GROUND MOVEMENT ASSESSMENT REPORT

70 Elsworthy Road
London
NW3 3BP

Client: Latitude London

Engineer: Elliott Wood

J15143A

November 2015




Geotechnical & Environmental Associates

Document Control

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CONTENTS

1.0 INTRODUCTION

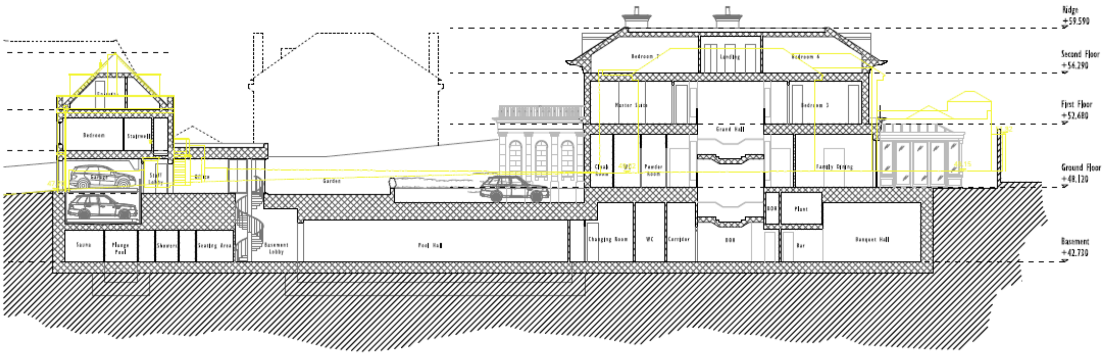
Geotechnical and Environmental Associates (GEA) has been commissioned by Elliott Wood, on behalf of Latitude London, to carry out a ground movement assessment for the proposed redevelopment of this site at 70 Elsworthy Road, London, NW3 3BP, which is to include the demolition of the existing building and construction of a new two-storey property with a single level basement.

A Desk Study and Ground Investigation has previously been carried out by GEA (report ref J15143, dated July 2015), the findings of which have been used in the derivation of parameters for use in this assessment.

The purpose of this assessment has been to determine the effects of the demolition of the existing building and proposed basement construction upon the neighbouring structures.

1.1 Proposed Development

Consideration is being given to the demolition of the existing building and construction of a new building with a single level basement. It is also proposed to refurbish the existing mews buildings in the south of the site and a section through the proposed development is shown below.



It is understood that the consulting engineer is favouring the installation of contiguous piled wall to support the basement.

This report is specific to the proposed development and the advice herein should be reviewed if the development proposals are amended.

1.2 Limitations

The conclusions and recommendations made in this report are limited to those that can be made on the basis of the investigation. The results of the work should be viewed in the context of the range of data sources consulted, the number of locations where the ground was sampled and the number of soil, gas or groundwater samples tested; no liability can be accepted for information in other data sources or conditions not revealed by the sampling or testing. Any comments made on the basis of information obtained from the client or other third parties are given in good faith on the assumption that the information is accurate; no independent validation of such information has been made by GEA.

2.0 THE SITE

2.1 Site Description

The site is located approximately 500 m southeast of Swiss Cottage London Underground station and is bounded by Elsworthy Road to the south and by neighbouring residential buildings and their associated gardens to the north, east and west. It can also be located using National Grid Reference 526990, 183930.

The site is roughly rectangular in shape, measuring approximately 75m by 20 m. A large two-storey house occupies the north of the site and a driveway along the length of the western boundary provides access to a mews building in the south of the site. The mews building is a two-storey structure that appears to be used for residential purposes.

A large garden / landscaped area is located between the main building and the mews building and consists of a large lawn area with perimeter flower beds. No large trees were present on site at the time of the field work. Mature trees are present close to the east and west of the site.

2.2 Previous Exploratory Work

The previous GEA site investigation consisted of a single cable percussion borehole drilled to a depth of 15 m and two opendrive sampler boreholes to depths of 5.0 m and 8.0 m.

Standard penetration tests (SPTs) were carried out at regular intervals in all boreholes and disturbed and undisturbed samples were recovered for subsequent laboratory examination, geotechnical testing and contamination analysis.

Groundwater monitoring standpipes were installed to depths of 5.0 m and 8.0 m and have been monitored on a single occasion.

3.0 SUMMARY OF GROUND CONDITIONS

The investigation confirmed the expected ground conditions in that, beneath a variable and locally significant thickness of made ground, the London Clay was encountered, which proved to the full depth of the investigation.

The made ground generally comprised brown to dark brown silty sandy clay with brick, flint, rootlets and occasional decaying carbon was encountered to depths of between 0.75 m (48.4 m OD) to 1.2 m (46.5 m OD).

The underlying London Clay initially comprised an upper layer of generally soft to firm becoming stiff brown mottled grey clay to depths of 5.0 m (44.1 m OD). Below this depth stiff to very stiff blue grey fissured clay was encountered to a maximum of 15.0 m depth, where the investigation was completed.

In Borehole Nos 1 and No 3 claystones were encountered at 3.7 m depth (45.4 m OD) and 12.0 m depth (35.7 m OD), respectively.

Laboratory plasticity index test results indicate the clay to be of high volume change potential.

The London Clay generally increases in strength with depth from medium strength to very high strength with undrained shear strength increasing from 50 kN/m^2 at a depth of 2.0 m, to 165 kN/m^2 at a depth of 15.0 m.

Groundwater was encountered as seepages associated with claystones in the London Clay at a depth of 3.7 m (45.4 m OD). It was also encountered as seepage in the made ground at 0.3 m depth (47.4 m OD) in Borehole No 3. This was suspected to be a perched water table resulting from surface run off from the brick driveway.

Groundwater monitoring standpipes were installed to depths of 5.0 m and 8.0 m and were monitored on two occasions.

Results of the monitoring visits are shown in the table below.

Borehole No	Standpipe depth (m)	Depth to groundwater (m) [Level m OD]	
		01/07/2015	18/11/2015
1	8.00	1.70 [47.40 m]	2.00 [49.1]
2	5.00	4.10 [45.00 m]	Inaccessible
3	5.00	Dry	2.40 [45.20]

3.1 British Geological Survey (BGS) Archives

A review of deep borehole records held on the British Geological Survey (BGS) database, the closest of which is located approximately 450 m to the northwest of the site, indicated that the London Clay extends to a depth of approximately 84.2 m (-28.2 m OD), below which the Lambeth Group extends to a depth of approximately 96.2 m (-0.2 m OD), whereafter the Thanet Sand and Upper Chalk are found to be present.

4.0 CONSTRUCTION SEQUENCE

The following sequence of operations has been based on the Preliminary Construction Method Statement dated 20/07/2015, provided by the consulting engineer, to enable analysis of the ground movements around the basement both during and after construction.

In general, the sequence of works for basement construction will comprise the following stages.

1. Demolition of the existing main building to ground floor level and the removal of the ground floor slab;

2. Installation of the contiguous piled wall from ground floor level around the majority of the basement perimeter, leaving the section below the mews building. Installation of temporary piles will be required to support the temporary works for retention of the mews building.

3. Excavation of local trenches around the perimeter of the basement, propping off adjacent earth bunds, to allow for the ground floor reinforced concrete capping beam

to be formed. Where required, the installation of the temporary props to the perimeter of the basement to provide support for the piled wall.

4. Excavation of the new basement and temporary retention and strengthening of the new retaining walls with sufficient propping and walling beams.

5. Installation of basement piles and casting of the pile caps and basement slab.

6. Construction of the basement walls and ground floor slab.

Reinforced concrete will be used for floor slabs and it is anticipated that heave protection or tension piles will be installed beneath the basement slab.

5.0 GROUND MOVEMENTS

An assessment of ground movements within and surrounding the excavation has been undertaken using the X-Disp and P-Disp computer programs licensed from the OASYS suite of geotechnical modelling software from Arup. These programs are commonly used within the ground engineering industry and are considered to be appropriate tools for this analysis.

The X-Disp program has been used to predict ground movements likely to arise from the construction of the proposed basement. This includes the settlement of the ground (vertical movement) and the lateral movement of soil behind the proposed retaining walls (horizontal movement).

The analysis of potential ground movements within the excavation, as a result of unloading of the underlying soils, has been carried out using the Oasys P-Disp Version 19.3 – Build 12 software package and is based on the assumption that the soils behave elastically, which provides a reasonable approximation to soil behaviour at small strains.

For the purpose of these analyses, the corners have been defined by x and y coordinates, with the x-direction parallel with the orientation northeast-southwest, whilst the y-direction is parallel with the orientation of northwest-southeast. Vertical movement is in the z-direction.

The full outputs of all the analyses can be provided on request but samples of the output movement contour plots are included within the appendix.

5.1 Ground Movements – Surrounding the Basement

5.1.1 Model Used

For the X-Disp analysis, the soil movement relationships used for the embedded retaining walls are the default values within CIRIA report C580[1], which were derived from a number of historic case studies.

The ground movement curves for ‘excavations in front of high stiffness wall in clay’ have been adopted as being considered most appropriate for the proposed excavation and its support at this site.

1 Gaba, A, Simpson, B, Powrie, W and Beadman, D (2003) *Embedded retaining walls – guidance for economic design* .CIRIA Report C580.

The ground movement curves for 'installation of contiguous piled wall in front of high stiffness wall in clay' have been adopted as being considered most appropriate for the proposed wall installation phase at this site.

Due to the complex nature of the excavation and limitations within the software, the analysis was split into two models. One modelled the main excavation, which covers the basement beneath the main building and the garden, and a second modelled the smaller thinner excavation which covers the basement beneath the Mews Building. The results of both were analysed and are presented in the section below.

