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A19.8

Seepage Rates Assessment in Stations Executed with Cut & Cover Method (Plaxis2D Modelling)

SEEPAGE RATES ASSESSMENT IN STATIONS EXECUTED WITH CUT & COVER METHOD

PROJECT:	METROLINK. CHARLEMONT STATION (DUBLIN, IRELAND)
REF.:	EGINF135-11/23/20. REV.:02
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NOTES

- The original copy of this document is kept in SAP
- To allow continuous improvement, members of EIS GUIA can be directed to notify the author of errors, omissions or any other improvement opportunity

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1 INTRODUCTION

The purpose of this report is to carry out a seepage analysis to obtain the water ingress ratios to the excavated enclosures. Additionally, the inlet flows have been calculated in the hypothesis of incorporating bottom plugs generated with the Jet-Grouting technique in soils or the rock fracture sealing injection technique.

The calculations have been processed with the help of the Plaxis 2D program, incorporating for each station the information from the site's research terrain model and the site's hydrological regime.

2 REFERENCE DOCUMENTATION

For the preparation of the report the following documentation has been used, provided by the client:

- MetroLink Phase 1 Ground Investigation (Final Report). Report No.: 18-1076. Date: November 2019. Author: CAUSEWAY GEOTECH
- Geotechnical Design Report, Document No.:ML1-JAI-GEO-ROUT_XX-RP-Y-00004. Revision: P04.1. Date:16/04/2020. Author: JACOBS-IDOM
- Geotechnical Drawings: ML1-JAI-GEOT-ROUT_XX-M2-Y-00021
- Pumping Test: MetroLink-R132 Swords- North& South Areas, Swords Road and Portal 2
- Sections Drawings: Book 2- Alignment & Sections, ML1-JAI-RTA-SC**_XX-DR-Y-04000 (where ** are values from 01 to 16).

3 STATION GEOMETRICAL FEATURES

The table below shows the main geometric features for each station designed.

STATION	INITIAL STA	END STA	H	L	width (a)	length (b)
			(m)	(m)	(m)	(m)
SEATOWN	2+824	2+889	9,20	4,00	18,00	95,00
SWORDS CENTRAL	3+792	3+857	8,50	9,00	18,00	97,00
FOSTERSTOWN	4+758	4+823	4,50	9,00	21,00	85,00
DUBLIN AIRPORT	7+016	7+081	24,70	4,80	23,00	117,00
DARDISTOWN	9+021	9+086	1,00	5,00	23,00	75,00
NORTHWOOD	10+296	10+361	16,00	6,00	23,00	147,00
BALLYMUN	11+237	11+302	21,00	2,50	23,00	116,00
COLLINS AVENUE	12+195	12+260	20,30	4,70	23,00	116,00
GRIFFITH PARK	13+778	13+843	23,50	4,50	23,00	117,00

STATION	INITIAL STA	END STA	H	L	width (a)	length (b)
			(m)	(m)	(m)	(m)
GLASNEVIN	14+835	14+900	23,30	4,00	23,00	96,00
MATER	15+615	15+680	27,30	4,70	23,00	112,00
O´CONNELL STREET	16+1630	16+695	25,00	7,00	23,00	112,00
TARA	17+371	17+436	25,10	4,00	26,00	112,00
STEPHENS GREEN	18+452	18+571	24,90	4,50	23,00	111,26
CHARLEMONT	19+339	19+404	24,00	6,00	23,00	117,00

Table 3-1. Stations evaluated

Where:

H: water drawdown

L= embedded length

a= station box width

b= station box length

4 PROPOSED DEVELOPMENT

Plaxis 2D was used to carry out finite element modelling of the representative cross sections and the groundwater flow analyses were carried out using PlaxFlow.

PlaxFlow is an add-on module to Plaxis 2D that may be used for the analysis of both steady state and time dependant conditions. This module incorporates sophisticated models for saturated and unsaturated ground water flow using well know relations between pore pressure, saturation and permeability.

First, a steady state groundwater flow was carried out to determine the water seepage rates to the excavations of the Cut & Cover sections. The flows per linear meter of station box and the total inlet flow have been obtained.

4.1 Ground Model

The figures included in Annex A show the 2D geometry of each cross-section of stations considered in the calculations with Plaxis.

The terrain models that have been established in Plaxis have considered the stratigraphy of these geotechnical profiles, in addition to the information provided by the nearby boreholes.

The composition of the strata is presented in the following tables:

SEATOWN

STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Made Ground (**QX**)	0,90	0,90
Brown Boulder Clay (**QBR<10m**)	3,90	4,80
Base of Drift Deposit (**BoD**) and Top of Weathered Rock	2,40	7,20
Upper Member Malahide Formation (**CMUP**).	-	>7,20
N.F	-	3,00

Table 4-1. Geotechnical profile of Seatown Station.

SWORDS CENTRAL

STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Made Ground (**QX**)	1,20	1,20
Black Boulder Clay (**QBL<10m**)	1,40	2,60
Black Boulder Clay (**QBL<10m**) with Fluvio-Glacial sands **(FGS)**	1,50	4,10
Black Boulder Clay (**QBL<10m**)	1,10	5,20
Black Boulder Clay (**QBL<10m**) with Fluvio-Glacial sands **(FGS)**	0,60	5,80
Black Boulder Clay (**QBL<10m**)	2,20	8,00
Black Boulder Clay (**QBL<10m**) with Fluvio-Glacial sands **(FGS)**	1,00	9,00
Black Boulder Clay (**QBL<10m**)	1,00	10,00
Black Boulder Clay (**QBL>10m**)	1,00	11,00
Black Boulder Clay (**QBL>10m**) with Fluvio-Glacial sands (FGS)	3,80	14,80
Base of Drift Deposit (**BoD**) and Top of Weathered Rock	4,10	18,90
Lower Member Malahide Formation (**CMLO**).	-	>18,90
N.F	-	1,50

Table 4-2. Geotechnical profile of Swords Central Station.

FOSTERSTOWN

STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Made Ground (**QX**)	0,80	0,80
Black Boulder Clay (**QBL<10m**)	0,80	1,60
Black Boulder Clay (**QBL<10m**) with Fluvio-Glacial sands **(FGS)**	0,40	2,00
Black Boulder Clay (**QBL<10m**)	1,40	3,40
Black Boulder Clay (**QBL<10m**) with Fluvio-Glacial sands **(FGS)**	0,20	3,60
Black Boulder Clay (**QBL<10m**)	1,90	5,50
Black Boulder Clay (**QBL<10m**) with Fluvio-Glacial sands **(FGS)**	0,20	5,70

STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Black Boulder Clay (**QBL<10m**)	1,55	7,25
Black Boulder Clay (**QBL<10m**) with Fluvio-Glacial sands **(FGS)**	0,30	7,55
Black Boulder Clay (**QBL<10m**)	1,45	9,00
Black Boulder Clay (**QBL<10m**) with Fluvio-Glacial sands **(FGS)**	0,40	9,40
Black Boulder Clay (**QBL<10m**)	0,60	10,00
Black Boulder Clay (**QBL>10m**)	0,75	10,75
Black Boulder Clay (**QBL>10m**) with Fluvio-Glacial sands (FGS)	0,55	11,30
Black Boulder Clay (**QBL>10m**)	1,60	12,90
Black Boulder Clay (**QBL>10m**) with Fluvio-Glacial sands (FGS)	0,20	13,10
Black Boulder Clay (**QBL>10m**)	4,00	17,10
Base of Drift Deposit (**BoD**) and Top of Weathered Rock	2,40	19,50
Lower Member Malahide Formation (**CMLO**).	-	>19,50
N.F	-	6,50

Table 4-3. Geotechnical profile of Fosterstown Station.

DUBLIN AIRPORT

STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Made Ground (**QX**)	2,50	2,50
Black Boulder Clay (**QBL<10m**)	2,50	5,00
Base of Drift Deposit (**BoD**) and Top of Weathered Rock	2,50	7,50
Waulsortian Formation (**CWA**)	-	>7,50
N.F	-	3,00

Table 4-4. Geotechnical profile of Dublin Airport Station.

DARDISTOWN

STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Made Ground (**QX**)	1,50	1,50
Black Boulder Clay (**QBL<10m**)	8,50	10,00
Black Boulder Clay (**QBL>10m**)	3,20	13,20
Black Boulder Clay (**QBL>10m**) with Fluvio-Glacial sands (FGS)	3,00	16,20
Base of Drift Deposit (**BoD**) and Top of Weathered Rock	4,30	20,50
Tober Colleen Formation (**CTO**)	-	>20,50
N.F	-	9,50

Table 4-5. Geotechnical profile of Dardistown Station.

NORTHWOOD

STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Made Ground (**QX**)	1,20	1,20
Brown Boulder Clay (**QBR<10m**)	8,80	10,00
Brown Boulder Clay (**QBR>10m**)	10,20	20,20
Base of Drift Deposit (**BoD**) and Top of Weathered Rock	2,00	22,20
Lucan Formation (CLU)	-	>22,20
N.F	-	5,00

Table 4-6. Geotechnical profile of Northwood Station.

BALLYMUN

STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Made Ground (**QX**)	2,00	2,00
Brown Boulder Clay (**QBR<10m**)	3,00	5,00
Brown Boulder Clay (**QBR<10m**) with Fluvio-Glacial sands **(FGS)**	0,50	5,50
Brown Boulder Clay (**QBR<10m**)	4,50	10,00
Brown Boulder Clay (**QBR>10m**)	4,00	14,00
Brown Boulder Clay (**QBR>10m**) with Fluvio-Glacial sands **(FGS)**	2,70	16,70
Brown Boulder Clay (**QBR>10m**	2,30	19,00
Base of Drift Deposit (**BoD**) and Top of Weathered Rock	4,00	23,00
Lucan Formation (CLU)	-	>23
N.F	-	8,00

Table 4-7. Geotechnical profile of Ballymun Station.

COLLINS AVENUE

STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Made Ground (**QX**)	1,50	1,50
Brown Boulder Clay (**QBR<10m**)	1,50	3,00
Brown Boulder Clay (**QBR<10m**) with Fluvio-Glacial sands **(FGS)**	1,20	4,20
Brown Boulder Clay (**QBR<10m**)	3,80	8,00
Brown Boulder Clay (**QBR>10m**)	2,00	10,00
Brown Boulder Clay (**QBR>10m**) with Fluvio-Glacial sands **(FGS)**	3,30	13,30
Base of Drift Deposit (**BoD**) and Top of Weathered Rock	10,60	23,90
Lucan Formation (CLU)	-	>23,90

N.F	-	8,00

Table 4-8. Geotechnical profile of Collins Avenue Station.

GRIFFITH PARK

STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Made Ground (**QX**)	2,50	2,50
Brown Boulder Clay (**QBR<10m**)	6,70	9,20
Base of Drift Deposit (**BoD**) and Top of Weathered Rock	6,00	15,20
Lucan Formation (CLU)	-	>15,20
N.F	-	5,00

Table 4-9. Geotechnical profile of Griffith Park Station.

GLASNEVIN

STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Made Ground (**QX**)	2,70	2,70
Brown Boulder Clay (**QBR<10m**)	7,30	10,00
Brown Boulder Clay (**QBR>10m**)	6,30	16,30
Brown Boulder Clay (**QBR>10m**) with Fluvio-Glacial sands **(FGS)**	2,70	19,00
Brown Boulder Clay (**QBR>10m**)	9,90	28,90
Base of Drift Deposit (**BoD**) and Top of Weathered Rock	3,80	32,70
Lucan Formation (CLU)	-	>32,70
N.F	-	5,70

Table 4-10. Geotechnical profile of Glasnevin Station.

MATER

STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Made Ground (**QX**)	2,60	2,60
Brown Boulder Clay (**QBR<10m**)	3,60	6,20
Brown Boulder Clay (**QBR<10m**) with Fluvio-Glacial sands **(FGS)**	3,8	10,00
Brown Boulder Clay (**QBR>10m**) with Fluvio-Glacial sands **(FGS)**	6,20	16,20
Brown Boulder Clay (**QBR>10m**)	6,30	22,50
Base of Drift Deposit (**BoD**) and Top of Weathered Rock	4,60	27,10
Lucan Formation (CLU)	-	>27,10
N.F	-	11,00

Table 4-11. Geotechnical profile of Mater Station.

O'CONNELL STREET

STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Made Ground (**QX**)	4,20	4,20
Brown Boulder Clay (**QBR<10m**) with Fluvio-Glacial sands **(FGS)**	5,80	10,00
Brown Boulder Clay (**QBR>10m**) with Fluvio-Glacial sands **(FGS)**	2,20	12,20
Brown Boulder Clay (**QBR>10m**)	6,80	19,00
Brown Boulder Clay (**QBR>10m**) with Fluvio-Glacial sands **(FGS)**	2,20	21,20
Base of Drift Deposit (**BoD**) and Top of Weathered Rock	3,90	25,10
Lucan Formation (CLU)	-	>25,10
N.F	-	4,00

Table 4-12. Geotechnical profile of O'Connell ST Station.

TARA

STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Made Ground (**QX**)	2,70	2,70
Alluvial sands and gravels (**QAG**)	1,80	4,50
Base of Drift Deposit (**BoD**) and Top of Weathered Rock	6,20	10,70
Lucan Formation (CLU)	-	>10,70
N.F	-	2,70

Table 4-13. Geotechnical profile of Tara Station.

ST STEPHENS GREEN

STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Made Ground (**QX**)	2,75	2,75
Brown Boulder Clay (**QBR<10m**)	4,80	7,55
Base of Drift Deposit (**BoD**) and Top of Weathered Rock	3,25	10,80
Lucan Formation (CLU)	-	>10,80
N.F	-	4,60

Table 4-14. Geotechnical profile of ST Stephens Green Station.

CHARLEMONT

STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Made Ground (**QX**)	2,00	2,00
Brown Boulder Clay (**QBR<10m**)	5,50	7,50
Base of Drift Deposit (**BoD**) and Top of Weathered Rock	2,40	9,90
Lucan Formation (CLU)	-	>9,90
N.F	-	5,00

Table 4-15. Geotechnical profile of Charlemont Station.

4.2 Water Levels

For all the sections, the position of the phreatic level represented in the geotechnical profile has been considered.

4.3 Constitutive Soil Models and Geotechnical Parameters

Drained Mohr-Coulomb soil model were adopted for soil materials and drained Hoek-Brown model were adopted for bedrock materials.

The material parameters adopted for the Plaxis assessment were as per the values outlined in Table 4-16, Table 4-17 and Table 4-18. The parameters have been obtained mainly from the *Geotechnical Design Report, Document No.:ML1-JAI-GEO-ROUT_XX-RP-Y-00004. Revision: P04.1. Date:16/04/2020*, contrasting with the results obtained in the pumping tests and boreholes close to the cross sections.

IDENTIFICATION	U	Qx	QBR < 10 m	QBR < 10 m SAND	QBR > 10 m	QBR > 10 m SAND
Material model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Bulk unit Weight	kN/m³	18	23,1	23,8	23,4	24,7
e_0	-	0,68	0,26	0,2	0,24	0,12
E	kN/m²	6.000	3,70E+04	3,50E+04	5,50E+04	5,50E+04
v	-	0,35	0,35	0,3	0,35	0,3
G	kN/m²	2.222	1,37E+04	1,35E+04	2,04E+04	2,12E+04
E_oed	kN/m²	9.630	5,94E+04	4,71E+04	8,83E+04	7,40E+04
c´	kN/m²	0	20	0	30	0
φ (phi)	°	28	26	32	28	35
Kx	m/s	7,65E-07	7,62E-07	2,90E-06	6,64E-06	8,59E-06

Ky	m/s	7,65E-07	7,62E-07	2,90E-06	6,64E-06	8,59E-06

Table 4-16. Material parameters. Soils (1)

IDENTIFICATION	**U**	**QBL < 10 m**	**QBL < 10 m SAND**	**QBL > 10 m**	**QBR > 10 m SAND**	**QAG**	**BoD**
Material model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Bulk unit Weight	kN/m³	22,8	22,8	23,2	23,2	18,7	23,5
e_0	-	0,28	0,28	0,25	0,25	0,56	0,22
E	kN/m²	3,50E+04	3,50E+04	7,50E+04	7,50E+04	2,00E+04	1,30E+05
v	-	0,35	0,35	0,35	0,35	0,4	0,3
G	kN/m²	1,30E+04	1,30E+04	2,78E+04	2,78E+04	7,14E+03	5,00E+04
E_oed	kN/m²	5,62E+04	5,62E+04	1,20E+05	1,20E+05	4,29E+04	1,75E+05
c´	kN/m²	50	50	70	70	0	40
φ (phi)	°	30	30	30	30	29	32
Kx	m/s	7,21E-07	2,90E-06	7,15E-07	8,59E-06	1,37E-05	2,90E-04
Ky	m/s	7,21E-07	2,90E-06	7,15E-07	8,59E-06	1,37E-05	2,90E-04

Table 4-17. Material parameters. Soils (2)

IDENTIFICATION	**U**	**UWR**	**CMUP**	**CMLO**	**CWA**	**CTO**	**CLU**
Material model	-	Hoek-Brown	Hoek-Brown	Hoek-Brown	Hoek-Brown	Hoek-Brown	Hoek-Brown
Bulk unit Weight	kN/m³	26,6	27	27	27,1	26,9	26,7
E'_rm	kN/m²	1,50E+07	1,50E+07	2,00E+07	2,00E+07	2,40E+07	2,30E+07
v	-	0,3	0,3	0,3	0,23	0,23	0,25
|σ_ci|	kN/m²	2,50E+04	3,50E+04	4,00E+04	4,50E+04	6,00E+04	6,00E+04
m_i	-	8	8	8	8	8	8
GSI	-	30	45	45	45	45	45
D	-	0	0	0	0	0	0
Kx	m/s	5,63E-06	5,97E-06	1,38E-06	5,69E-07	1,40E-06	4,70E-06
Ky	m/s	5,63E-07	5,97E-07	1,38E-07	5,69E-08	1,40E-07	4,70E-07

Table 4-18. Material parameters. Bedrock.

