Maximum Number of Iterations: 500
  Tolerance: 0.001
  Number of Load Steps: Automatic
  Convergence Type: Absolute Energy
  Tensile Failure: Reduces Shear Strength
Groundwater
  Method: Piezometric Lines
  Pore Fluid Unit Weight: 0.00981 MN/m3

Field Stress

Field stress: gravity
Using actual ground surface
Total stress ratio (horizontal/vertical in-plane): 1
Total stress ratio (horizontal/vertical out-of-plane): 1
Locked-in horizontal stress (in-plane): 0
Locked-in horizontal stress (out-of-plane): 0

Mesh

Mesh type: graded
Element type: 3 noded triangles
Number of elements on Stage 1: 2443
  Number of nodes on Stage 1: 1287
Number of elements on Stage 2: 2443
  Number of nodes on Stage 2: 1287
Number of elements on Stage 3: 1859
  Number of nodes on Stage 3: 1003
Number of elements on Stage 4: 1859
  Number of nodes on Stage 4: 1003
Number of elements on Stage 5: 1430
  Number of nodes on Stage 5: 796
Number of elements on Stage 6: 1430
  Number of nodes on Stage 6: 796

Mesh Quality

4 of 2443 Elements (0.2 % of elements) are poor quality elements
0 of 2443 Elements (0.0 % of elements) are poor quality elements because of the side length ratio
1 of 2443 Elements (0.0 % of elements) are poor quality elements because of the minimum interior angle
3 of 2443 Elements (0.1 % of elements) are poor quality elements because of the maximum interior angle
 (elements can be of poor quality for more than one reason)

Mesh Quality Statistics
The worst element has (ratio = 2.93), (min angle = 19.87) (max angle = 129.40)
10.0% of elements have: (ratios > 1.9), (min angles < 31.5) (max angles > 90.0)
20.0% of elements have: (ratios > 1.7), (min angles < 36.2) (max angles > 84.6)
30.0% of elements have: (ratios > 1.5), (min angles < 40.2) (max angles > 79.8)
40.0% of elements have: (ratios > 1.4), (min angles < 43.0) (max angles > 77.2)
50.0% of elements have: (ratios > 1.4), (min angles < 45.1) (max angles > 74.8)
60.0% of elements have: (ratios > 1.3), (min angles < 47.0) (max angles > 72.5)

70.0% of elements have: (ratios > 1.3), (min angles < 48.9) (max angles > 70.8)
80.0% of elements have: (ratios > 1.2), (min angles < 51.1) (max angles > 69.0)
90.0% of elements have: (ratios > 1.2), (min angles < 53.0) (max angles > 67.1)
100.0% of elements have: (ratios > 1.1), (min angles < 55.4) (max angles > 64.7)

Poor quality elements are those with:
(maximum side length) / (minimum side length) > 10.00
Minimum interior angle < 20.0 degrees
Maximum interior angle > 120.0 degrees

Material Properties

Material: Claygate Beds
Initial element loading: field stress & body force
Unit weight: 0.02 MN/m3
Elastic type: isotropic
Young's modulus: 45 MPa
Poisson's ratio: 0.3
Failure criterion: Mohr-Coulomb
Tensile strength: 0 MPa
Peak friction angle: 35 degrees
Peak cohesion: 0.01 MPa
Material type: Elastic
Stage 1: Piezo to use: 1
Stage 5: Piezo to use: 2
Hu Type: Custom
Hu value: 1

Material: London Clay
Initial element loading: field stress & body force
Unit weight: 0.02 MN/m3
Elastic type: isotropic
Young's modulus: 35 MPa
Poisson's ratio: 0.2
Failure criterion: Mohr-Coulomb
Tensile strength: 0 MPa
Peak friction angle: 25 degrees
Peak cohesion: 0.01 MPa
Material type: Elastic
Stage 1: Piezo to use: 1
Stage 5: Piezo to use: 2
Hu Type: Custom
Hu value: 1

Excavation Areas

Original Un-deformed Areas
Excavation Area: 120.000 m2
Excavation Perimeter: 52.000 m
External Boundary Area: 2093.550 m2
External Boundary Perimeter: 199.570 m

Stage 1
Excavation Area: 119.986 m2 (-0.0143139 m2 change from original area)
Excavation Perimeter: 51.992 m (-0.00790031 m change from original perimeter)
External Boundary Area: 2093.154 m2 (-0.395849 m2 change from original area)
External Boundary Perimeter: 199.567 m (-0.00302173 m change from original perimeter)
Volume Loss to Excavation: 0.329874 %

Stage 2
Values not available until this stage is viewed in a window

Stage 3
Values not available until this stage is viewed in a window

Stage 4
Values not available until this stage is viewed in a window

Stage 5

Values not available until this stage is viewed in a window

Stage 6
Excavation Area: 119.145 m2 (-0.85497 m2 change from original area)
Excavation Perimeter: 51.990 m (-0.0102392 m change from original perimeter)
External Boundary Area: 2093.717 m2 (0.16749 m2 change from original area)
External Boundary Perimeter: 199.570 m (0.000371548 m change from original perimeter)
Volume Loss to Excavation: -0.139575 %

Liner Properties

Liner: Pile
Liner Type: Beam
Formulation: bernoulli
Geometry:
Thickness: 0.6 m
Elastic properties:
Young's modulus: 30000 MPa
Poisson's ratio: 0.3

Liner: Strut
Liner Type: Beam
Formulation: bernoulli
Geometry:
Thickness: 0.3 m
Elastic properties:
Young's modulus: 30000 MPa
Poisson's ratio: 0.3

Displacements

Maximum total displacement for Stage 1: 0.0124978 m
Displacement data is not available for Stage 2 until total displacement is viewed in a window
Displacement data is not available for Stage 3 until total displacement is viewed in a window
Displacement data is not available for Stage 4 until total displacement is viewed in a window
Displacement data is not available for Stage 5 until total displacement is viewed in a window
Maximum total displacement for Stage 6: 0.0527722 m

List of All Coordinates

Excavation boundary

110.000	89.600
130.000	89.600
130.000	92.600
130.000	95.400
130.000	95.600
110.000	95.600
110.000	95.400
110.000	92.600

External boundary

85.567	65.600
155.352	65.600
155.352	90.000
155.352	91.379
155.352	95.600
135.000	95.600
132.000	95.600
130.000	95.600
110.000	95.600
108.000	95.600
105.000	95.600
85.567	95.600
85.567	87.000

Stage boundary

110.000	89.600
110.000	87.750

110.000	83.600
130.000	83.600
130.000	89.250
130.000	89.600

Stage boundary

110.000	92.600
130.000	92.600

Stage boundary

110.000	95.400
130.000	95.400

Stage boundary

110.000	83.600
110.000	79.600

Stage boundary

110.000	79.600
130.000	79.600

Stage boundary

130.000	79.600
130.000	83.600

Material boundary

155.352	91.379
130.000	89.250
110.000	87.750
85.567	87.000

Piezometric line

155.352	94.651
130.000	92.600
130.000	89.600
110.000	89.600
110.000	91.600
85.567	90.498