5.1.2 Results

The predicted movements are based on the worst case of the individually analysed segments of 'hogging' and 'sagging' and these are summarised in the tables below.

Main Excavation

Phase of Works	Wall Movement (mm)	
	Vertical Settlement	Horizontal Movement
Pile Installation	6	6
Basement Excavation	4	9
Combined Movements	9	15

The analysis has indicated that the maximum vertical settlements that will result from pile installation are less than 10 mm, whilst any horizontal movements will be less than 10 mm. The maximum vertical settlement that will take place behind the walls as a result of the basement excavation has generally been shown to be less than 10 mm.

The movements arising from the combined piling and excavation phases are therefore not likely to exceed 15 mm vertical settlement, whilst the maximum horizontal movements are also anticipated to be less than 15 mm.

The movements calculated are considered to represent a worst case scenario, particularly as the movements resulting from basement excavation will be minimised due to control of the propping in the temporary works and a regime of monitoring.

Mews Excavation

Phase of Works	Wall Movement (mm)	
	Vertical Settlement	Horizontal Movement
Pile Installation	6	6
Basement Excavation	4	9
Combined Movements	9	14

The analysis has indicated that the maximum vertical settlements that will result from pile installation are less than 10 mm, whilst any horizontal movements will be less than 10 mm.

The maximum vertical settlement that will take place behind the walls as a result of the basement excavation has generally been shown to be less than 5 mm.

The movements arising from the combined piling and excavation phases are therefore not likely to exceed 10 mm vertical settlement, whilst the maximum horizontal movements are also anticipated to be less than 15 mm.

The movements calculated are considered to represent a worst case scenario, particularly as the movements resulting from basement excavation will be minimised due to control of the propping in the temporary works and a regime of monitoring.

5.2 Movements within the Excavation (Heave)

5.2.1 Model Used

At this site unloading of the London Clay will take place as a result of the demolition of the existing building and basement excavation. The reduction in vertical stress will cause heave to take place. Undrained soil parameters have been used to estimate the potential short term movements, which include the "immediate" or elastic movements as a result of the demolition of the existing building and basement excavation. Drained parameters have been used to provide an estimate of the total long-term movement.

The elastic analysis requires values of soil stiffness at various levels to calculate displacements. Values of stiffness for the soils at this site are readily available from published data and we have used a well-established method to provide our estimates. This relates values of E_u and E', the drained and undrained stiffness respectively, to values of undrained cohesion, as described by Padfield and Sharrock[2] and Butler[3] and more recently by O'Brien and Sharp[4]. Relationships of $E_u = 500\ C_u$ and $E' = 300\ C_u$ for the cohesive soils and 2000 x SPT 'N' for granular soils have been used to obtain values of Young's modulus. More recent published data[5] indicates stiffness values of 750 x Cu for the London Clay and a ratio of E' to Cu of 0.75, but it is considered that the use of the more conservative values provides a sensible approach for this stage in the design.

The proposed demolition of the existing building and construction of the new basement will result in a net unloading of roughly 140 kN/m² beneath the existing building footprint, 110 kN/m² beneath the existing garden footprint and 90 kN/m² beneath the existing Mews building footprint, assuming a unit weight of overburden soil of 19 kN/m^3.

A rigid boundary for the analysis has been set at a depth of about 77.3 m below existing ground level (-28.2 m OD), where nearby BGS records indicate that the base of the London Clay is likely to be present.

5.2.2 Results

The P-Disp analysis indicates that, by the time the existing building has been demolished and basement construction is complete, up to 20 mm of heave is likely to have taken place beneath the existing building footprint reducing to 18 mm toward the existing Mews, reducing to approximately 10 mm at the edges.

2 Padfield CJ and Sharrock MJ (1983) *Settlement of structures on clay soils*. CIRIA Special Publication 27

3 Butler FG (1974) *Heavily overconsolidated clays: a state of the art review*. Proc Conf Settlement of Structures, Cambridge, 531-578, Pentech Press, Lond

4 O'Brien AS and Sharp P (2001) *Settlement and heave of overconsolidated clays - a simplified non-linear method.* Part Two, Ground Engineering, Nov 2001, 48-53

5 Burland JB, Standing, JR, and Jardine, FM (2001) Building response to tunnelling, case studies from construction of the Jubilee Line Extension.. CIRIA Special Publication 200

Assuming a unit weight of 12.5 kN/m^3 per floor, in the long term, following completion of the new building and basement construction, a further 20 mm of heave is estimated as a result of long term swelling of the underlying London Clay. However due to the construction of the new building it is likely not all of this further movement will be realised.

The results of the P-Disp analysis also indicate the likely impact of the proposed basement construction beyond the site boundaries. On the basis of the analysis, total vertical heave movements outside the proposed basement are unlikely to exceed 10 mm at a distance of approximately 5 m, reducing to approximately than 5 mm at distances in excess of 10 m.

The potential movements are summarised in the table.

Location	Movement (mm)		
	Short-term Heave (Demolition and Excavation	Long-term Heave (post construction)	Total Heave
Centre of excavations	20	18	40
Edge of excavations	10	8	18
At 5 m from edge of excavations	<5	<5	<10

The above figures are based on an unrestrained excavation as the model is unable to take account of the mitigating effect of the existing structures, proposed underpins and the contiguous pile wall, which in reality will combine to restrict these movements within the basement excavation. The movements predicted at or just beyond the site boundaries are unlikely to be fully realised and should not therefore have a detrimental impact upon any nearby structures.

In order to mitigate the effects of heave on the new building, the basement could be designed to transmit heave forces into basement walls and tension piles.

Alternatively, a void or layer of compressible material could be incorporated into the design to accommodate these potential long term movements.

In either case, the basement structure will need to be designed to be able to resist the potential uplift forces generated by the ground movements. In this respect potential heave pressures are typically taken to equate to around 50 % to 60 % of the total unloading pressure.

6.0 DAMAGE ASSESSMENT

In addition to the above assessment of the likely movements that will result from the proposed development, some of the neighbouring structures have been considered as sensitive structures, requiring Building Damage Assessments, on the basis of the classification given in Table 2.5 of C580[1]. These include the surrounding neighbouring properties which can be identified on the key plan in the appendix.

The sensitive structures outlined above have been modelled as lines in the analysis and are the lines along which the damage assessment has been undertaken.

For the purpose of the analyses ground level has been taken as a 48.1 m OD across the site, this was to keep the models consistent with each other with regards to excavation depth and assumed founding levels.

Neighbouring properties were plotted in the analysis by means of scaling from available OS maps and so distances between the site and the neighbouring properties are approximate. A survey should be completed in order to confirm the distances between the site and neighbouring properties. Information should also be sought on neighbouring foundation levels.

For the analyses it has been assumed that the neighbouring properties do not have basements and that their layout and average foundation depths are similar to that of the existing 70 Elsworthy Road, i.e. an assumed founding level of 1.5 m depth (47.6 m OD). However, Neighbour A is assumed to have a foundation depth of 2.5 m depth (46.1 m OD) in as a planning application (2010/0159/P) details a swimming pool within the structure.

Limitations within the software do not allow analysis to account for temporary or stabilising works that will act upon sensitive structures. In order to model the stabilising effects of the underpinning and temporary piling of the mews building, a founding depth of 5.4 m (42.7 m OD) has been assumed.

6.1 Damage to Neighbouring Structures

The combined short term movements resulting from both retaining wall installation and basement excavation calculated using the X-Disp modelling software have been used to carry out an assessment of the likely damage to adjacent properties and the results are summarised in the table below. The detailed tabular output can be seen in the Appendix alongside a key plan for reference. As the analysis had to be split into two models, the worst case is presented below.

Building Damage Assessment		
Sensitive Structure	**Elevation**	**Category of Damage***
Mews Building	Northern	0 (Negligible)
	Eastern	0 (Negligible)
	Southern	0 (Negligible)
Neighbour A	Northern	0 (Negligible)
	Eastern	1 (Very Slight)
	Southern	0 (Negligible)
	Western	1(Very Slight)
Neighbour B	Northern	0 (Negligible)
	Eastern	0 (Negligible)
	Southern	0 (Negligible)

Building Damage Assessment		
Sensitive Structure	**Elevation**	**Category of Damage***
	Western	0 (Negligible)
Neighbour C	Northern	1 (Very Slight)
	Eastern	0 (Negligible)
	Southern	1 (Very Slight)
	Western	0 (Negligible)
Neighbour D	Northern	0 (Negligible)
	Eastern	0 (Negligible)
	Southern	0 (Negligible)
	Western	0 (Negligible)
Neighbour E	Northern	0 (Negligible)
	Eastern	0 (Negligible)
	Southern	0 (Negligible)
	Western	0 (Negligible)
Neighbour F	Northern	1 (Very Slight))
	Eastern	0 (Negligible)
	Southern	0 (Negligible)
	Western	0 (Negligible)

**From Table 2.5 of C580[1]: Classification of visible damage to walls.*

The building damage reports for sensitive structures highlighted in the above table predict that the damage to the neighbouring structures would generally be Category 0 (Negligible), with some limited areas of Category 1 (Very Slight) to parts of those structures closest to the proposed basement structure, which would fall within acceptable limits.

The analysis assesses each individual building line being able to behave as a series of individual segments, which in reality is unlikely to be the case. In the analyses that have been carried out the segments have been combined to reflect the stiffness of the structures, but further enhancements would be prudent once details have been obtained of nearby structures.

6.2 Monitoring of Ground Movements

The predictions of ground movement based on the ground movement analysis should be checked by monitoring of adjacent properties and structures. The structures to be monitored during the construction stages should include the neighbouring properties A, C and F.