Taking into account the stratification of the limestones, a relationship between permeabilities Kx / Ky = 10 has been established.

4.4 Model extents and Calculation Phases

The boundaries of the 2D models of each section has been established considering the radius of influence of a theoretical well obtained with the empirical formula of Sichardt (1923):

$$R = 3000 \cdot s_w \cdot \sqrt{k}$$

Where:

s_w: Drawdown

K: Equivalent permeability $= \sqrt{K_X \cdot K_Y}$

And the definitive radius of influence for the stations has been obtained considering the dimensions of each station as follows:

$$R_0 = \sqrt{R^2 + r^2}$$

Where:

$$r = \sqrt{\frac{a\ x\ b}{\pi}}$$

a= station with

b= station length

The following table lists the radius of influence obtained for each station following the procedure indicated above:

STATION	INITIAL STA	END STA	Kh (m/s)	Ky (m/s)	Kxy (m/s)	width (a) (m)	length (b) (m)	R (m)
SEATOWN	2+824	2+889	3,83E-05	6,89E-07	5,14E-06	18,00	95,00	66,79
SWORDS CENTRAL	3+792	3+857	4,57E-05	3,69E-07	4,11E-06	18,00	97,00	56,80
FOSTERSTOWN	4+758	4+823	3,31E-05	2,83E-07	3,06E-06	21,00	85,00	33,57
DUBLIN AIRPORT	7+016	7+081	1,88E-05	6,47E-08	1,10E-06	23,00	117,00	83,20
DARDISTOWN	9+021	9+086	8,65E-05	4,53E-07	6,26E-06	23,00	75,00	24,61
NORTHWOOD	10+296	10+361	2,30E-05	8,10E-07	4,32E-06	23,00	147,00	104,97
BALLYMUN	11+237	11+302	3,93E-05	7,80E-07	5,54E-06	23,00	116,00	151,13
COLLINS AVENUE	12+195	12+260	1,71E-04	8,46E-07	1,20E-05	23,00	116,00	213,22
GRIFFITH PARK	13+778	13+843	4,83E-05	5,93E-07	5,35E-06	23,00	117,00	165,71
GLASNEVIN	14+835	14+900	3,43E-05	1,25E-06	6,55E-06	23,00	96,00	180,88
MATER	15+615	15+680	3,62E-05	9,71E-07	5,93E-06	23,00	112,00	201,50

STATION	INITIAL STA	END STA	Kh	Ky	Kxy	width (a)	length (b)	R
			(m/s)	(m/s)	(m/s)	(m)	(m)	(m)
O´CONNELL ST.	16+1630	16+695	3,21E-05	8,79E-07	5,31E-06	23,00	112,00	175,20
TARA	17+371	17+436	4,86E-05	5,84E-07	5,33E-06	26,00	112,00	176,45
STEPHENS GREEN	18+452	18+571	2,78E-05	5,32E-07	3,84E-06	23,00	111,26	149,22
CHARLEMONT	19+339	19+404	2,19E-05	5,12E-07	3,35E-06	23,00	117,00	134,95

Table 4-19. Radius of influence (R) obtained for each station box

It should be remembered that the radius of influence R does not depend on the pumping flow, but on the parameters of the aquifer, T (Transmissivity) and S (Storage coefficient) and the time t that has been pumped. R is greater the greater is T and t and the smaller is S.

Since T and S are fixed, R increases with pumping time and can reach extremely high values especially in highly transmissive captive aquifers.

4.5 Interfaces

Only the interfaces of the secant piles were modelled (i.e no structural elements). The interfaces had a permeability set to seepage only. The interfaces were activated from ground level down to the pile tip.

In the transient flow calculations, the deactivation of the soil within the excavation was not required to be deactivated.

The interfaces of the retaining walls had a permeability set to seepage only. The interfaces were activated from ground level down to the toe of the retaining walls.

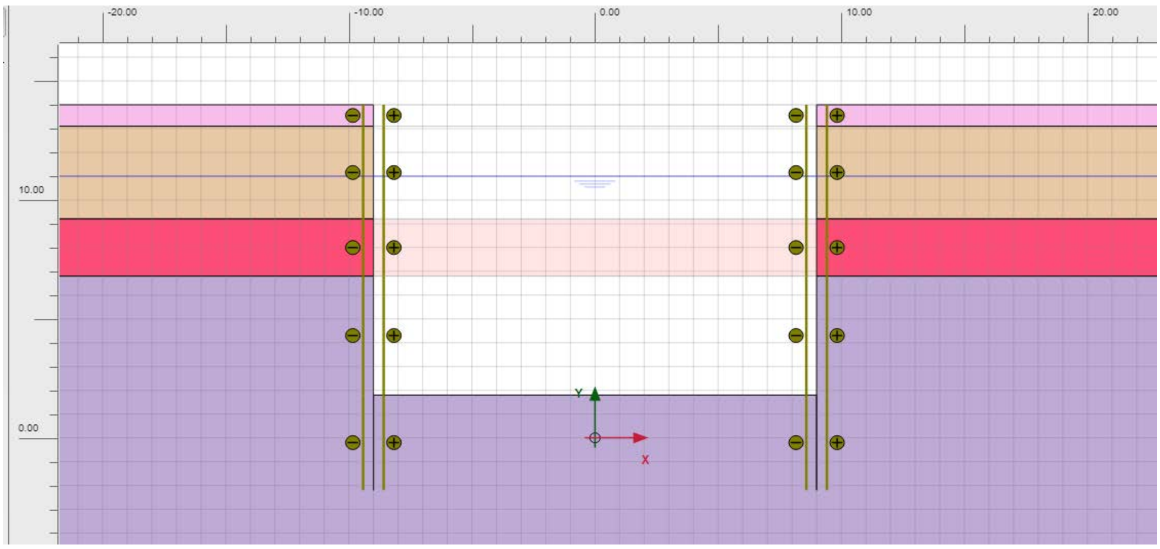


Figure 4-1. Illustration of the interfaces (Seatown Station) at station box in Plaxis 2D

4.6 Mesh generation

To model soil layers and other clusters, a 15-node or 6-node triangular elements may be used. A 15-node element provides fourth order interpolation for the variable field (displacements) and the numerical integration involves twelve Gauss points also known as stress points. A 15-node triangular element is preferred over a 6-node element for its very accurate and high-quality stress results. This would enable accurate determination of the stress gradients within the vicinity of the tunnel to be analysed. A very fine mesh discretization was selected with a local refinement around the interfaces.

4.7 Tolerated error

In any nonlinear analysis where a finite number of calculation steps are used there will be some drift from the exact solution. The purpose of a solution is to ensure that any errors remain within acceptable bounds. Within each load step, the calculation program continues to carry out iterations until the calculated errors are smaller than the specified value. Plaxis suggests the standard error setting of 0.01 is suitable for most calculations but for failure load calculations it may be more practical to use an increased value of 0.03 or even 0.05. For this study, the standard error tolerance of 0.01 was held constant.

4.8 Grouted excavation bottom plug model

To model the bottom plug, a new material called "Grout" has been created to which a permeability $K = 10^{-8}$ has been assigned. This permeability is the minimum that is usually achieved with Jet-Grouting type treatments or injections in rock fractures with grout. Furthermore, and adopting a conservative point of view, a bottom plug thickness equal to 1.50 m has been considered, although normally the thickness of these plugs is usually somewhat greater (> 2-2.5 m).

The rest of the material's properties have remained similar to those of the levels where the bottom plug is inserted.

The standard geometry for the bottom plugs that has been included in the Plaxis models is shown in the following Figure 4-2 and Figure 4-3.

Both Jet-Grouting and Rock Sealing Injection Technique are normally adopted in a variety of geometrical configurations to ensure provisional or final earth re-taining and waterproofing functions at the bottom and walls of excavations (e.g. Balossi Restelli et al., 1986; Santoro & Bianco, 1995; Sondermann & Toth, 2001; Miyasaka et al., 1992).

In the case of the Jet-Grouting technique, the basic solution consists in a continuous impervious barrier formed with assemblies of overlapped columns. On the other hand, grout injections have been widely used in sealing underground excavations to prevent water ingress. For example, cement and sodium silicate grout (C–S grout), a typical quick-setting slurry, is becoming increasingly more popular in fracture-sealing grouting operations (W. Zhang, *Shandong University of Science and Technology*. 2018)

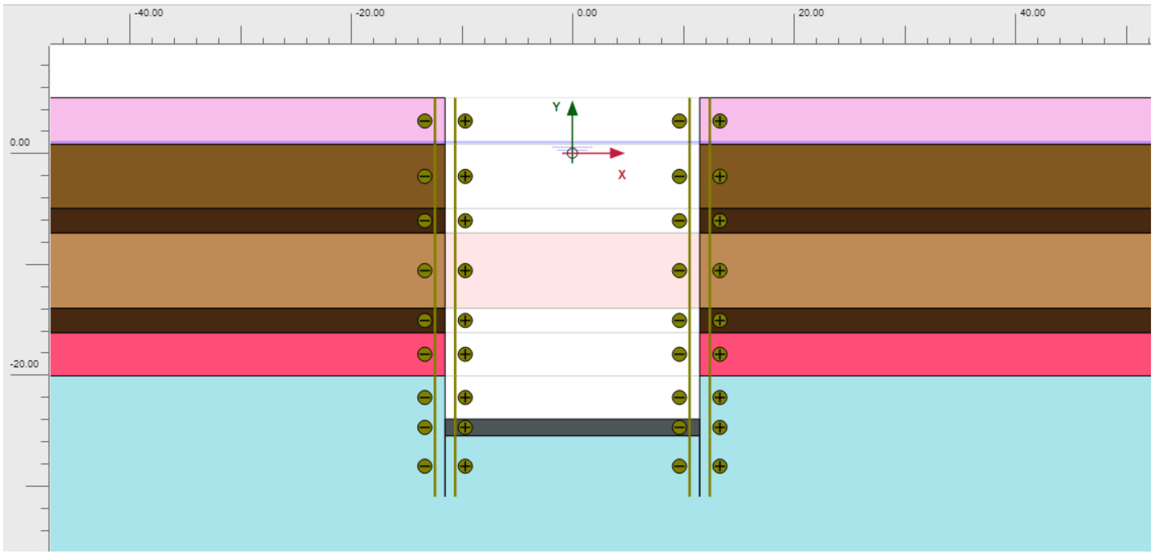


Figure 4-2. Geometry for the bottom plugs adopted in 2D models in Plaxis.

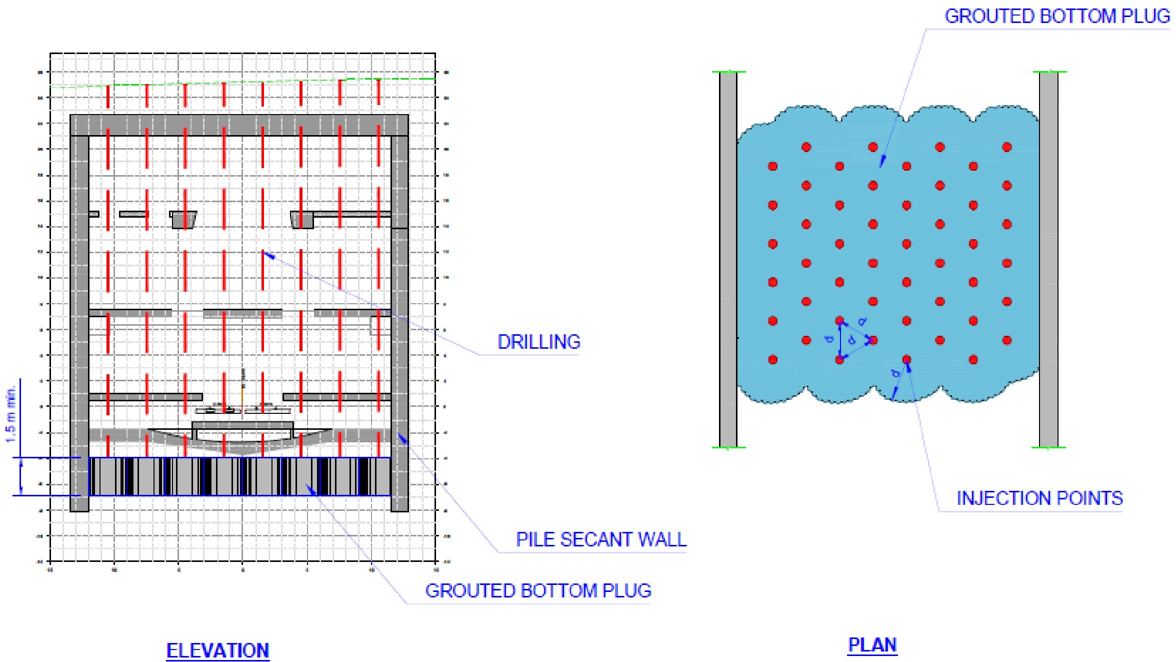


Figure 4-3. Scheme type of grouted excavation bottom plug in Cut&Cover sections

And the following table lists the radius of influence obtained for each station following the procedure indicated above:

STATION	INITIAL STA	END STA	width (a)	length (b)	R´
			(m)	(m)	(m)
SEATOWN	2+824	2+889	18,00	95,00	46,35
SWORDS CENTRAL	3+792	3+857	18,00	97,00	45,33
FOSTERSTOWN	4+758	4+823	21,00	85,00	29,91
DUBLIN AIRPORT	7+016	7+081	23,00	117,00	79,91
DARDISTOWN	9+021	9+086	23,00	75,00	23,94
NORTHWOOD	10+296	10+361	23,00	147,00	62,53
BALLYMUN	11+237	11+302	23,00	116,00	106,13
COLLINS AVENUE	12+195	12+260	23,00	116,00	147,46
GRIFFITH PARK	13+778	13+843	23,00	117,00	124,55
GLASNEVIN	14+835	14+900	23,00	96,00	107,35
MATER	15+615	15+680	23,00	112,00	140,47
O´CONNELL STREET	16+630	16+695	23,00	112,00	124,49
TARA	17+371	17+436	26,00	112,00	134,27
STEPHENS GREEN	18+452	18+571	23,00	111,26	114,95
CHARLEMONT	19+339	19+404	23,00	117,00	104,67

Table 4-20. adius of influence (R) obtained for each station box with Bottom Plug

5 RESULTS

The water seepage rates of the Cut & Cover stations box are summarized in the Table 5-1 and Table 5-2 where the effect of bottom plugs is taken into account.

The following subchapters show the graphic outputs with the most representative results for each station obtained with Plaxis 2D:

- Summary of results tables
- Illustration of Plaxis 2D Model
- Illustration of groundwater head
- Illustration of groundwater flow
- Water discharge ratio at the bottom of the excavation

STATION	INITIAL STA	END STA	Kx (m/s)	Ky (m/s)	Kxy (m/s)	width (a) (m)	length (b) (m)	R (m)	WATER INGRESS Q Plaxis (m3/s/m)	Q Plaxis (m3/d/m)	Qt Plaxis (l/s)	Qt Plaxis (m3/d)
SEATOWN	2+824	2+889	3,83E-05	6,89E-07	5,14E-06	18,00	95,00	66,79	1,20E-05	1,04	1,14	98,50
SWORDS CENTRAL	3+792	3+857	4,57E-05	3,69E-07	4,11E-06	18,00	97,00	56,80	7,11E-06	0,61	0,69	59,59
FOSTERSTOWN	4+758	4+823	3,31E-05	2,83E-07	3,06E-06	21,00	85,00	33,57	3,00E-06	0,26	0,26	22,03
DUBLIN AIRPORT	7+016	7+081	1,88E-05	6,47E-08	1,10E-06	23,00	117,00	83,20	3,24E-06	0,28	0,38	32,75
DARDISTOWN	9+021	9+086	8,65E-05	4,53E-07	6,26E-06	23,00	75,00	24,61	5,30E-06	0,46	0,40	34,34
NORTHWOOD	10+296	10+361	2,30E-05	8,10E-07	4,32E-06	23,00	147,00	104,97	1,80E-05	1,56	2,65	228,61
BALLYMUN	11+237	11+302	3,93E-05	7,80E-07	5,54E-06	23,00	116,00	151,13	3,00E-05	2,59	3,48	300,67
COLLINS AVENUE	12+195	12+260	1,71E-04	8,46E-07	1,20E-05	23,00	116,00	213,22	2,00E-05	1,73	2,32	200,45
GRIFFITH PARK	13+778	13+843	4,83E-05	5,93E-07	5,35E-06	23,00	117,00	165,71	2,60E-05	2,25	3,04	262,83
GLASNEVIN	14+835	14+900	3,43E-05	1,25E-06	6,55E-06	23,00	96,00	180,88	7,24E-05	6,26	6,95	600,68
MATER	15+615	15+680	3,62E-05	9,71E-07	5,93E-06	23,00	112,00	201,50	3,10E-05	2,68	3,47	299,98
O´CONNELL STREET	16+1630	16+695	3,21E-05	8,79E-07	5,31E-06	23,00	112,00	175,20	2,20E-05	1,90	2,46	212,89
TARA	17+371	17+436	4,86E-05	5,84E-07	5,33E-06	26,00	112,00	176,45	2,60E-05	2,25	2,91	251,60
STEPHENS GREEN	18+452	18+571	2,78E-05	5,32E-07	3,84E-06	23,00	111,26	149,22	2,70E-05	2,33	3,00	259,55
CHARLEMONT	19+339	19+404	2,19E-05	5,12E-07	3,35E-06	23,00	117,00	134,95	2,00E-05	1,73	2,34	202,18

Table 5-1. Water seepage rates for the Cut & Cover sections obtained with Plaxis

						BOTTOM PLUG (GROUT)		WATER INGRESS WITH BOTTOM PLUG				
STATION	INITIAL STA	END STA	width (a)	length (b)	R´	Grout conductivity	Grout Thickness	Q Plaxis	Q Plaxis	Qt Plaxis	Qt Plaxis	Water pressure under Bottom Plug
			(m)	(m)	(m)	m/s	m)	(m3/s/m)	(m3/d/m)	(l/s)	(m3/d)	(kN/m2)
SEATOWN	2+824	2+889	18,00	95,00	46,35	1,00E-08	1,50	1,02E-06	0,09	0,10	8,37	102,00
SWORDS CENTRAL	3+792	3+857	18,00	97,00	45,33	1,00E-08	1,50	9,00E-07	0,08	0,09	7,54	91,21
FOSTERSTOWN	4+758	4+823	21,00	85,00	29,91	1,00E-08	1,50	5,20E-07	0,04	0,04	3,82	53,00
DUBLIN AIRPORT	7+016	7+081	23,00	117,00	79,91	1,00E-08	1,50	1,88E-06	0,16	0,22	19,00	142,00
DARDISTOWN	9+021	9+086	23,00	75,00	23,94	1,00E-08	1,50	1,50E-07	0,01	0,01	0,97	25,75
NORTHWOOD	10+296	10+361	23,00	147,00	62,53	1,00E-08	1,50	2,60E-06	0,22	0,38	33,02	150,00
BALLYMUN	11+237	11+302	23,00	116,00	106,13	1,00E-08	1,50	2,96E-06	0,26	0,34	29,67	210,00
COLLINS AVENUE	12+195	12+260	23,00	116,00	147,46	1,00E-08	1,50	2,76E-06	0,24	0,32	27,66	197,00
GRIFFITH PARK	13+778	13+843	23,00	117,00	124,55	1,00E-08	1,50	3,22E-06	0,28	0,38	32,55	229,00
GLASNEVIN	14+835	14+900	23,00	96,00	107,35	1,00E-08	1,50	3,41E-06	0,29	0,33	28,28	238,00
MATER	15+615	15+680	23,00	112,00	140,47	1,00E-08	1,50	3,73E-06	0,32	0,42	36,09	261,00
O´CONNELL STREET	16+630	16+695	23,00	112,00	124,49	1,00E-08	1,50	3,30E-06	0,29	0,37	31,93	238,00
TARA	17+371	17+436	26,00	112,00	134,27	1,00E-08	1,50	3,76E-06	0,32	0,42	36,38	251,00
STEPHENS GREEN	18+452	18+571	23,00	111,26	114,95	1,00E-08	1,50	3,40E-06	0,29	0,38	32,68	238,00
CHARLEMONT	19+339	19+404	23,00	117,00	104,67	1,00E-08	1,50	2,74E-06	0,24	0,32	27,70	230,00

Table 5-2. Water seepage rates for the Cut & Cover sections with Bottom Plug

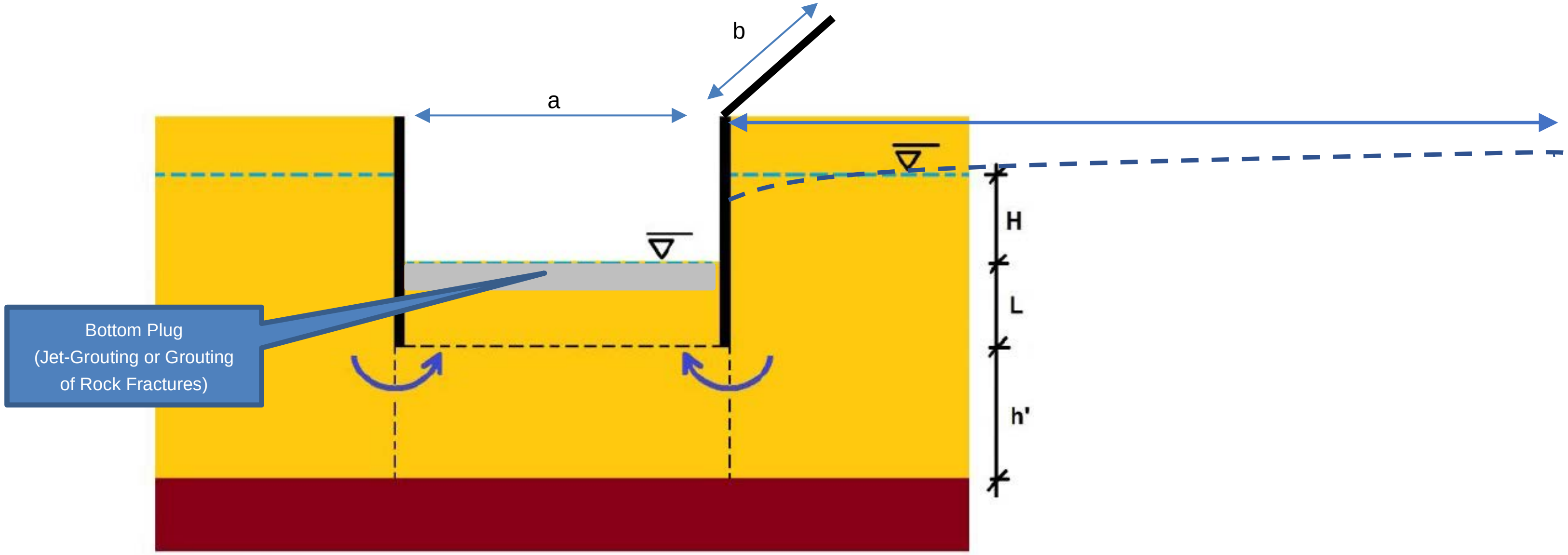


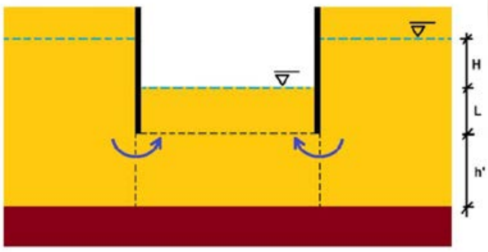
Figure 5-1. Representative Cut&Cover section scheme used in Plaxis

5.1 Seatown

N	STATION NAME	Levels				
		TOP	Qx	QBR<10 m	BoD	CMUP
		(m)	(m)	(m)	(m)	(m)
2	SEATOWN	14	13,10	9,2	6,8	-9,77

	thickness			
	Qx	QBR<10 m	BoD	CMUP
	(m)	(m)	(m)	(m)
	0,00	1,80	2,40	16,57
	K(Permeability)			
	Qx	QBR<10 m	BoD	CMUP
	(m/s)	(m/s)	(m/s)	(m/s)
Kx	7,65E-07	7,62E-07	2,90E-04	5,97E-06
Kv	7,65E-07	7,62E-07	2,90E-04	5,97E-07

Exc.	W.L.
(m)	(m)
1,8	11



$$k_{II} = \frac{H}{\sum_{1}^{m} \frac{H_n}{k_n}}$$

$$h'_{min} = \frac{ab}{2(a+b)}$$

$$k_I = \frac{\sum_{i=1}^{n} k_i \cdot H_i}{H}$$

Kh	Kv	H	L	a	b	h´	Vol	ro	φ1	φ2	R	Rf	Qv (Dupuit formula)	Q Plaxis	Q Plaxis	Qt
(m/s)	(m/s)	(m)	(m)	(m)	(m)	(m)	(m3)	(m)	(m)	(m)	(m)	(m)	(m3/s/m)	(m3/s/m)	(m3/d/m)	(m3/d)
3,83E-05	6,89E-07	9,20	4,00	18,00	95,00	7,57	1,57E+04	23,33	61,00	51,80	62,58	66,79	1,07E-05	1,20E-05	1,04	98,50

WELLS	m3/d/m	m3/d	l/s	time Plaxis (d)
Plaxis	11,00	1.045,00	12,09	15,25

WITH BOTTON PLUG			
Q Plaxis	Q Plaxis	Qt	Water pressure under grout
(m3/s/m)	(m3/d/m)	(m3/d)	(kN/m2)
1,02E-06	0,09	8,37	102,00

Figure 5-2. Summary of results. Seatown Station.

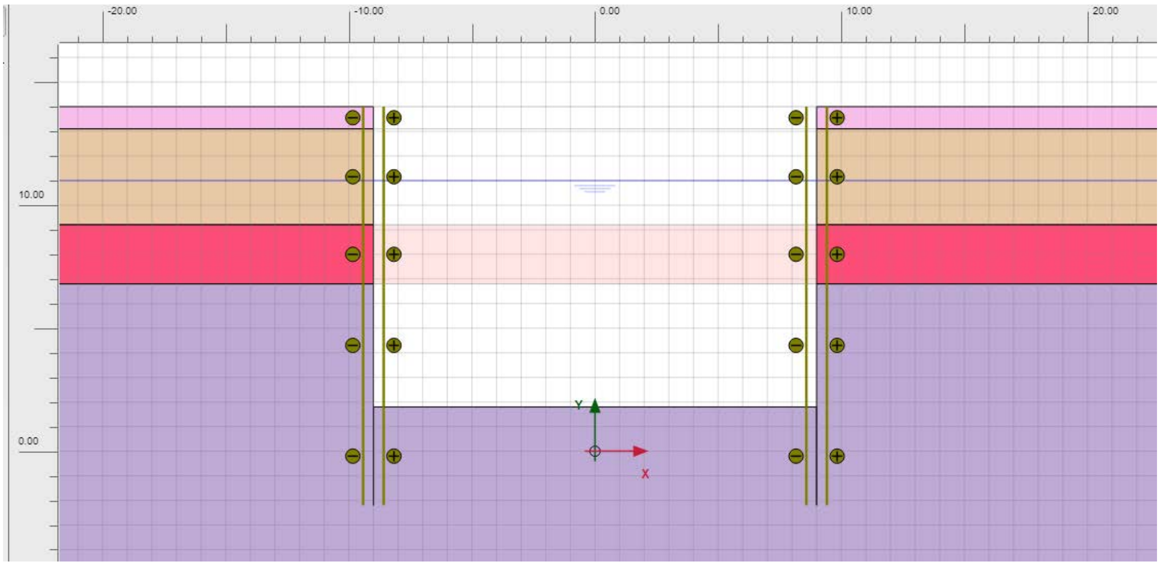


Figure 5-3. Illustration of Plaxis 2D Model. Seatown Station.

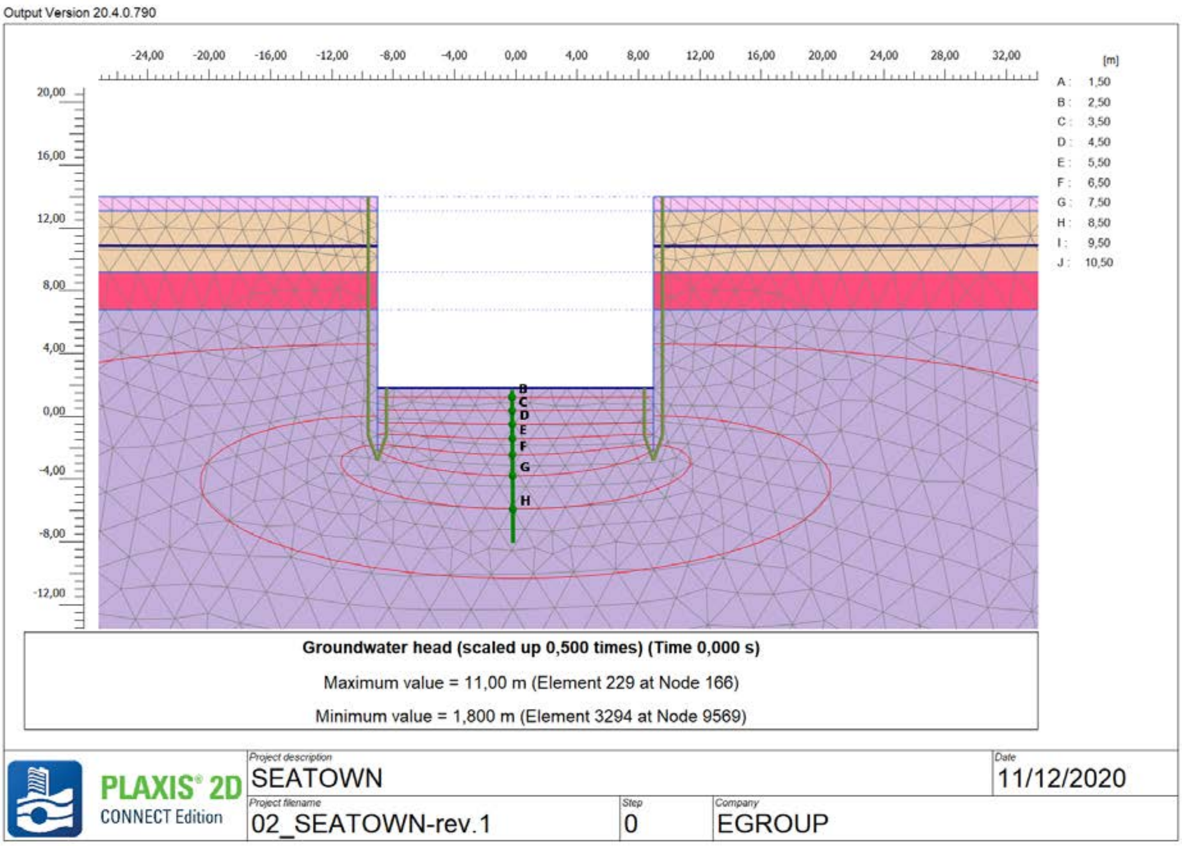


Figure 5-4. Illustration of groundwater head at Seatown Station.