Condition surveys of the above existing structures should be carried out before and after the proposed works.

The precise monitoring strategy will be developed at a later stage and it will be subject to discussions and agreements with the owners of the adjacent properties and structures. Contingency measures will be implemented if movements of the adjacent structures exceed predefined trigger levels. Both contingency measures and trigger levels will need to be developed within a future monitoring specification for the works.

7.0 CONCLUSIONS

The analysis has concluded that the predicted damage to the neighbouring properties would generally be 'Negligible', with some limited areas of 'Very Slight' on the walls of some neighbouring properties. On this basis, the damage that would inevitably occur as a result of such an excavation would fall within the acceptable limits.

It is recommended that movement monitoring is carried out on all structures prior to and during the proposed basement construction and that a ground improvement specialist is consulted prior to the proposed excavation to ensure the necessary preparations have been made, in the event that wall movements during excavation render compensation grouting necessary.

The separate phases of work, including excavation of the proposed 5.4 m deep basement, will in practice be separated by a number of weeks during which time construction of permanent supports, contiguous piled wall and basement slab will take place. This will provide an opportunity for the ground movements during and immediately after contiguous wall construction to be measured and the data acquired can be fed back into the design and compared with the predicted values. Such a comparison will allow the ground model to be reviewed and the predicted wall movements to be reassessed prior to the main excavation taking place so that propping arrangements can be adjusted if required.

APPENDIX

Trial Pit Logs

X-DISP ANALYSIS

Contiguous Piled Wall Installation

Contour Plots of Vertical Movements and Horizontal Movements for both Main and Mews Analysis

Basement Excavation

Contour Plot of Vertical Movements and Horizontal Movements for both Main and Mews Analysis

Contiguous Piled Wall and Basement Excavation

Contour Plots of Combined Vertical Movements and Horizontal Movements for both Main and Mews Analysis

P-DISP ANALYSIS

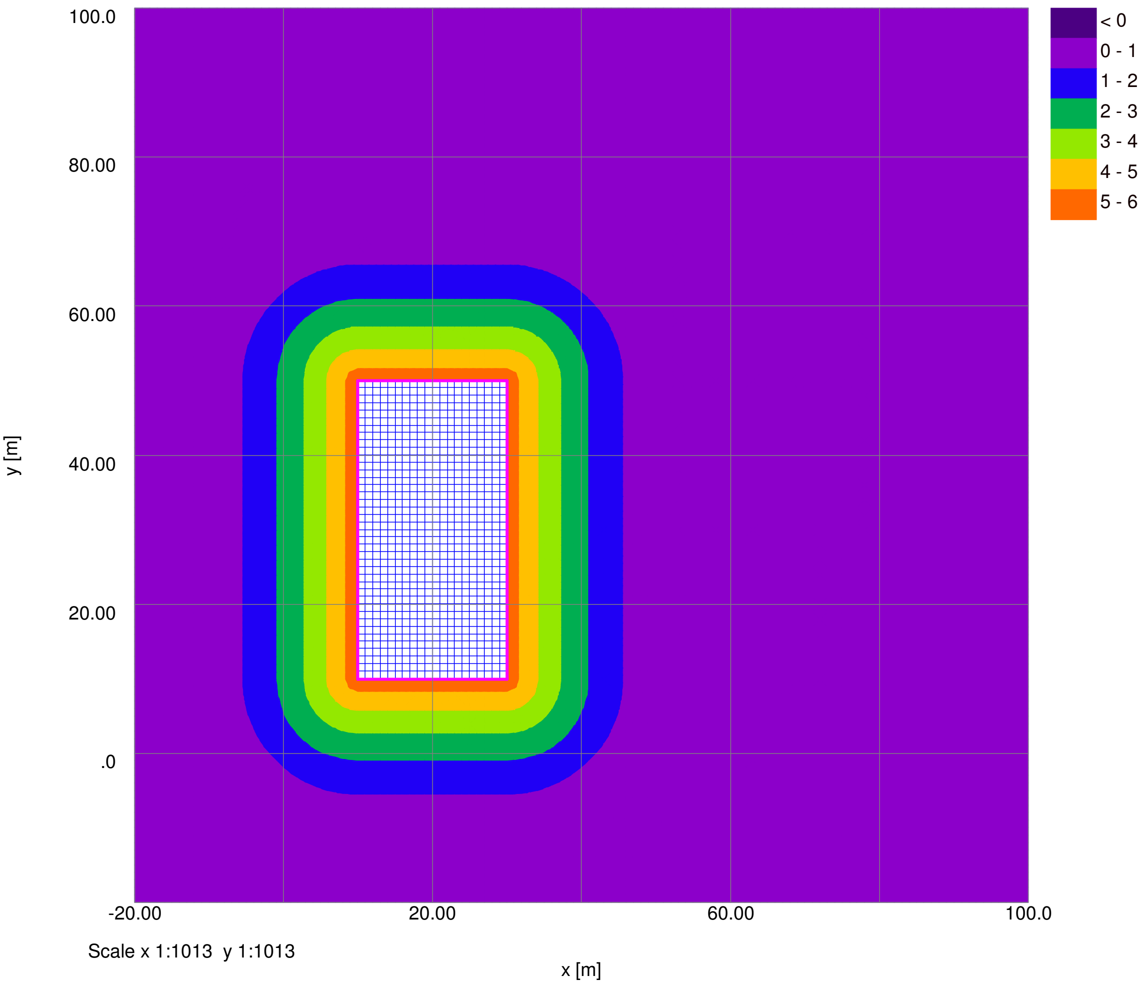
Short Term Movement

Total Movement

BUILDING DAMAGE ASSESSMENT (X-DISP)

Key Plan

Horizontal Displacement Contours: Grid 1 (level 48.100m) Interval 1mm



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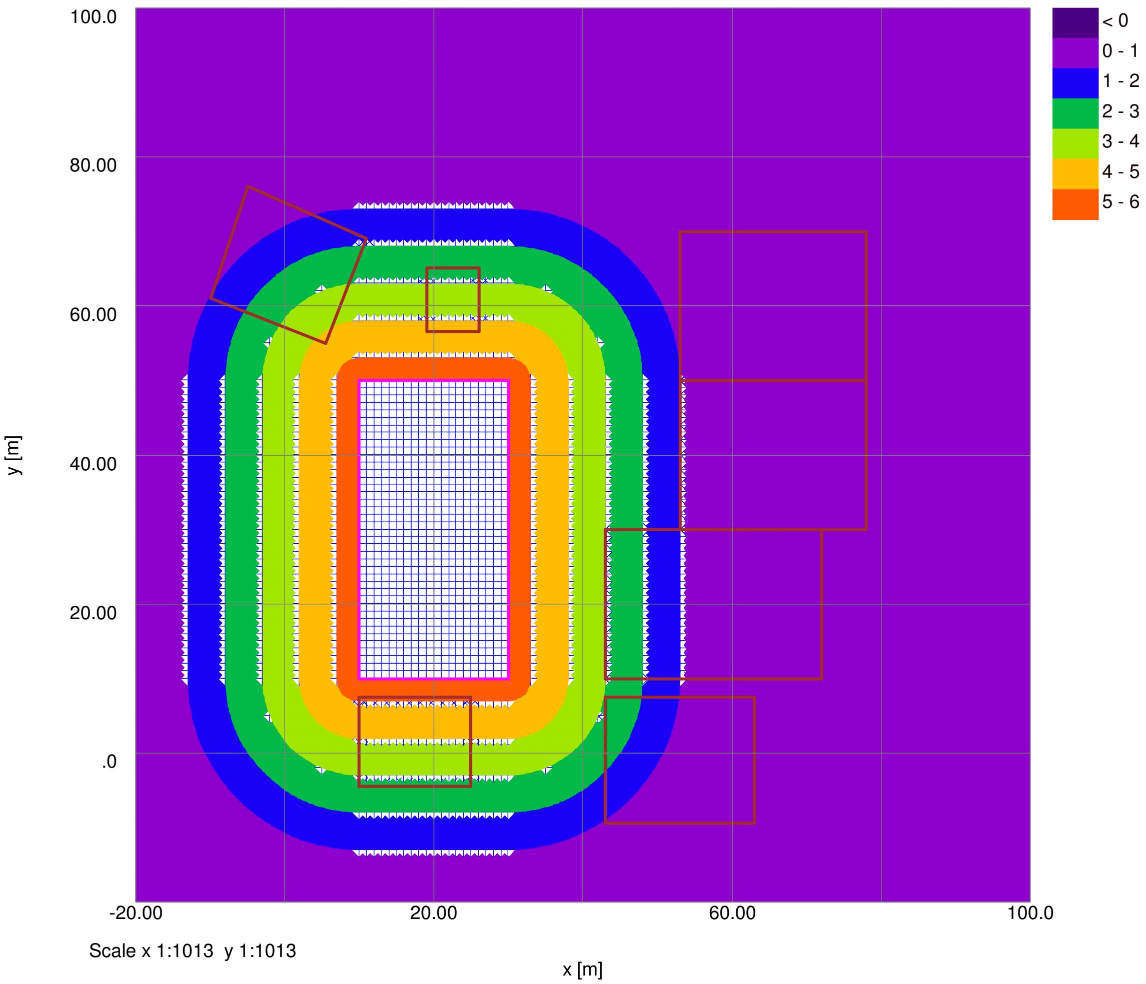