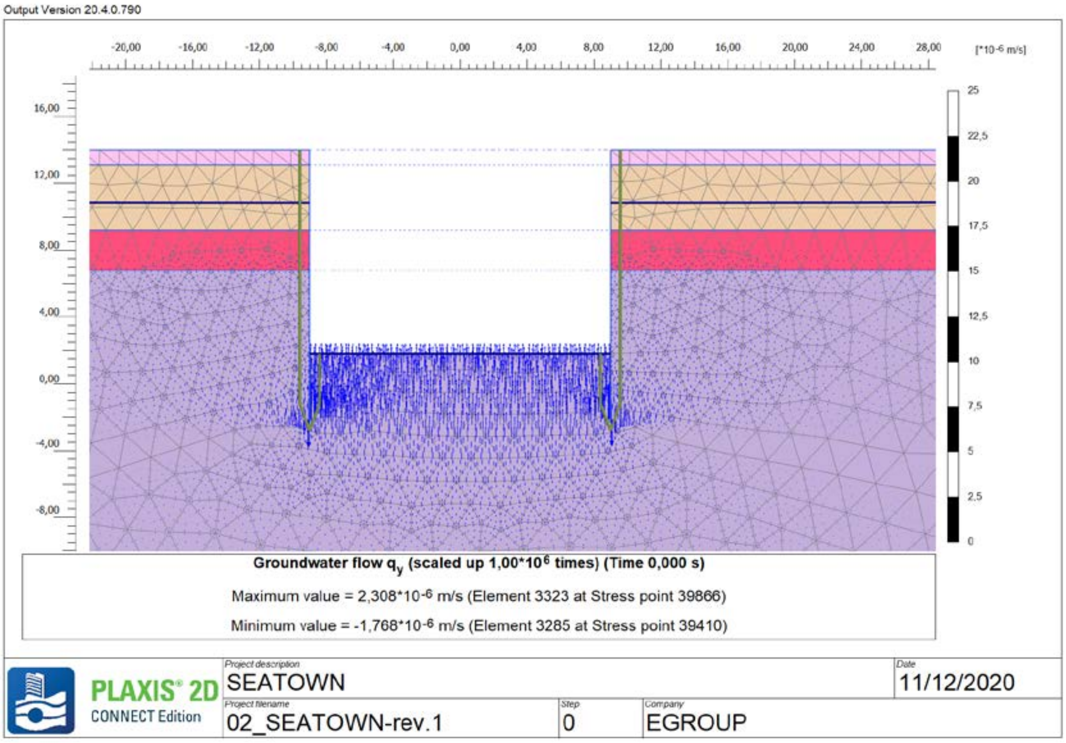


Figure 5-5. Groundwater flow (qy). Seatown Station.

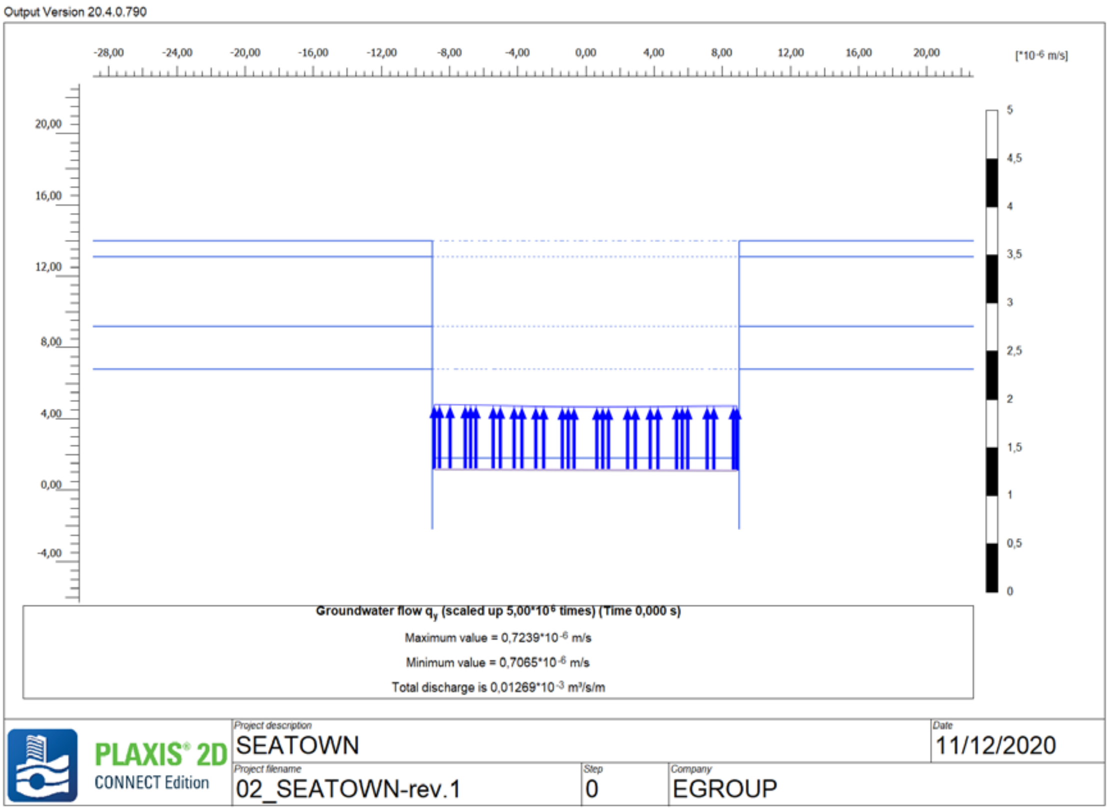


Figure 5-6. Water discharge ratio at the bottom of the excavation. Seatown Station.

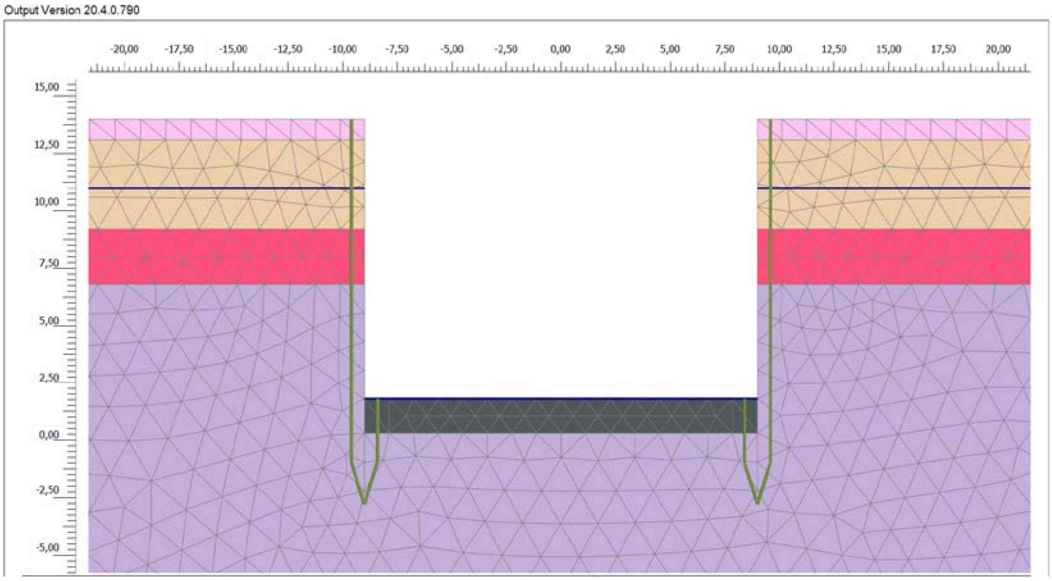


Figure 5-7. Bottom Plug geometry embedded in 2D model

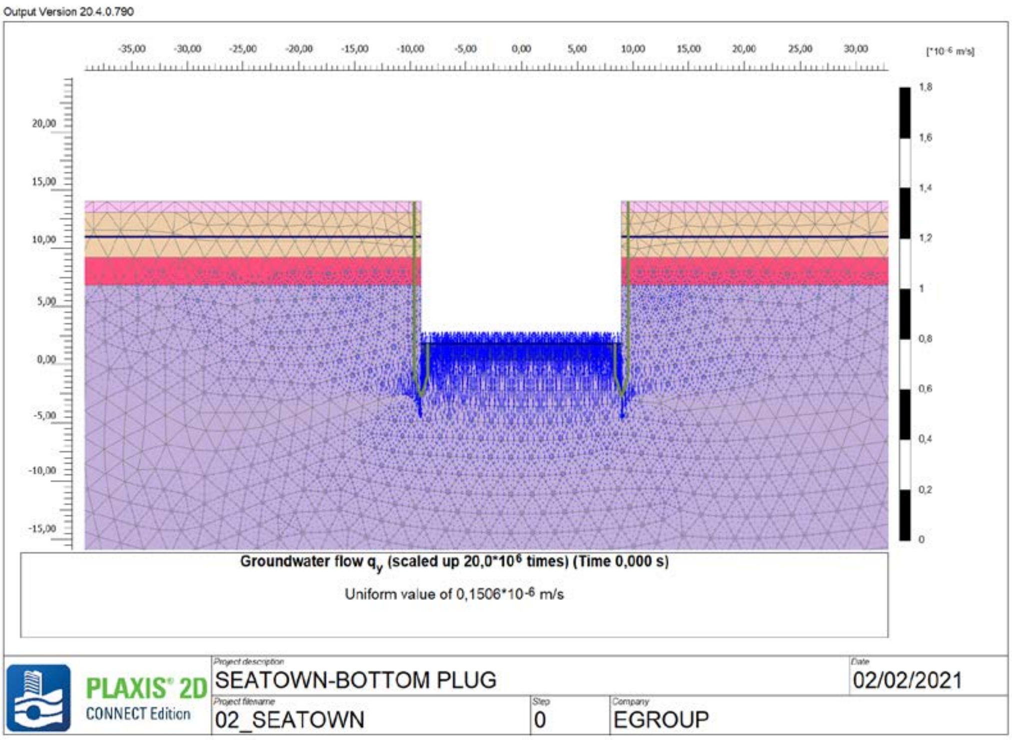


Figure 5-8. Groundwater flow (qy) with Bottom Plug. Seatown Station

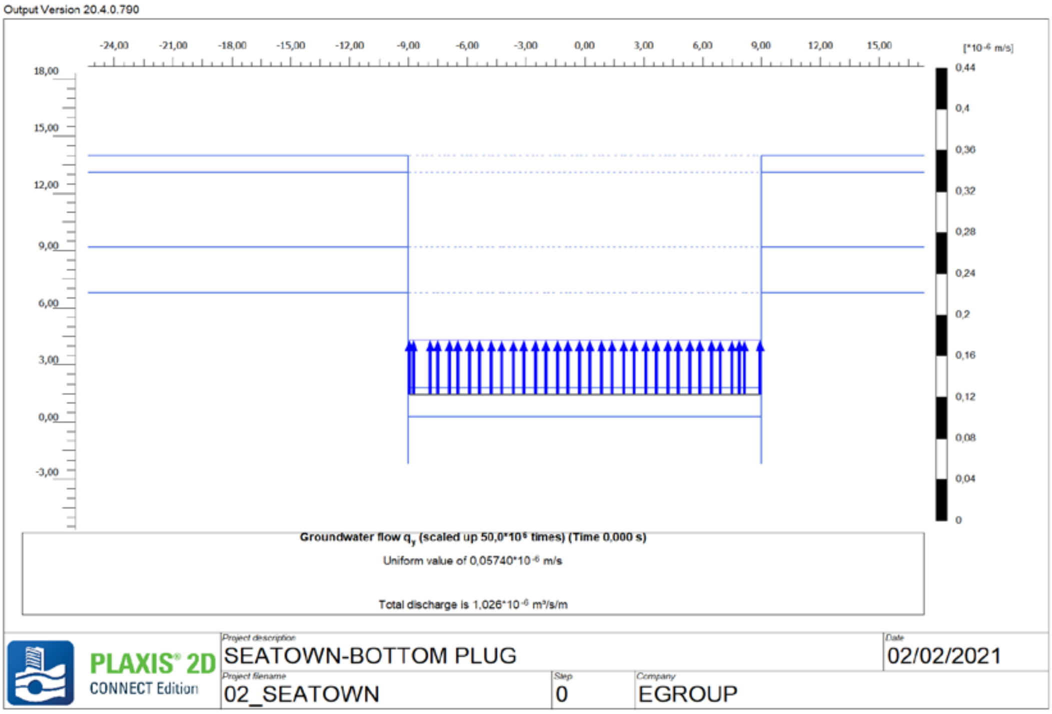


Figure 5-9. Water discharge ratio at the bottom of the excavation with Bottom Plug. Seatown Station.

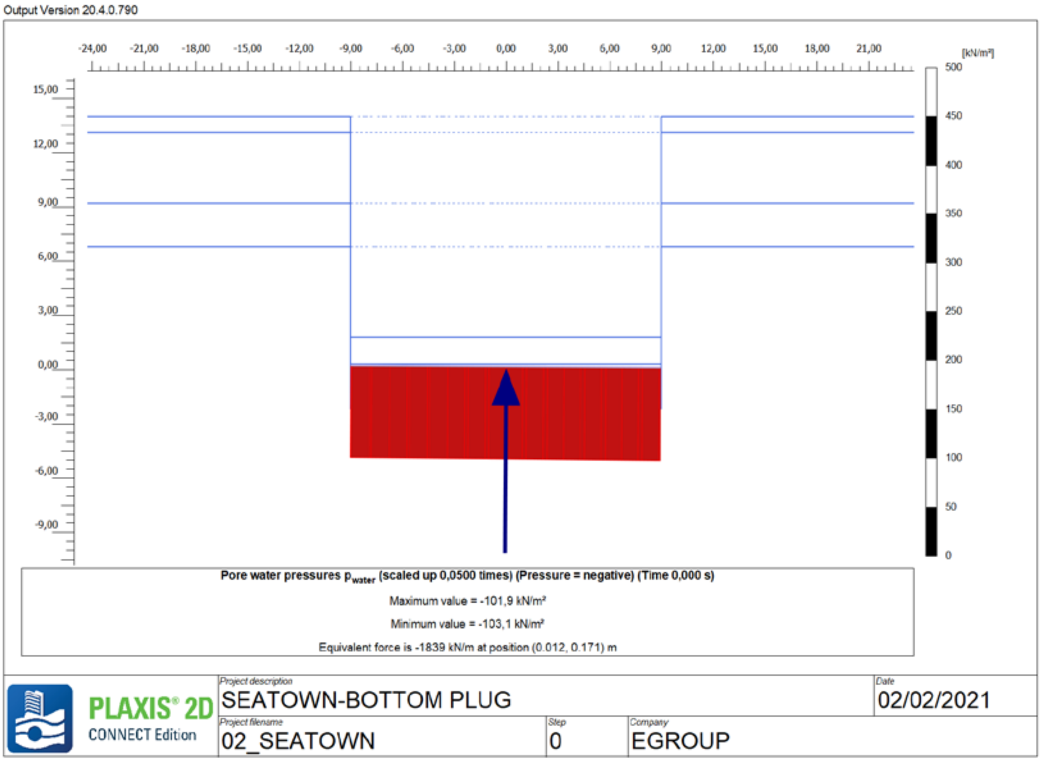


Figure 5-10. Pore water pressure under bottom plug. Seatown Station

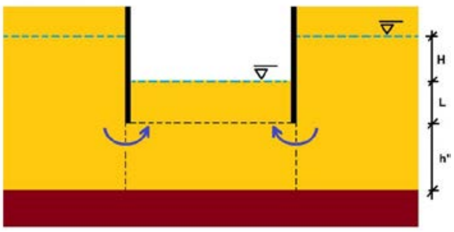
5.2 Swords central

N	STATION NAME	TOP	Qx	QBL<10 m	QBL<10 m sand	QBL < 10 m	QBL < 10 m sand	QBL < 10 m	QBL < 10 m sand	QBL < 10 m	QBL > 10 m	QBL > 10 m sand	BoD	CMLO
		Levels												
		(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
3	SWORDS CENTRAL	25	23,8	22,4	20,9	19,8	19,2	17	16	15	14	10,2	6,4	-1,59

Thickness	Qx	QBL < 10 m	QBL < 10 m sand	QBL < 10 m	QBL < 10 m sand	QBL < 10 m	QBL < 10 m sand	QBL < 10 m	QBL > 10 m	QBL > 10 m sand	BoD	CMLO
	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
	0	1,4	1,5	1,1	0,6	2,2	1	1	1	3,8	3,8	7,99

K(Permeability)	Qx	QBL < 10 m	QBL < 10 m sand	QBL < 10 m	QBL < 10 m sand	QBL < 10 m	QBL < 10 m sand	QBL < 10 m	QBL > 10 m	QBL > 10 m sand	BoD	CMLO
	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)
Kx	7,65E-07	7,21E-07	2,90E-06	7,21E-07	2,90E-06	7,21E-07	2,90E-06	7,21E-07	7,15E-07	8,59E-06	2,90E-04	1,38E-06
Kv	7,65E-07	7,21E-07	2,90E-06	7,21E-07	2,90E-06	7,21E-07	2,90E-06	7,21E-07	7,15E-07	8,59E-06	2,90E-04	1,38E-07

Exc.	W.L.
(m)	(m)
15	23,5



$$k_{II} = \frac{H}{\sum_{1}^{m} \frac{H_a}{k_a}}$$

$$h'_{min} = \frac{ab}{2(a+b)}$$

$$k_I = \frac{\sum_{i=1}^{n} k_i \cdot H_i}{H}$$

Kh	Kv	H	L	a	b	h´	Vol	ro	φ1	φ2	R	Rf	Qv (Dupuit formula)	Q Plaxis	Q Plaxis	Qt
(m/s)	(m/s)	(m)	(m)	(m)	(m)	(m)	(m3)	(m)	(m)	(m)	(m)	(m)	(m3/s/m)	(m3/s/m)	(m3/d/m)	(m3/d)
4,57E-05	3,69E-07	8,50	9,00	18,00	97,00	7,59	1,48E+04	23,57	53,50	45,00	51,68	56,80	5,44E-06	7,11E-06	0,61	59,59

WITH BOTTON PLUG			
Q Plaxis	Q Plaxis	Qt	Water pressure under grout slab
(m3/s/m)	(m3/d/m)	(m3/d)	(kN/m2)
9,00E-07	0,08	7,54	91,21

Figure 5-11. Summary of results. Swords Central Station.

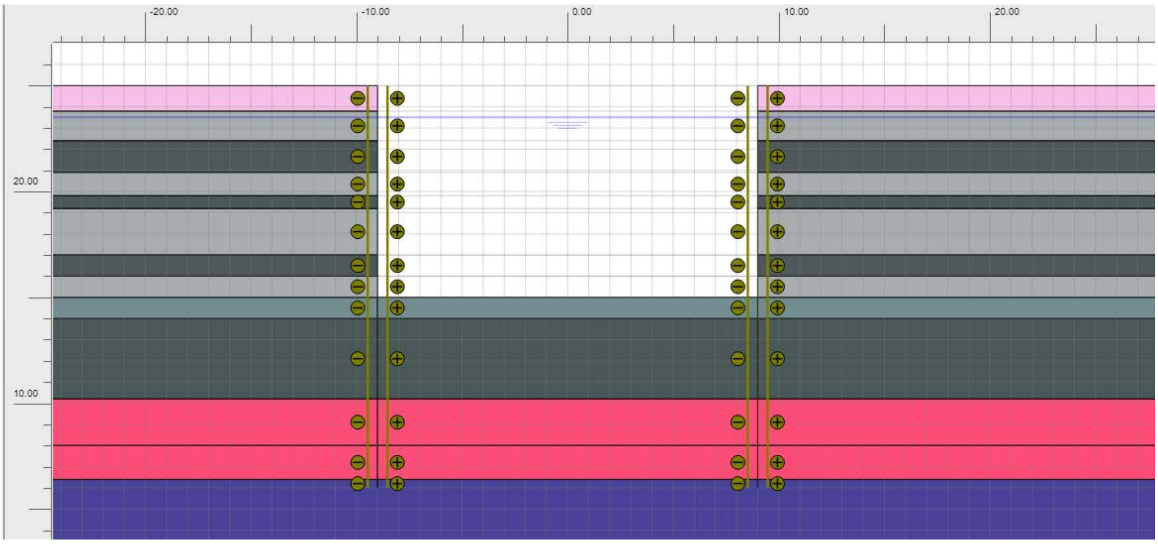


Figure 5-12. Illustration of Plaxis 2D Model. Swords Central Station.

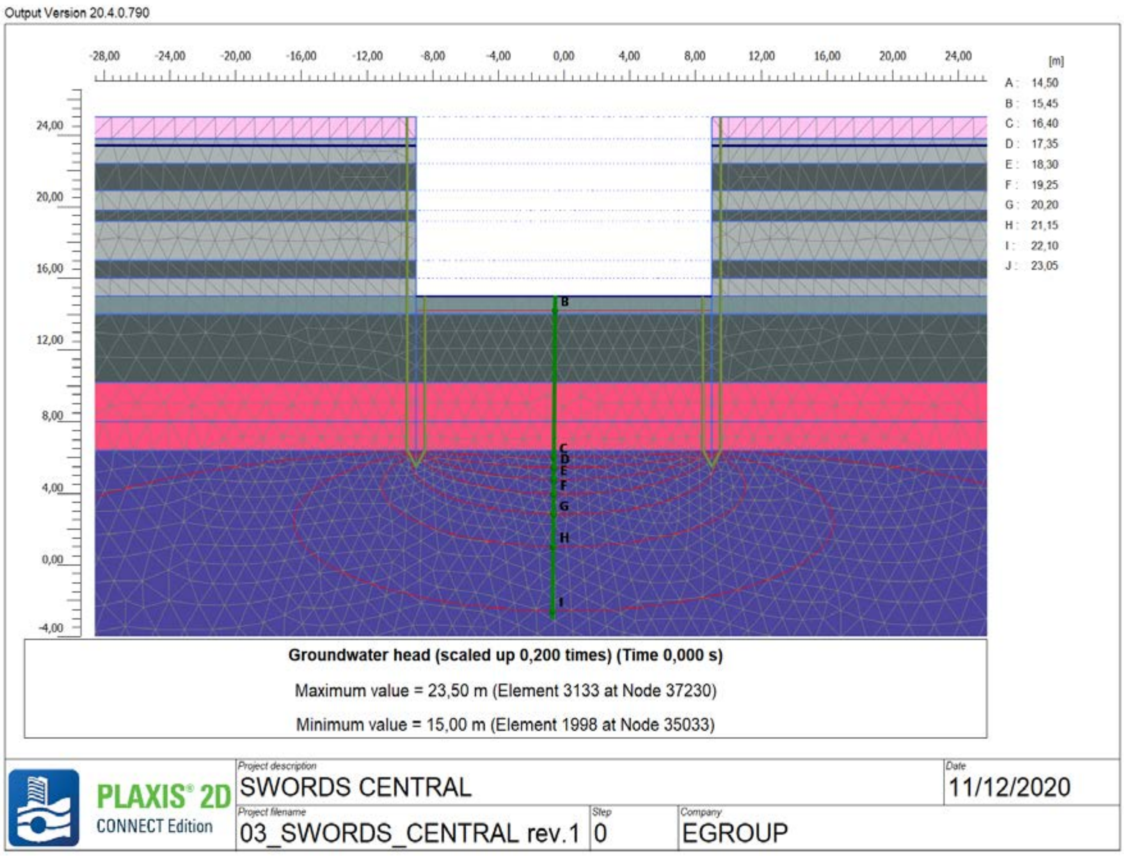


Figure 5-13. Illustration of groundwater head. Swords Central Station.

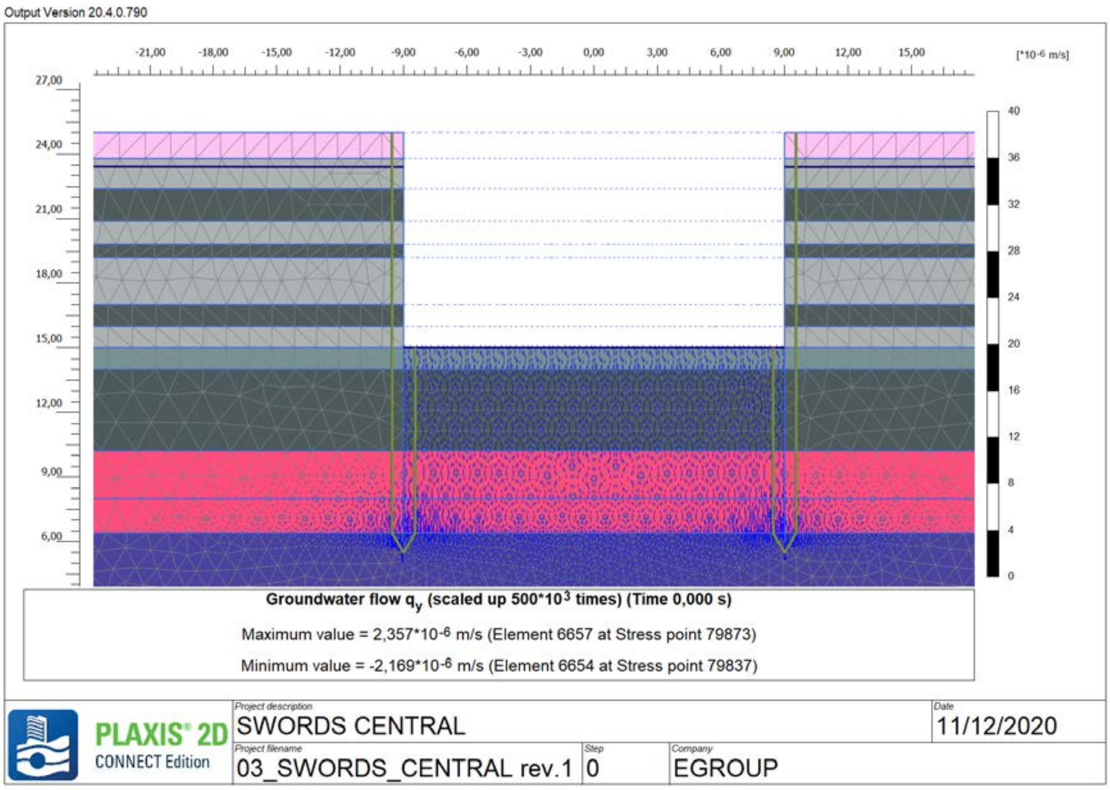


Figure 5-14. Illustration of groundwater flow. Swords Central Station.

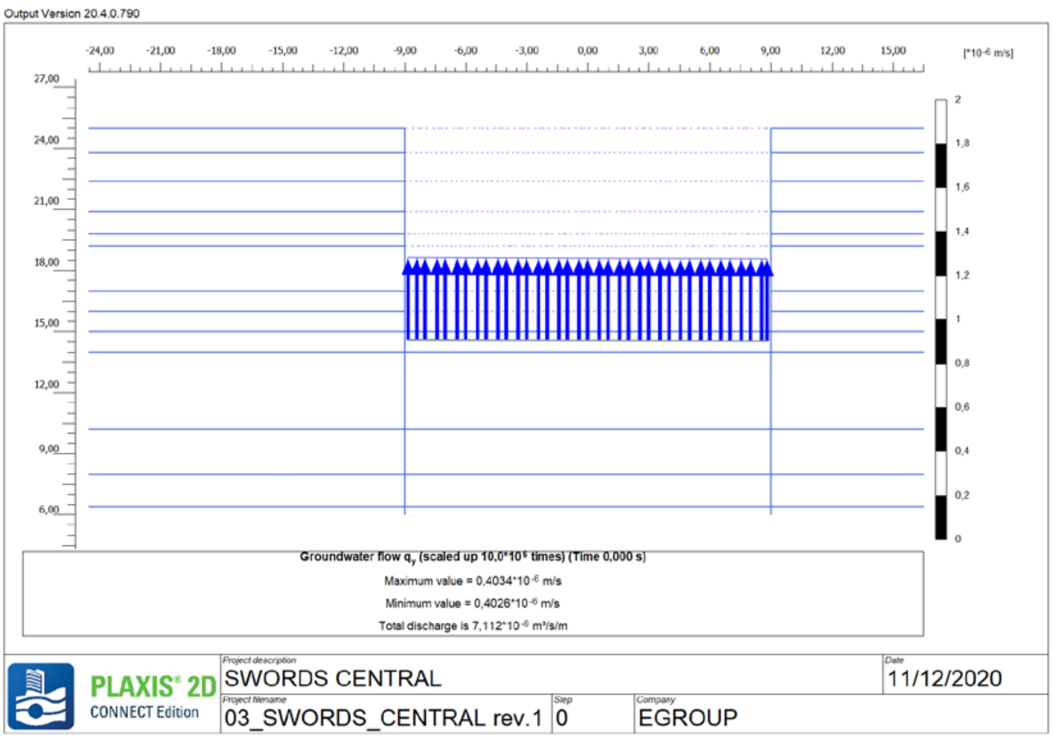


Figure 5-15. Water discharge ratio at the bottom of the excavation. Swords Central Station.

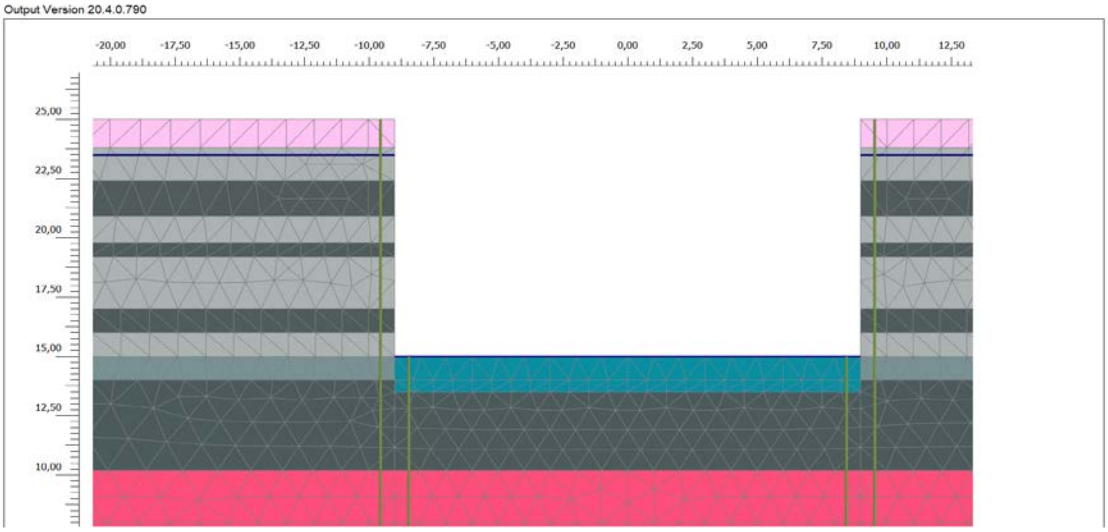


Figure 5-16. Bottom Plug geometry embedded in 2D model. Swords Central Station.

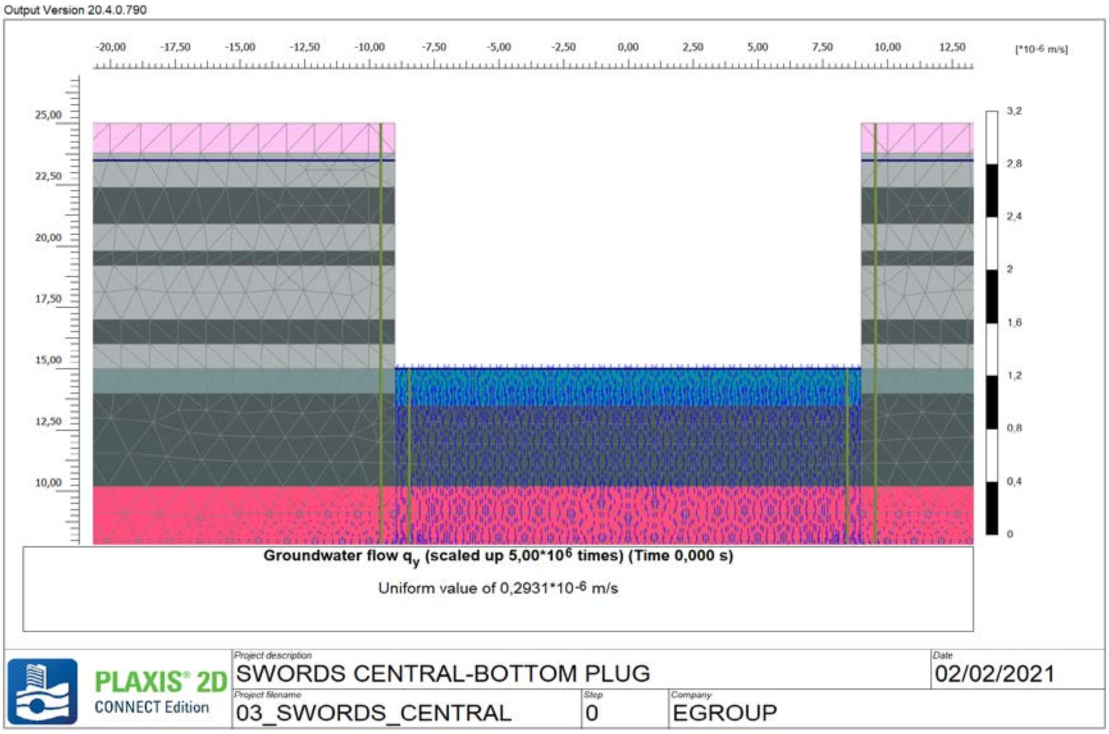


Figure 5-. Groundwater flow (qy) with Bottom Plug. Swords Central Station.