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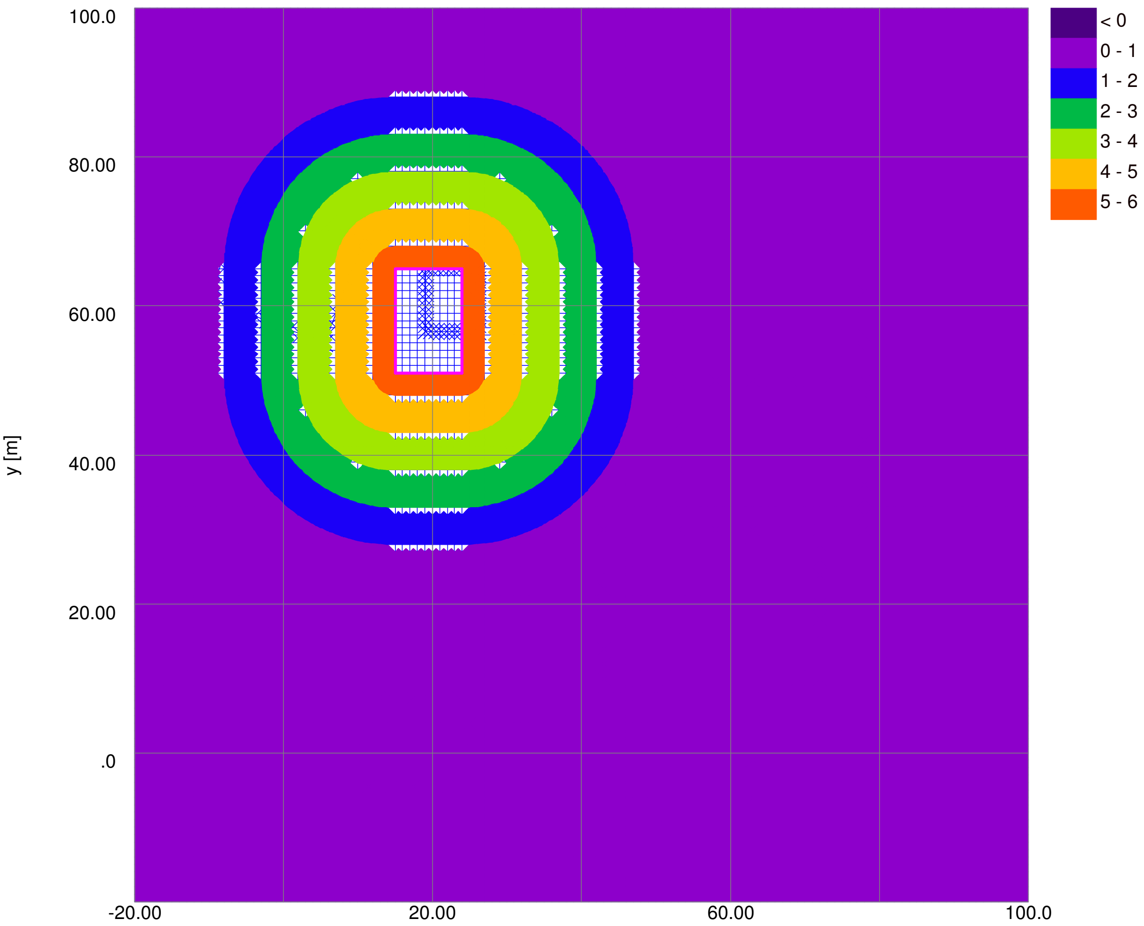

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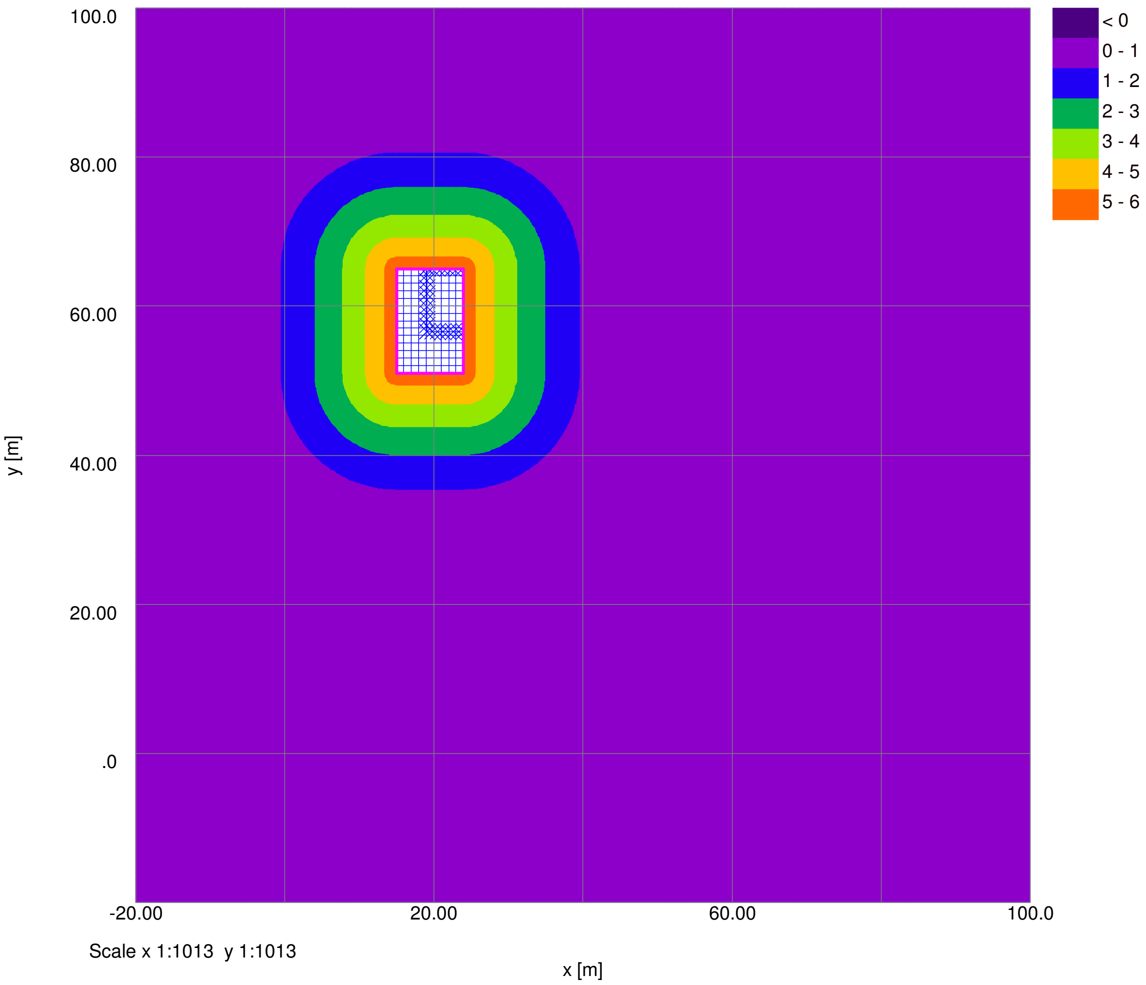

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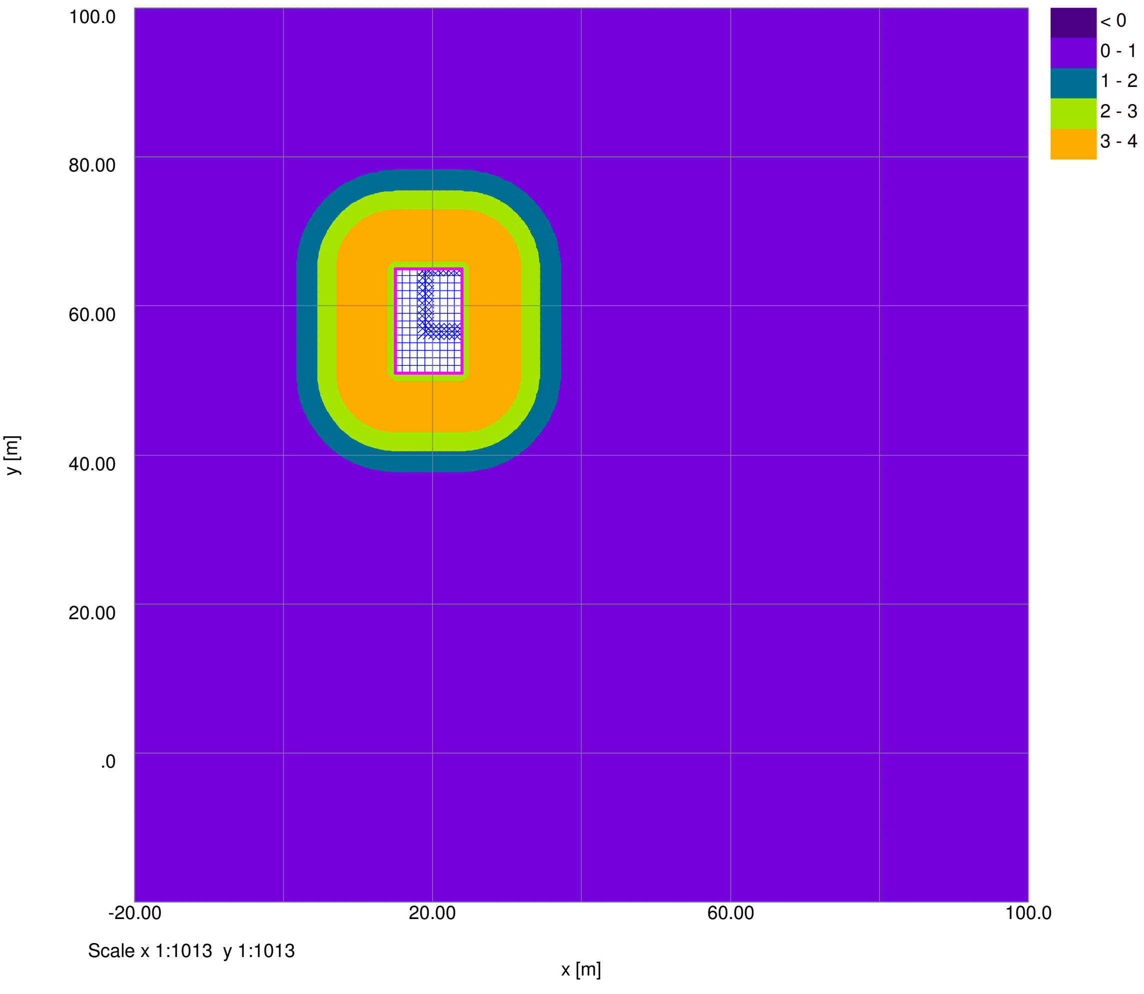