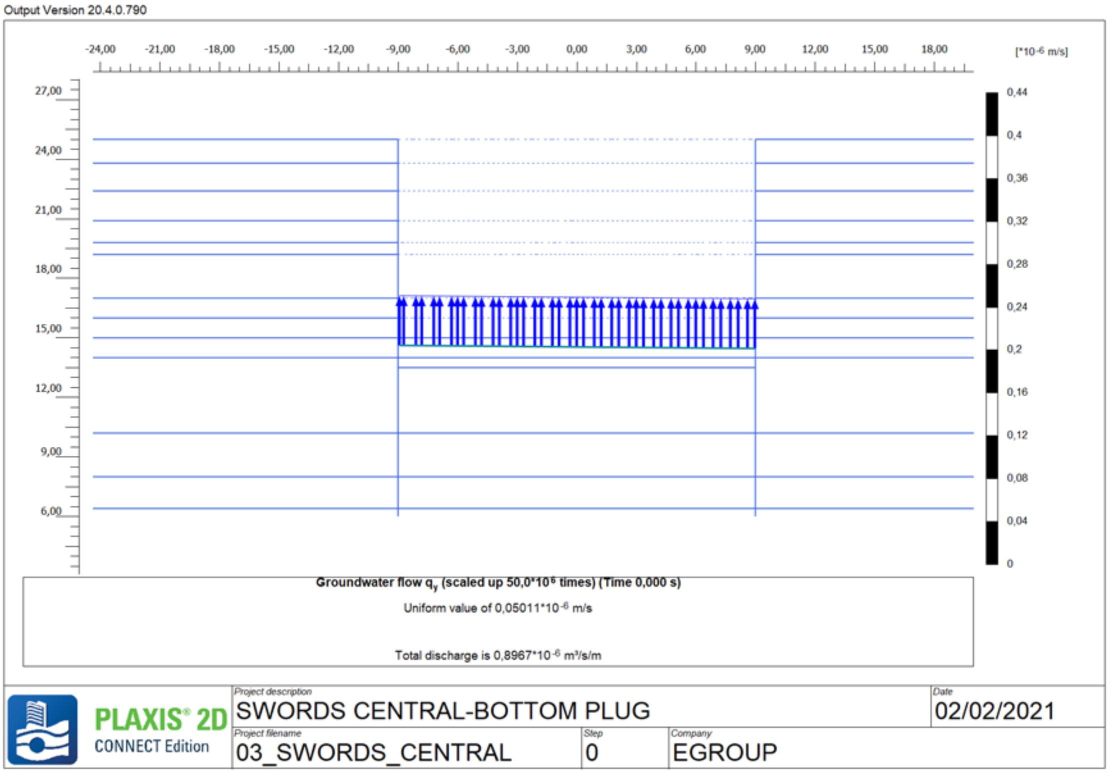


Figure 5-17. Water discharge ratio at the bottom of the excavation with Bottom Plug. Swords Central Station.

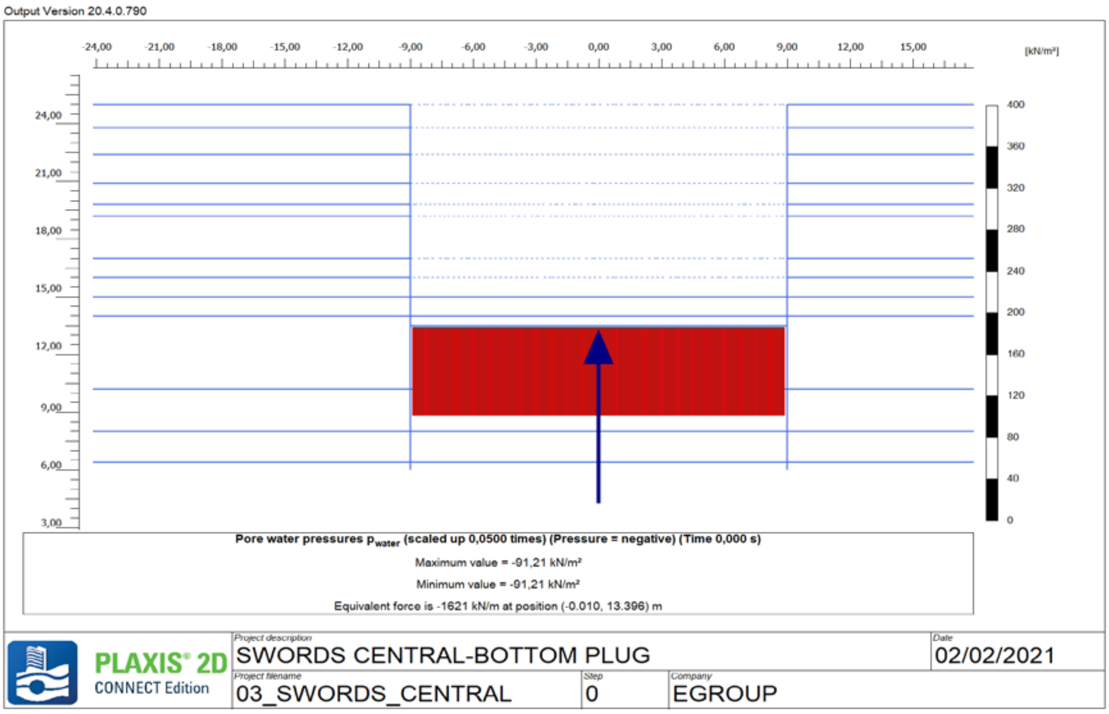


Figure 5-18. Pore water pressure under Bottom Plug. Swords Central Station.

5.3 Fosterstown

N	STATION NAME	Level TOP	Qx	QBL<10 m	QBL<10 m sand	QBL<10 m	QBL<10 m sand	QBL<10 m	QBL<10 m sand	QBL<10 m	QBL<10 m sand	QBL<10 m	QBL>10 m
		(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
4	FOSTERSTOWN	45,00	44,20	43,40	43,00	41,60	41,40	39,50	39,30	37,75	37,45	36,00	35,60

thicknes	Qx	QBL<10 m	QBL<10 m sand	QBL<10 m	QBL<10 m sand	QBL<10 m	QBL<10 m sand	QBL<10 m	QBL<10 m sand	QBL<10 m	QBL>10 m
	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,77	0,30	1,45	0,40

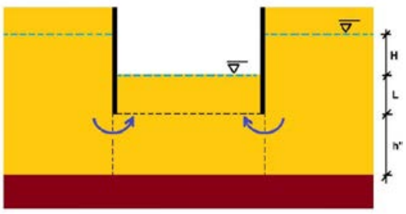
K(Perme	Qx	QBL<10 m	QBL<10 m sand	QBL<10 m	QBL<10 m sand	QBL<10 m	QBL<10 m sand	QBL<10 m	QBL<10 m sand	QBL<10 m	QBL>10 m
	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)
Kx	7,65E-07	7,21E-07	2,90E-06	7,21E-07	2,90E-06	7,21E-07	2,90E-06	7,21E-07	2,90E-06	7,21E-07	7,15E-07
Kv	7,65E-07	7,21E-07	2,90E-06	7,21E-07	2,90E-06	7,21E-07	2,90E-06	7,21E-07	2,90E-06	7,21E-07	7,15E-07

N	STATION NAME	Levels TOP	QBL>10 m sand	QBL>10 m	QBL>10 m sand	QBL>10 m	QBL>10 m sand	QBL>10 m	BoD	CMLO
		(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
4	FOSTERSTOWN	45,00	35,00	34,25	33,70	32,10	31,90	27,90	25,50	16,58

	QBL>10 m sand	QBL>10 m	QBL>10 m sand	QBL>10 m	QBL>10 m sand	QBL>10 m	BoD	CMLO
	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
	0,60	0,75	0,55	1,60	0,20	4,00	2,40	8,92

	QBL>10 m sand	QBL>10 m	QBL>10 m sand	QBL>10 m	QBL>10 m sand	QBL>10 m	BoD	CMLO
	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)
Kx	8,59E-06	7,15E-07	8,59E-06	7,15E-07	8,59E-06	7,15E-07	2,90E-04	1,38E-06
Kv	8,59E-06	7,15E-07	8,59E-06	7,15E-07	8,59E-06	7,15E-07	2,90E-04	1,38E-07

Exc.	W.L.
(m)	(m)
34	38,5



$$k_{II} = \frac{H}{\sum_{1}^{m} \frac{H_u}{k_u}}$$

$$h'_{min} = \frac{ab}{2(a+b)}$$

$$k_i = \frac{\sum_{i=1}^{n} k_i \cdot H_i}{H}$$

Kh	Kv	H	L	a	b	h´	Vol	ro	φ1	φ2	R	Rf	Qv (Dupuit formula)	Q Plaxis	Q Plaxis	Qt Plaxis
(m/s)	(m/s)	(m)	(m)	(m)	(m)	(m)	(m3)	(m)	(m)	(m)	(m)	(m)	(m3/s/m)	(m3/s/m)	(m3/d/m)	(m3/d)
3,31E-05	2,83E-07	4,50	9,00	21,00	85,00	8,42	8,03E+03	23,84	48,50	44,00	23,63	33,57	3,51E-06	3,00E-06	0,26	22,03

WITH BOTTON PLUG			
Q Plaxis	Q Plaxis	Qt Plaxis	Water pressure under grout slab
(m3/s/m)	(m3/d/m)	(m3/d)	(kN/m2)
5,20E-07	0,04	3,82	53,00

Figure 5-19. Summary of results. Fosterstown Station.

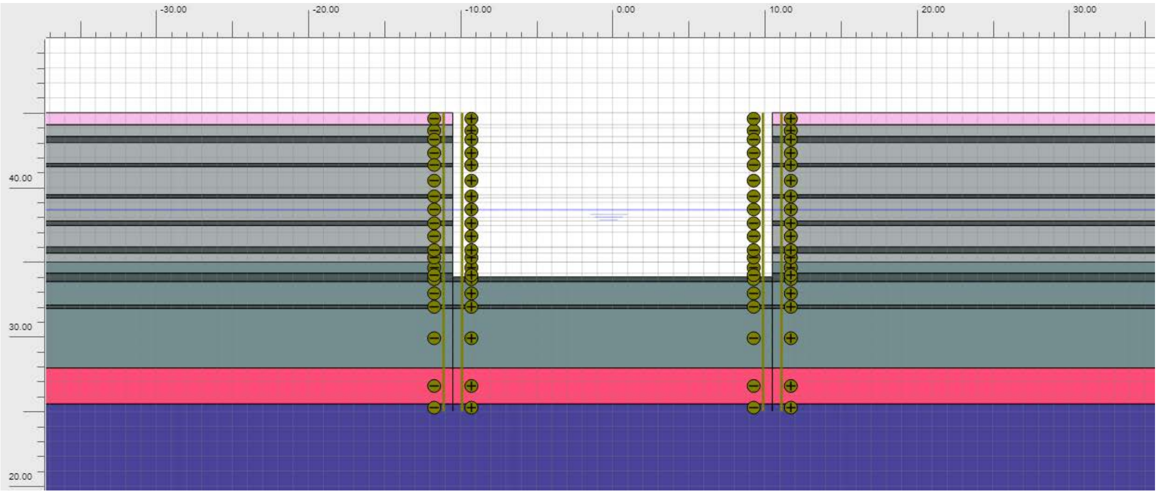


Figure 5-20. Illustration of Plaxis 2D Model. Fosterstown Station.

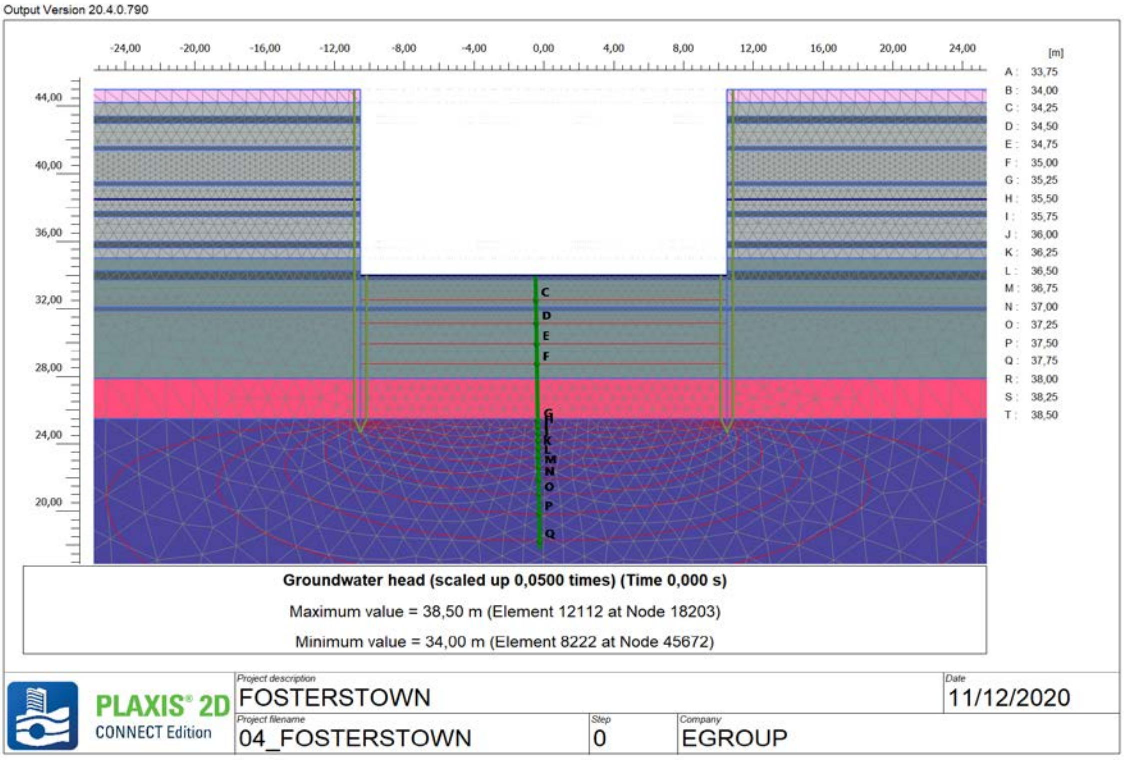


Figure 5-21. Illustration of groundwater head. Fosterstown Station.

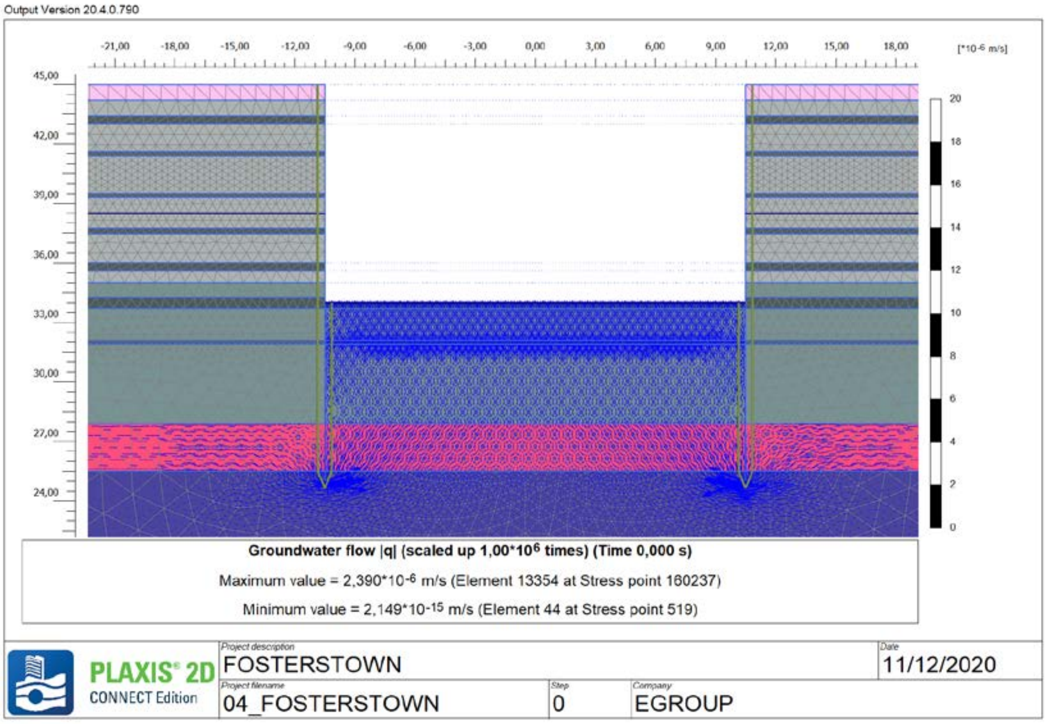


Figure 5-22. Illustration of groundwater flow. Fosterstown Station.

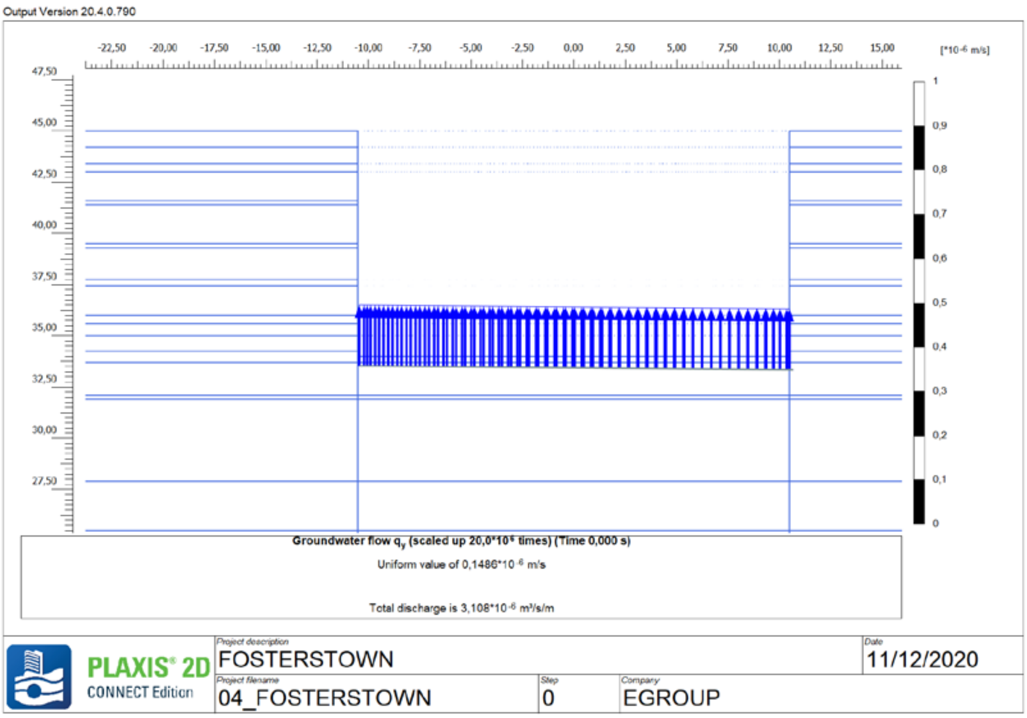


Figure 5-23. Water discharge ratio at the bottom of the excavation. Fosterstown Station.

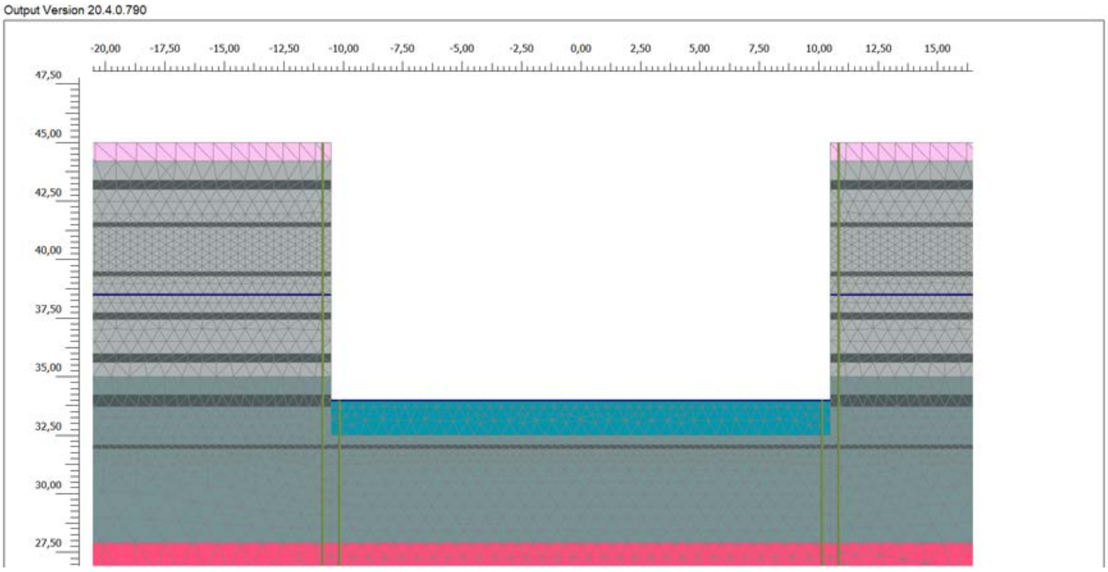


Figure 5-24. Bottom Plug geometry embedded in 2D model. Fosterstown Station.

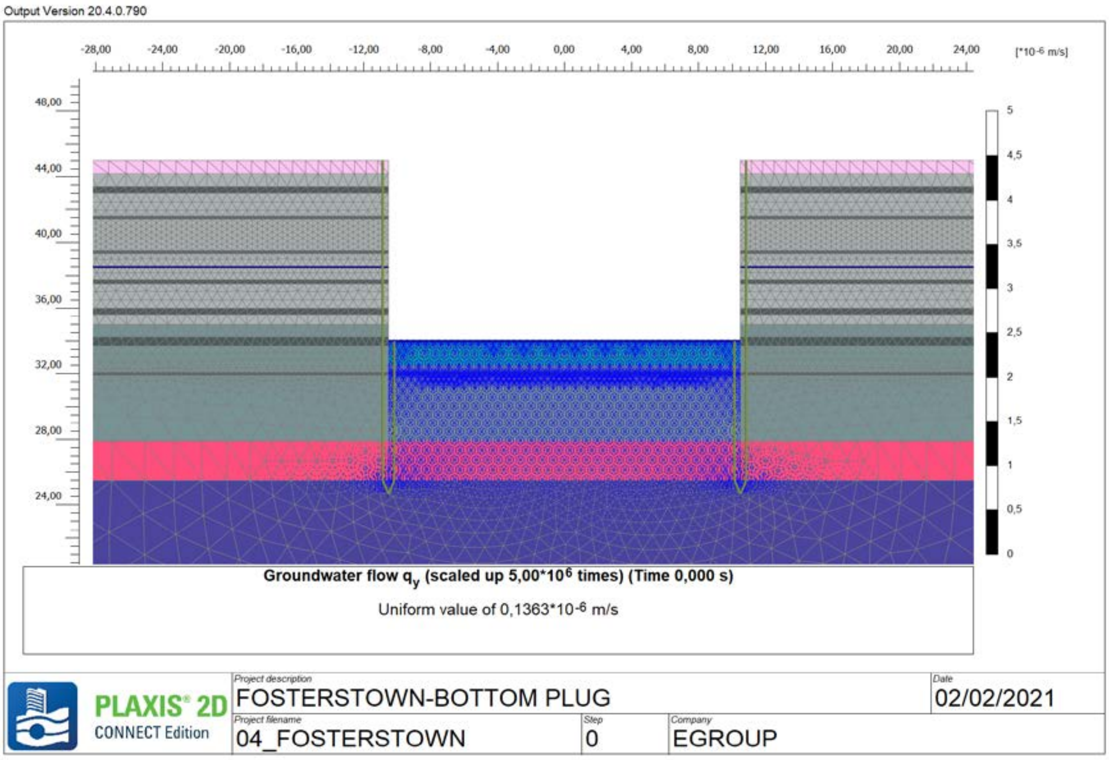


Figure 5-25. Groundwater flow (qy) with Bottom Plug. Fosterstown Station.

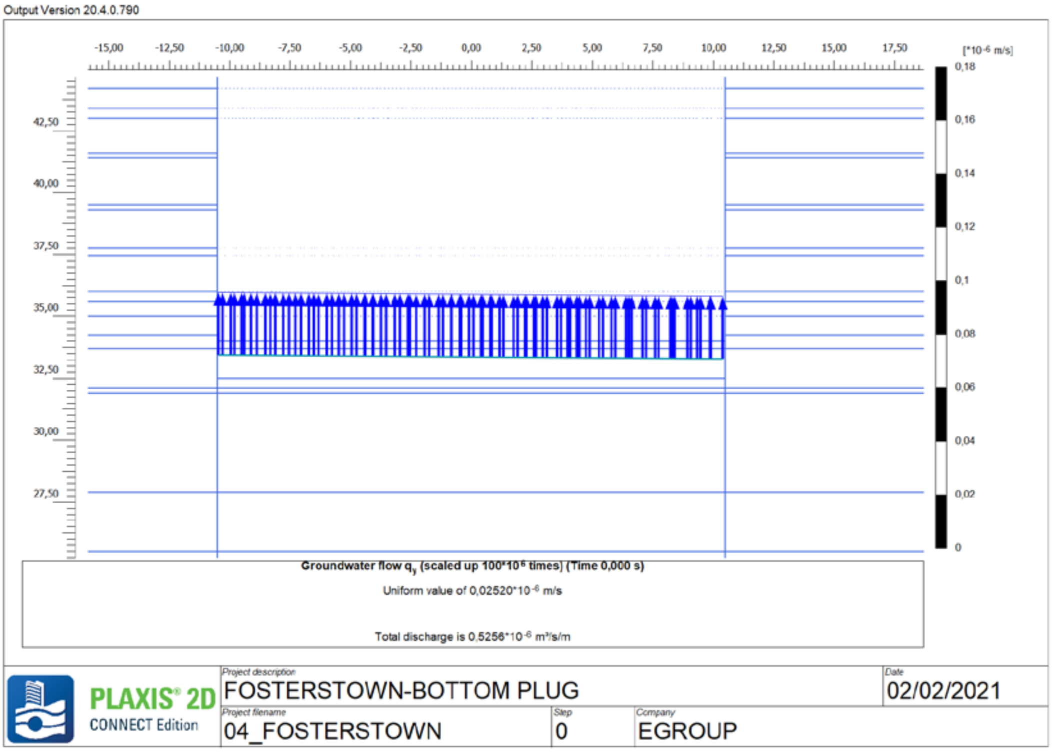


Figure 5-26. Water discharge ratio at the bottom of the excavation with Bottom Plug. Fosterstown Station.

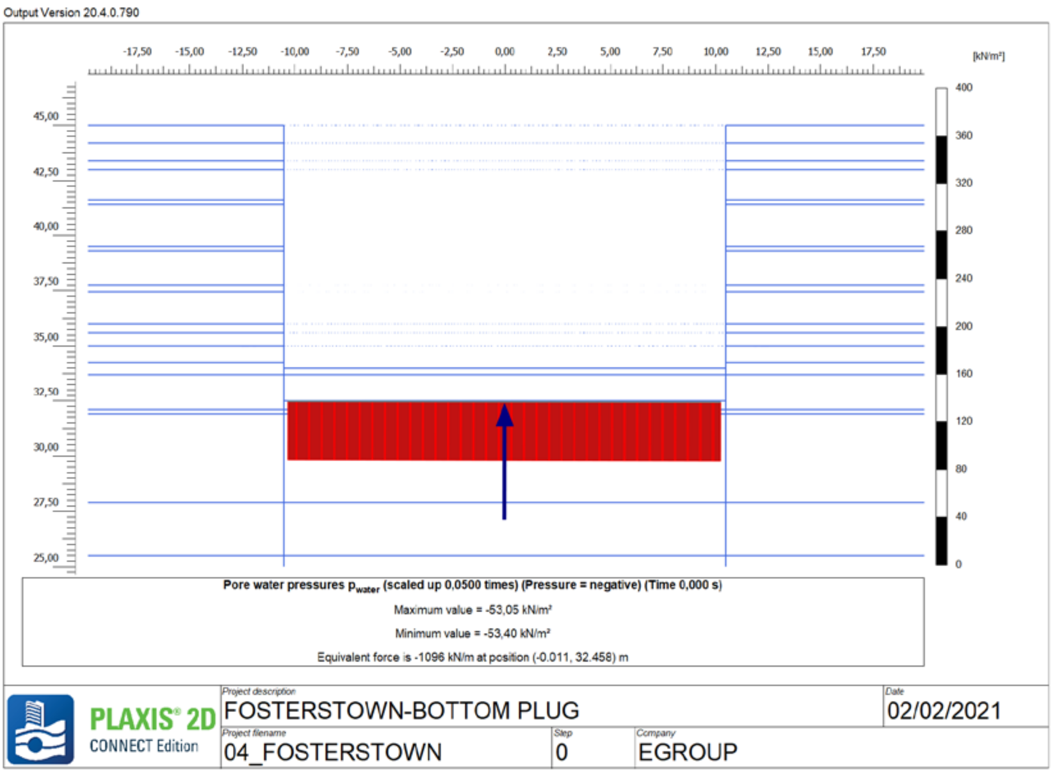


Figure 5-27. Pore water pressure under bottom plug. Fosterstown Station.

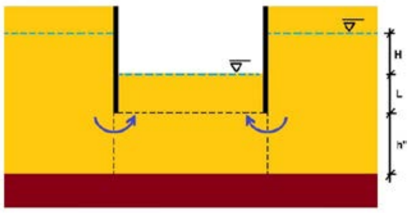
5.4 Dublin airport

N	STATION NAME	Levels				
		TOP (m)	Qx (m)	QBL<10 m (m)	BoD (m)	CWA (m)
5	DUBLIN AIRPORT	67,5	65	62,5	60	25,39

thickness			
Qx (m)	QBL<10 m (m)	BoD (m)	CWA (m)
0	2,5	2,5	34,61

K(Permeability)				
	Qx (m/s)	QBL<10 m (m/s)	BoD (m/s)	CWA (m/s)
Kx	7,65E-07	7,21E-07	2,90E-04	5,69E-07
Kv	7,65E-07	7,21E-07	2,90E-04	5,69E-08

Exc. (m)	W.L. (m)
39,8	64,5



$$k_{II} = \frac{H}{\sum_{1}^{m} \frac{H_a}{k_a}}$$

$$h'_{min} = \frac{ab}{2(a+b)}$$

$$k_I = \frac{\sum_{i=1}^{n} k_i \cdot H_i}{H}$$

Kh (m/s)	Kv (m/s)	H (m)	L (m)	a (m)	b (m)	h´ (m)	Vol (m3)	ro (m)	φ1 (m)	φ2 (m)	R (m)	Rf (m)	Qv (Dupuit formula) (m3/s/m)	Q Plaxis (m3/s/m)	Q Plaxis (m3/d/m)	Qt (m3/d)
1,88E-05	6,47E-08	24,70	4,80	23,00	117,00	9,61	6,65E+04	29,27	54,50	29,80	77,88	83,20	1,62E-06	3,24E-06	0,28	32,75

WITH BOTTON PLUG			
Q Plaxis (m3/s/m)	Q Plaxis (m3/d/m)	Qt (m3/d)	Water pressure under grout slab (kN/m2)
1,88E-06	0,16	19,00	142,00

Figure 5-28. Summary of results. Dublin Airport Station.

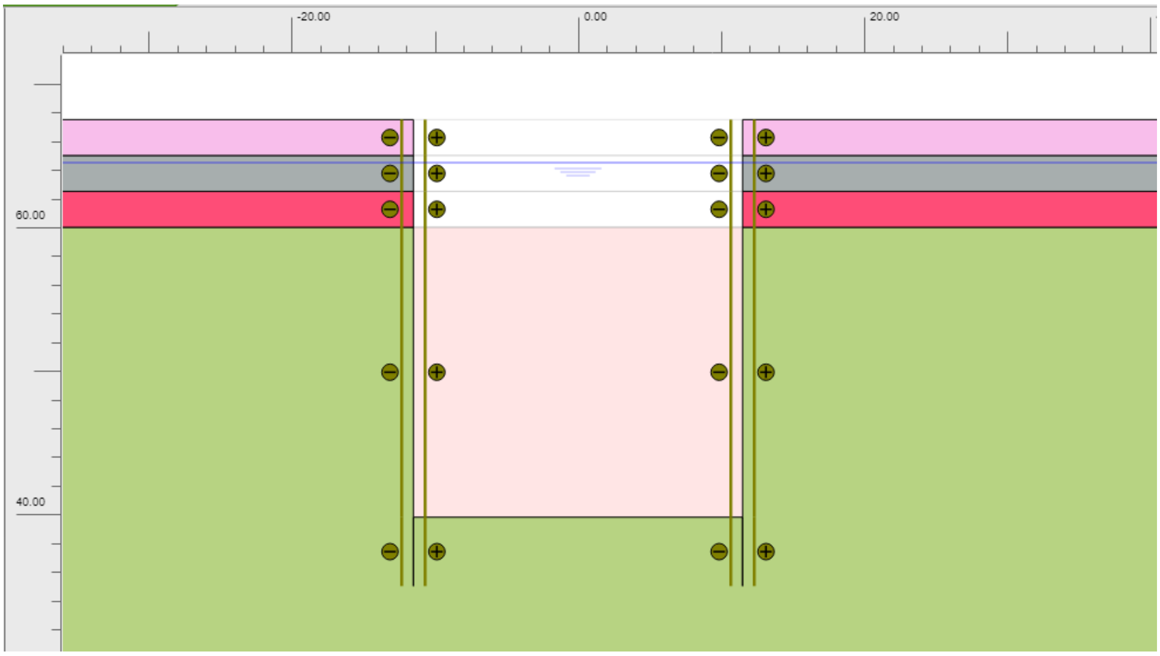


Figure 5-29. Illustration of Plaxis 2D Model. Dublin Airport Station.