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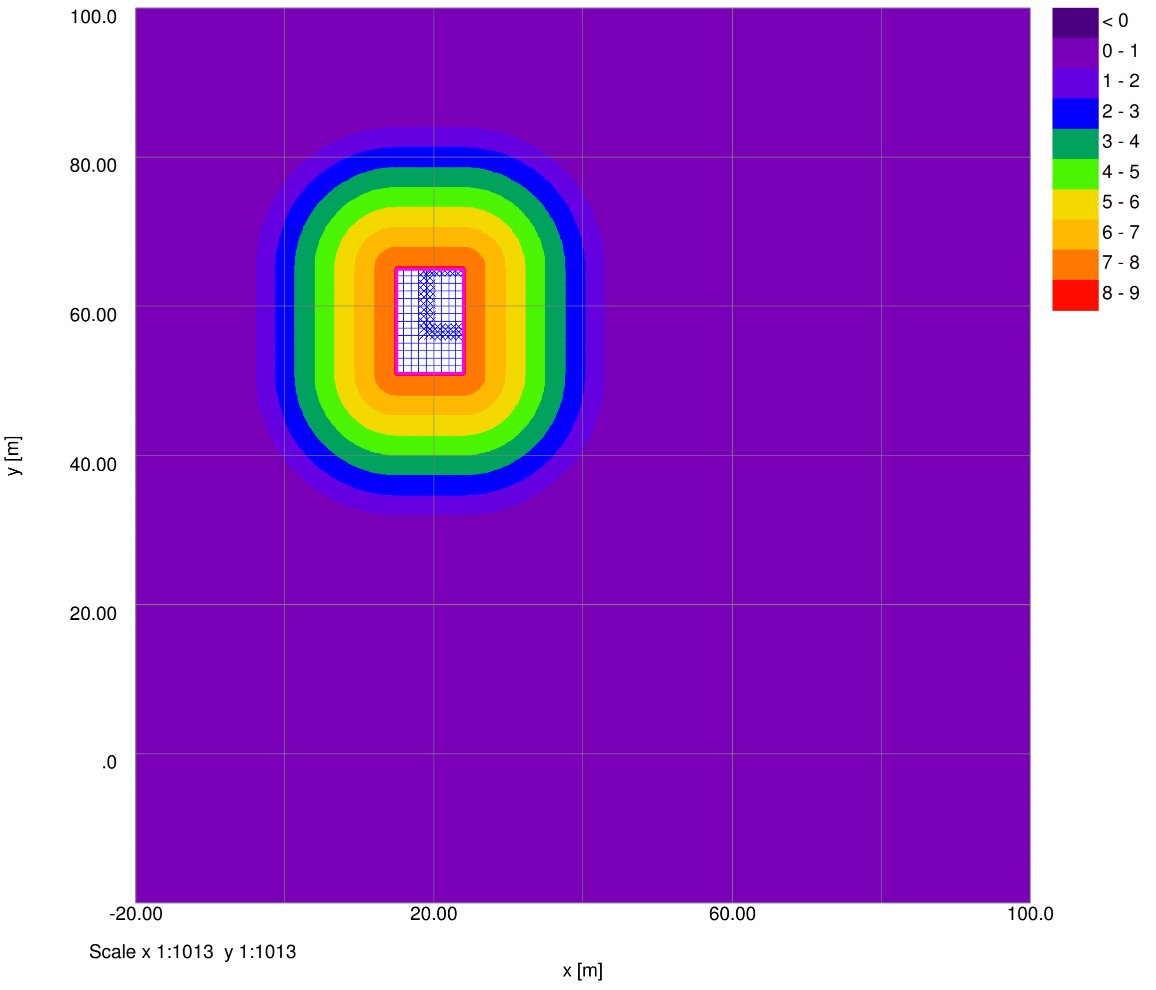

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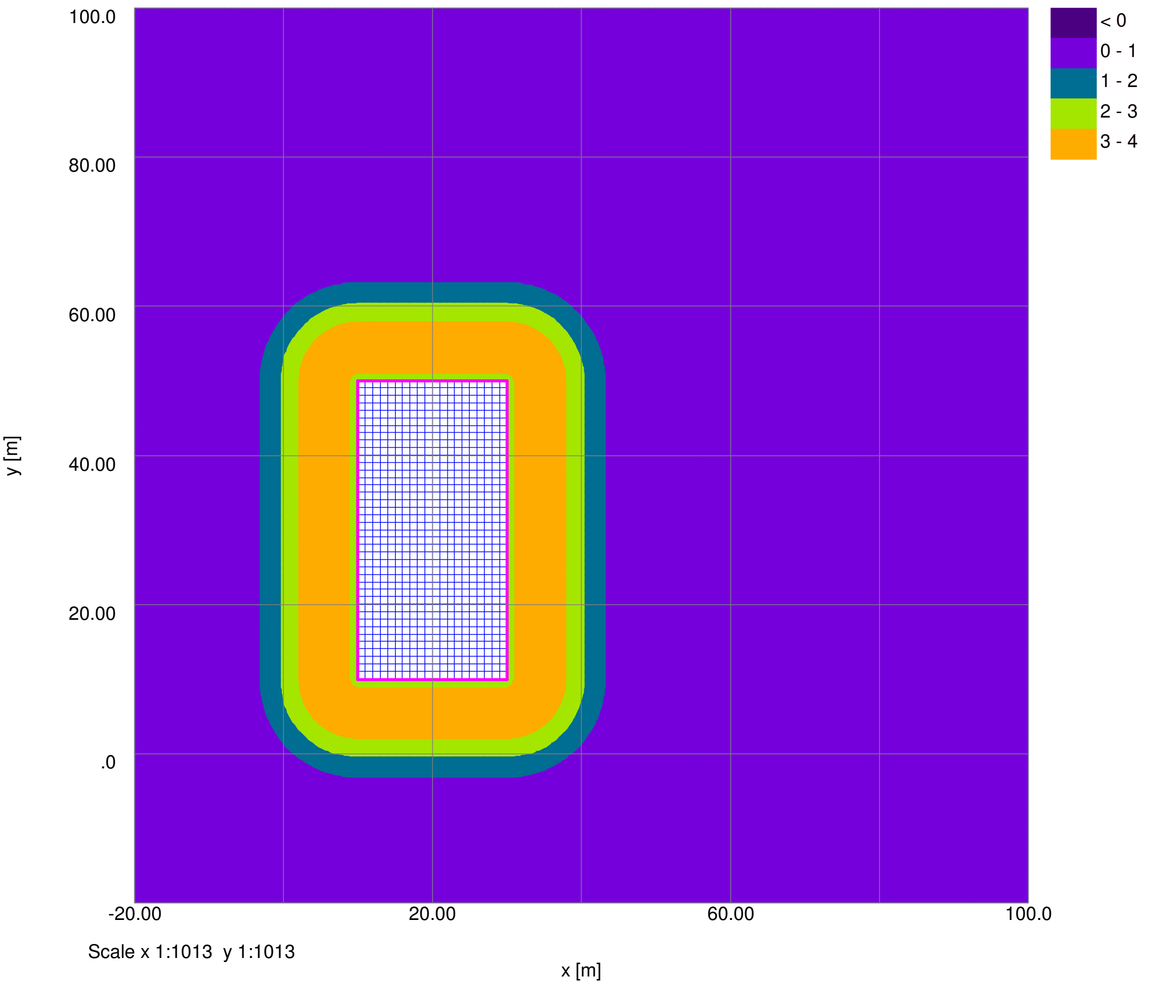

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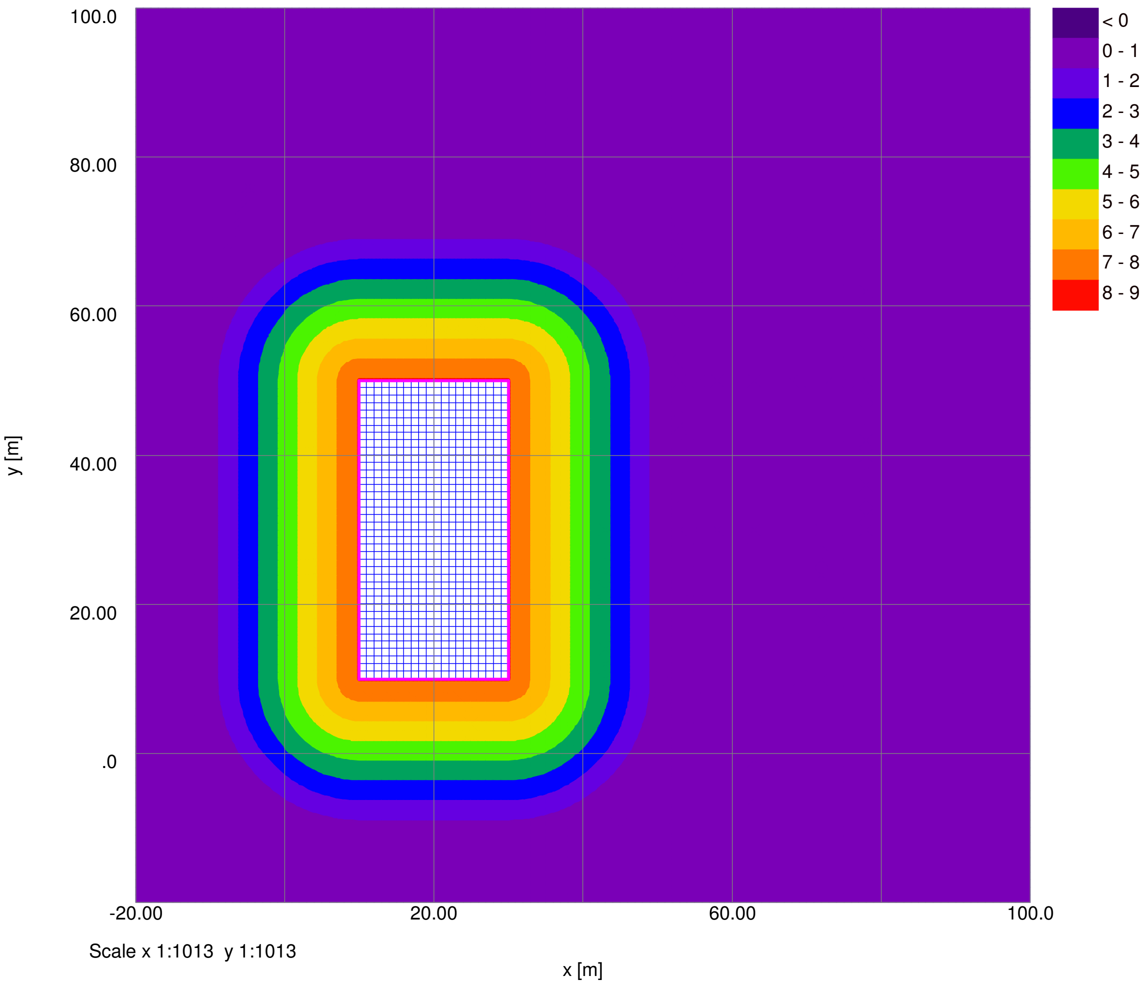

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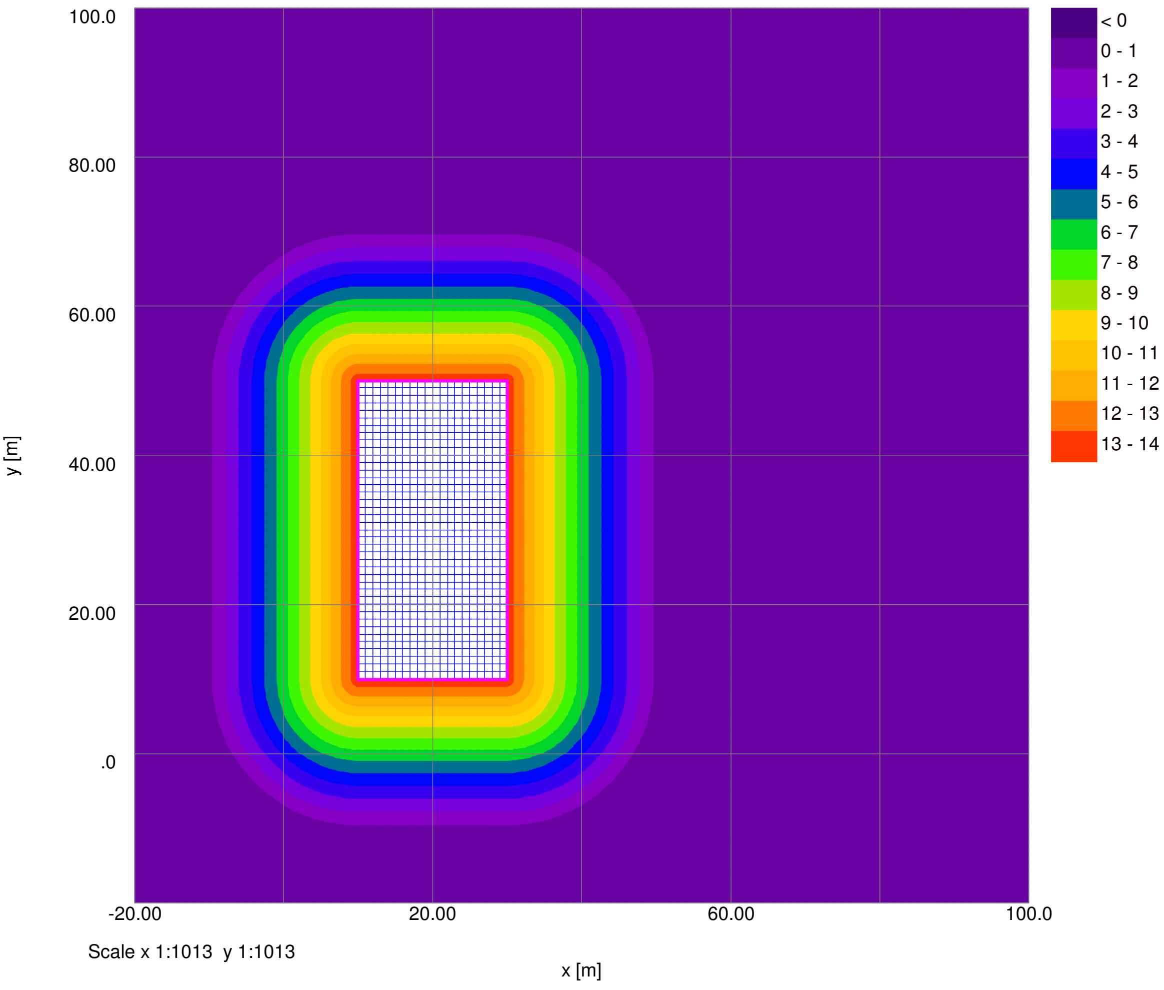

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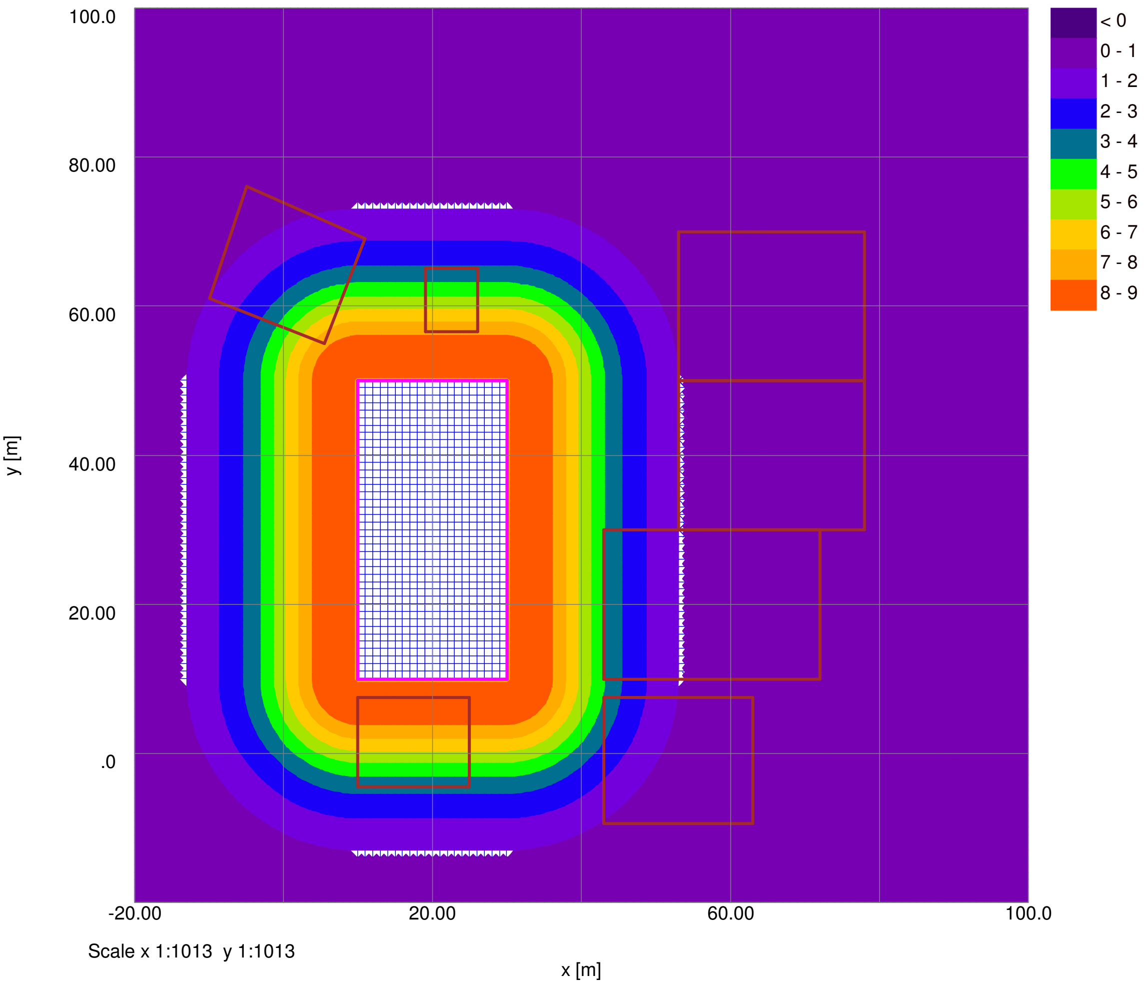

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70 Elsworthy Road Mews Excavation and piled wall		Drg. Ref.		
		Made by JD	Date 12-Aug-2015	Checked

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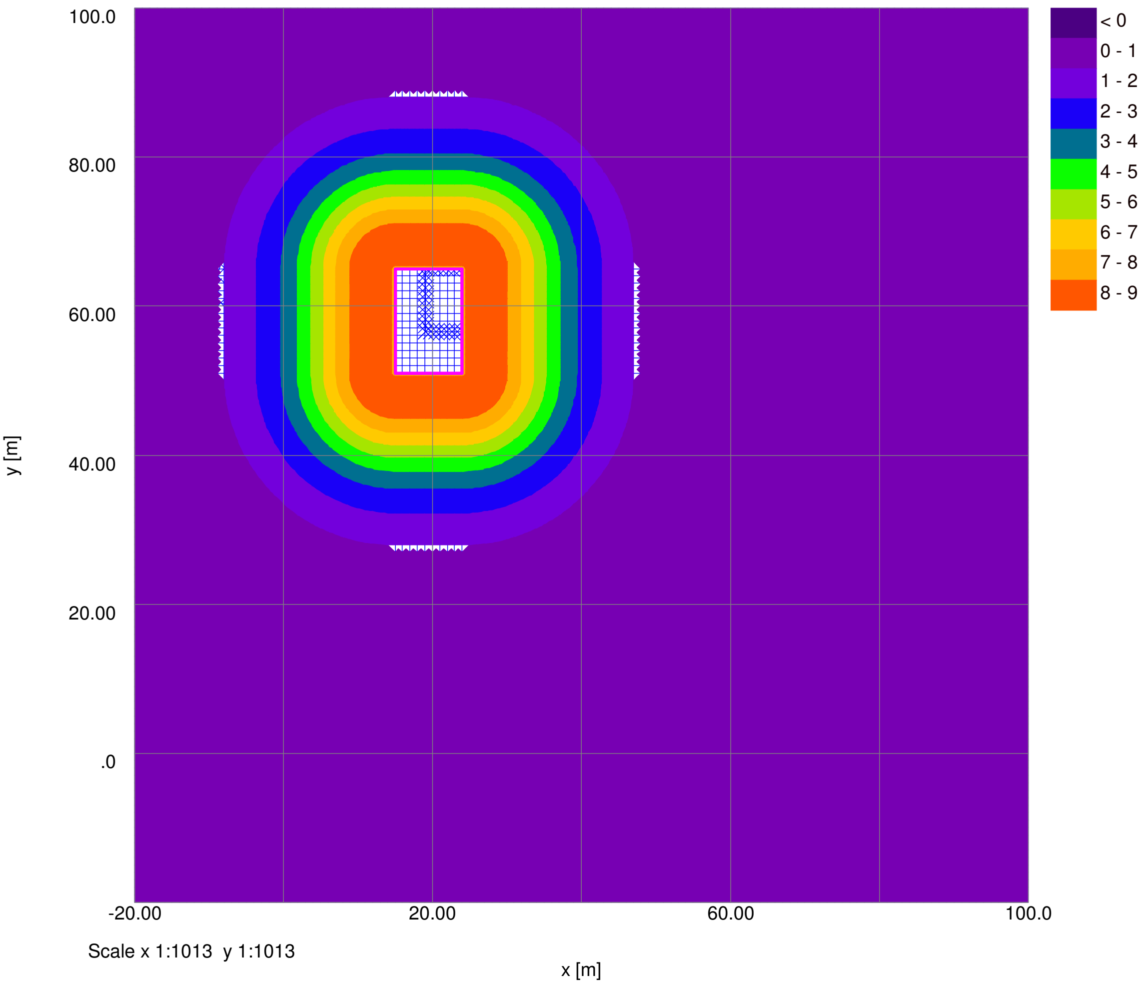

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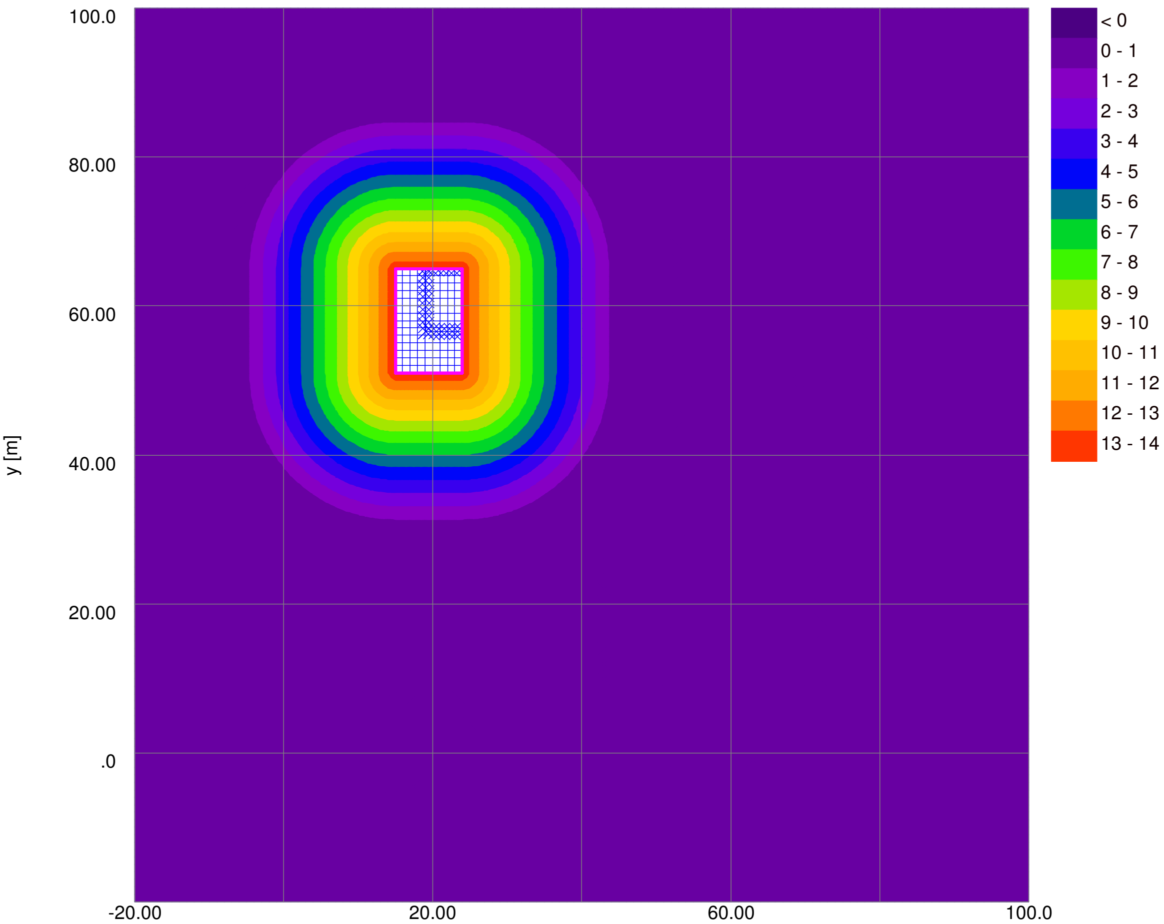

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x [m]

Oasys

GEA LIMITED
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70 Elsworthy Road, London, NW3 3BP
Short Term Heave

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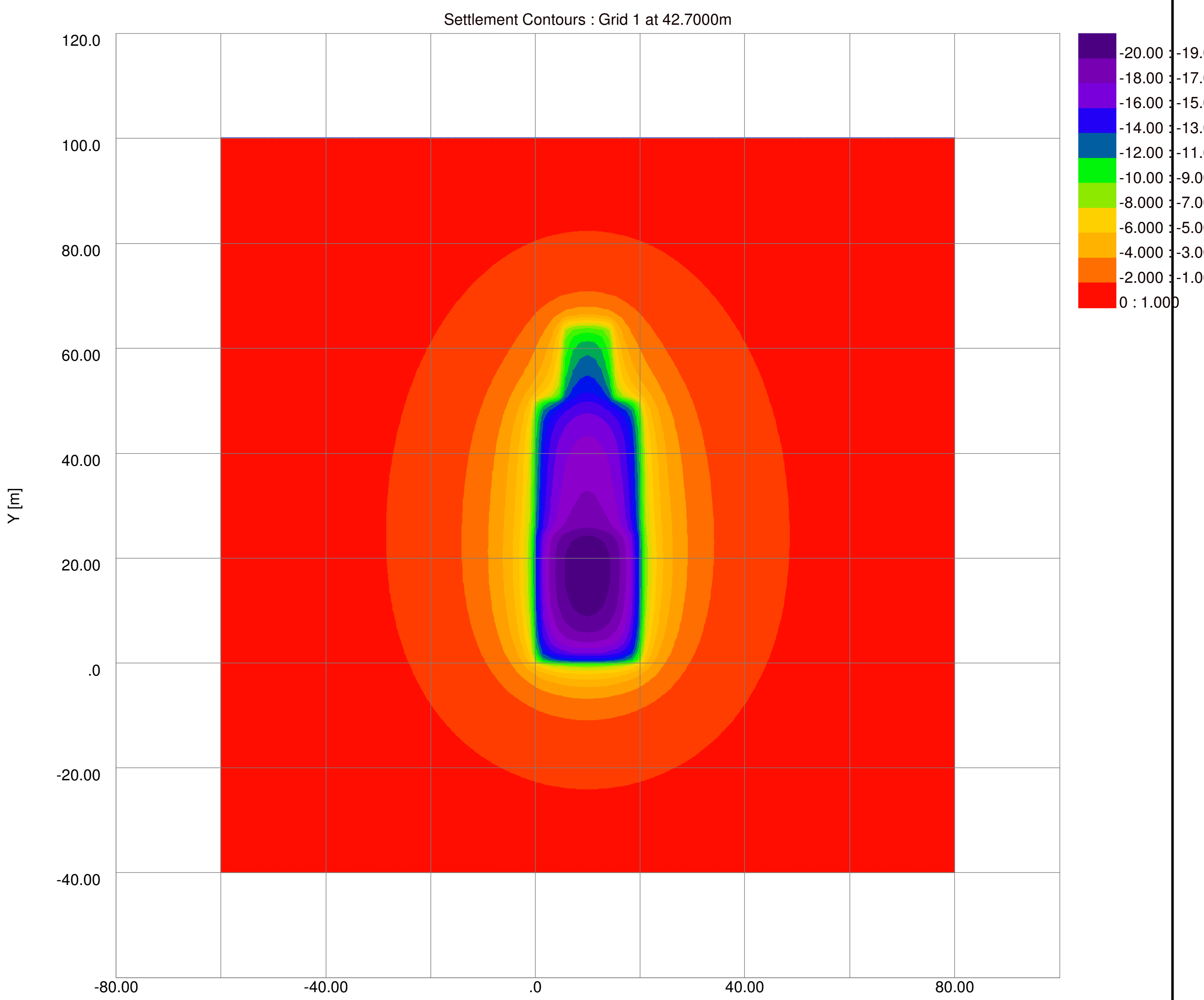
Made by JD	Date	Checked



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70 Elsworthy Road, London, NW3 3BP

Total Heave

Job No.	Sheet No.	Rev.
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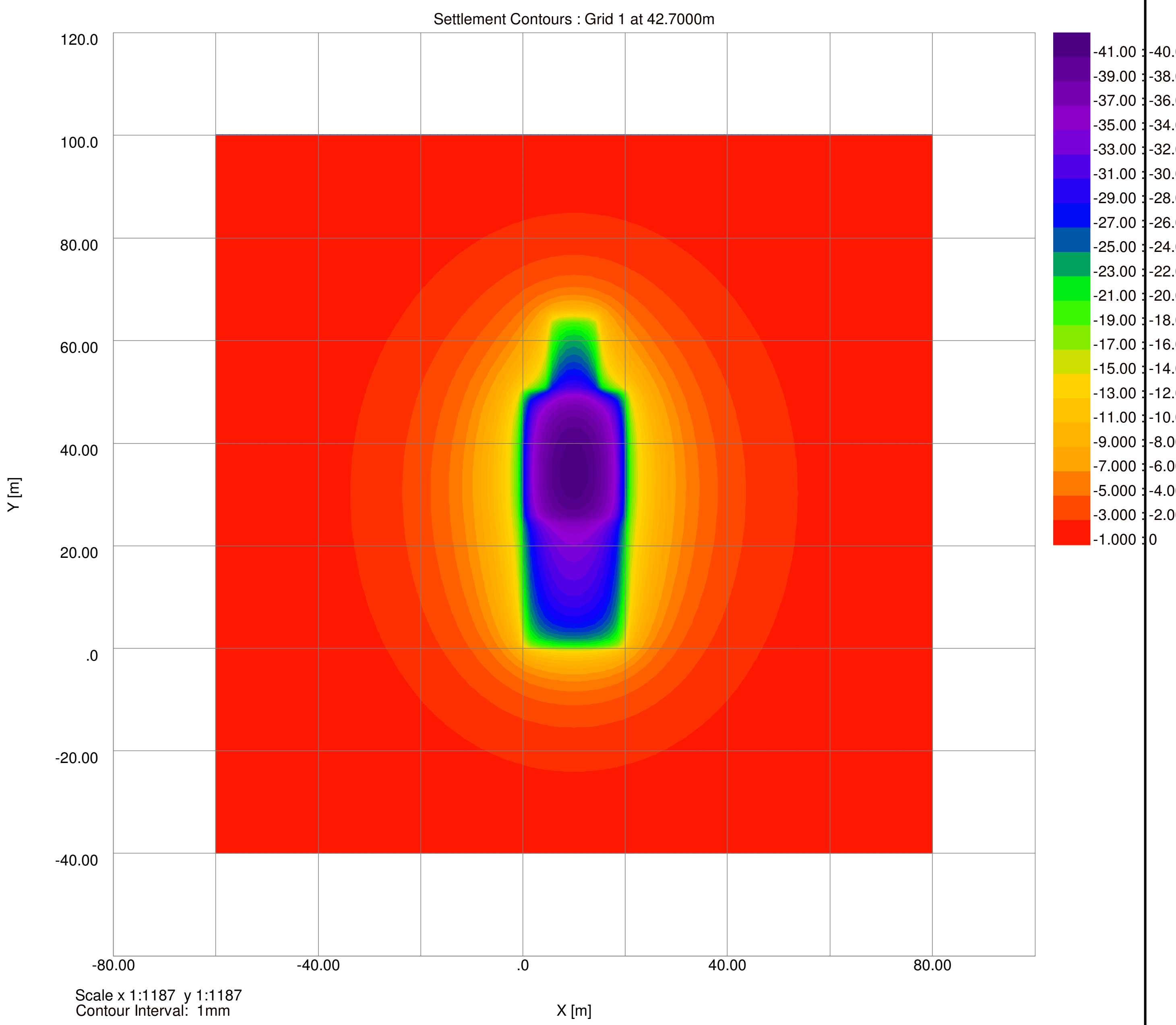

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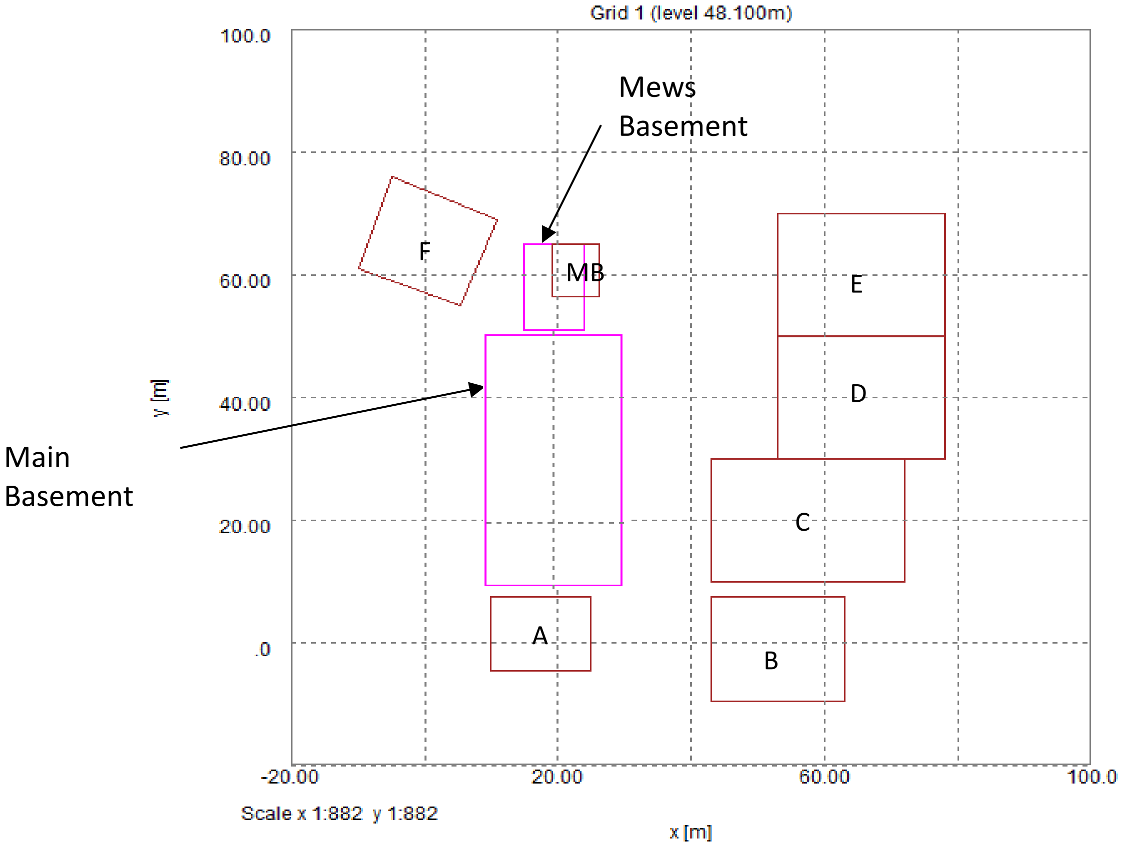
GEA Geotechnical & Environmental Associates
Widbury Barn
Widbury Hill
Ware
Herts SG12 7QE

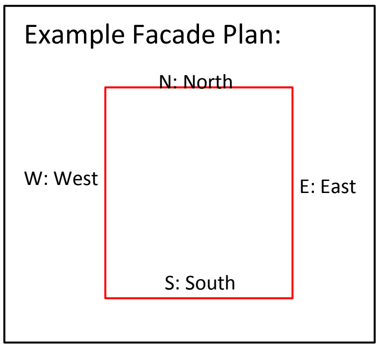
Key Plan

Site	70 Elsworthy Road, London, NW3 3BP	**Job Number** J15143
Client	Latitude London	**Sheet** 1 / 1
Engineer	Elliottwood	



Key

MB: Mews Building



Geotechnical & Environmental Associates (GEA)
is an engineer-led and client-focused independent specialist providing a complete range of geotechnical and contaminated land investigation, analytical and consultancy services to the property and construction industries.

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