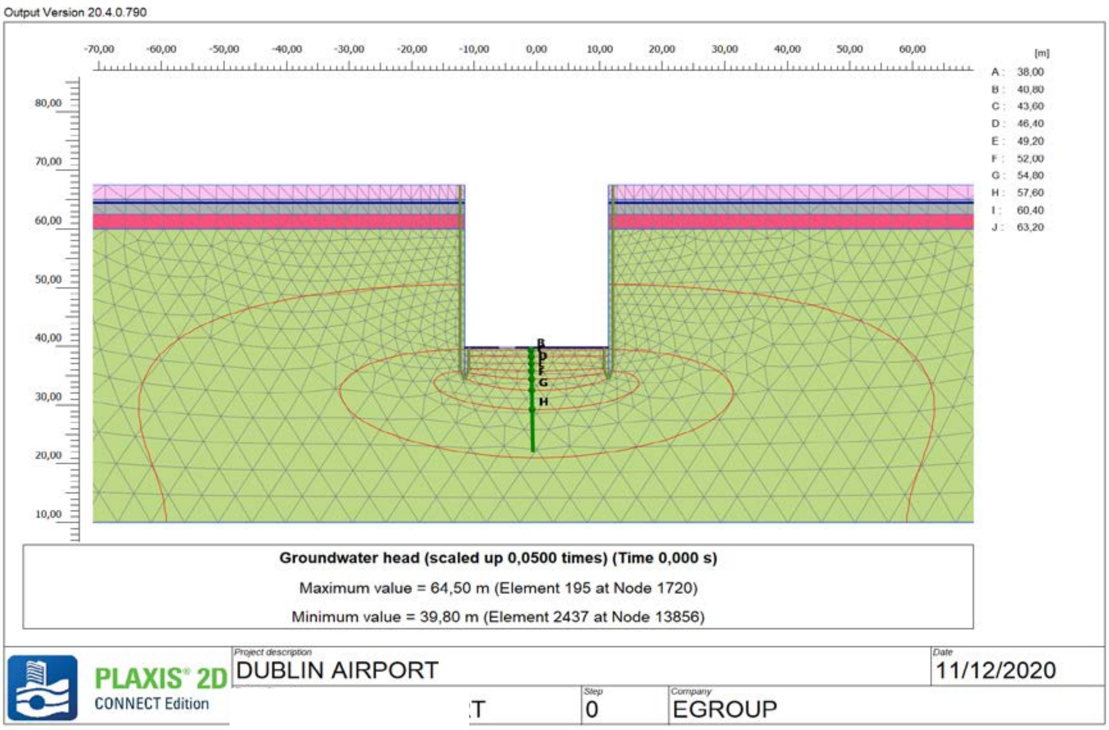


Figure 5-30. Illustration of groundwater head. Dublin Airport Station.

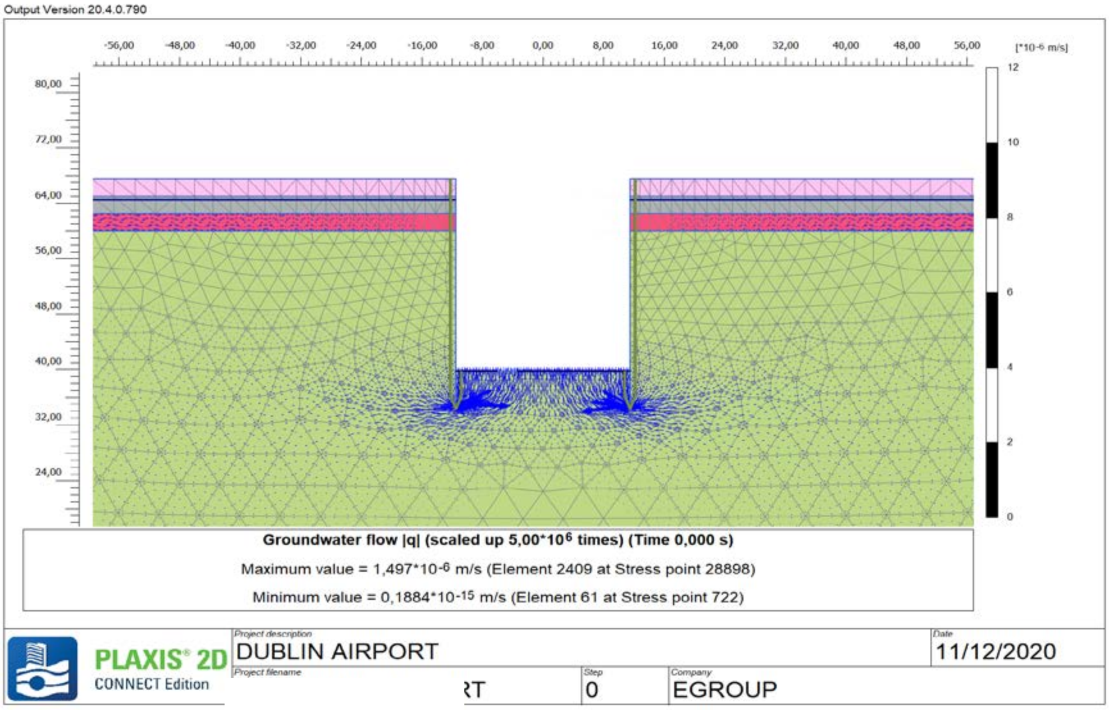


Figure 5-31. Illustration of groundwater flow. Dublin Airport Station.

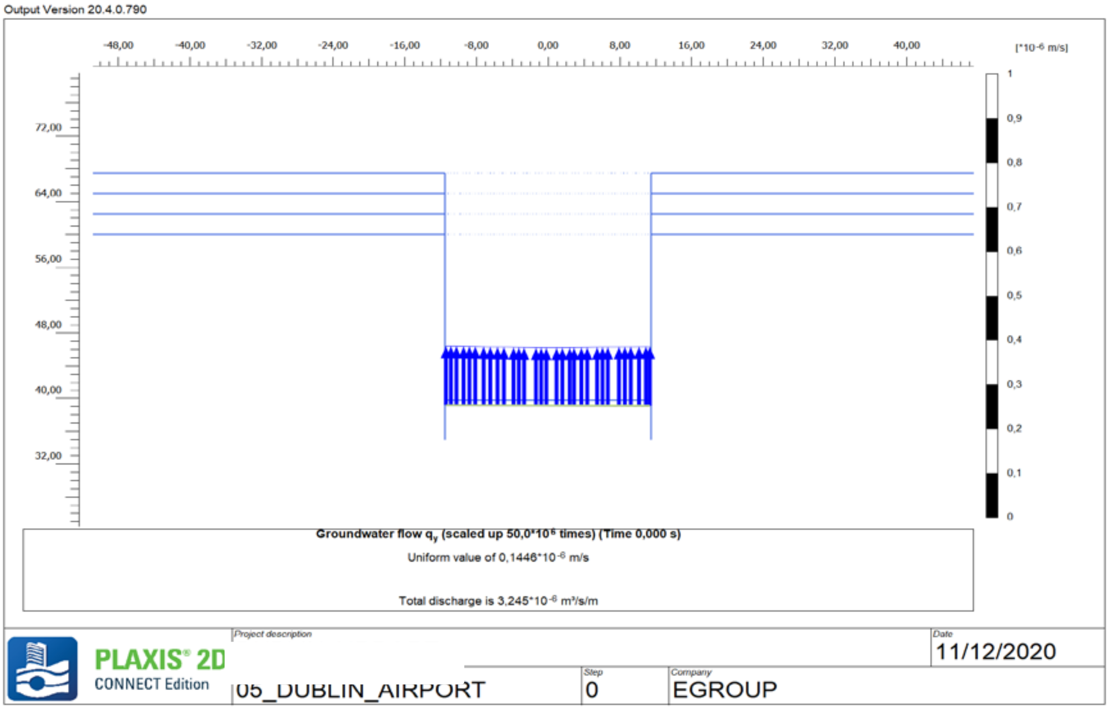


Figure 5-32. Water discharge ratio at the bottom of the excavation. Dublin Airport Station.

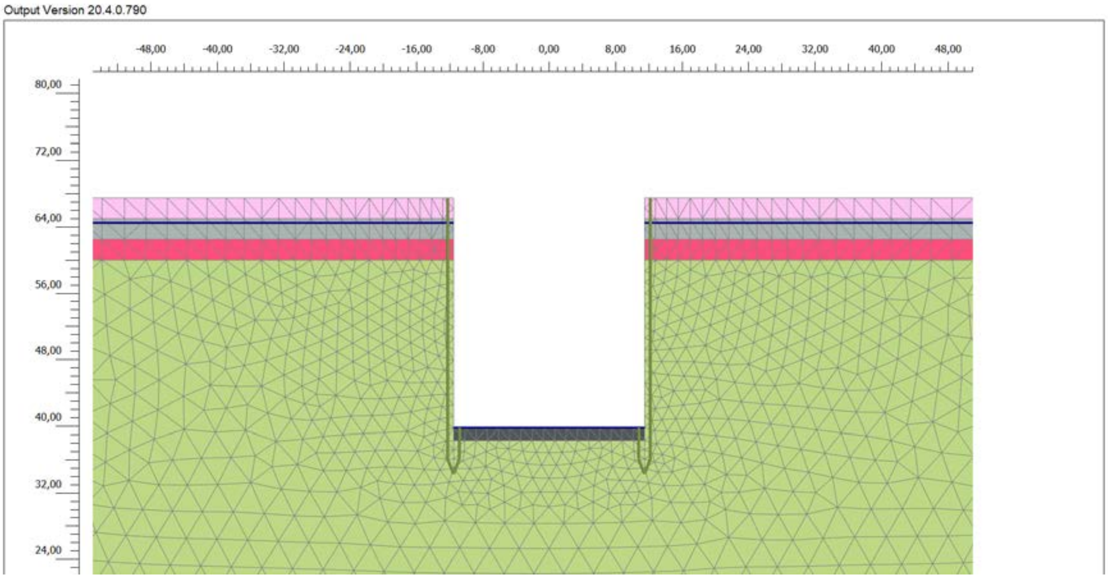


Figure 5-33. Bottom Plug geometry embedded in 2D model. Dublin Airport Station.

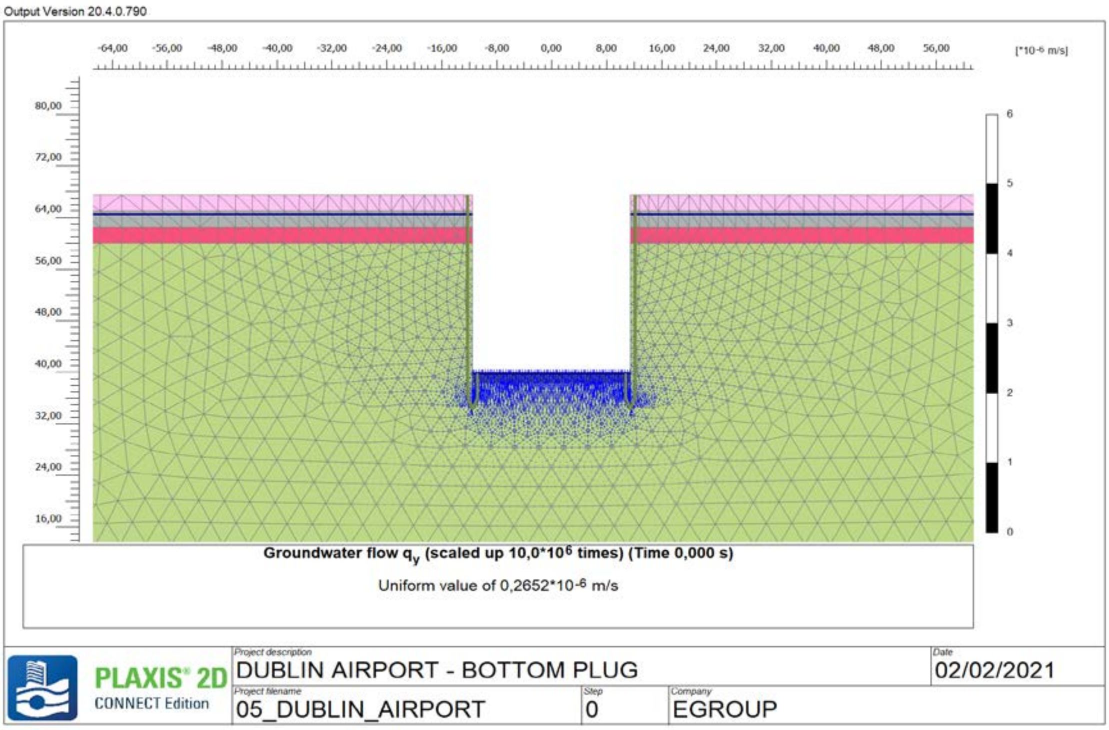


Figure 5-34. Groundwater flow (qy) with Bottom Plug. Dublin Airport Station.

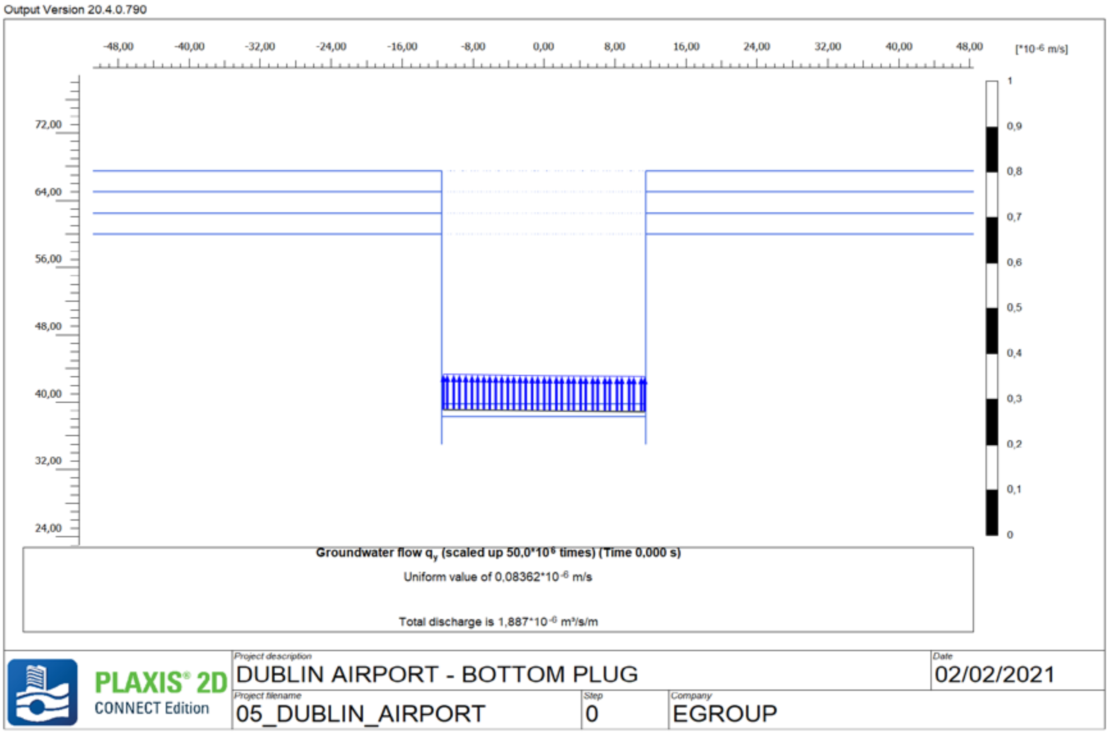


Figure 5-35. Water discharge ratio at the bottom of the excavation with Bottom Plug. Dublin Airport Station.

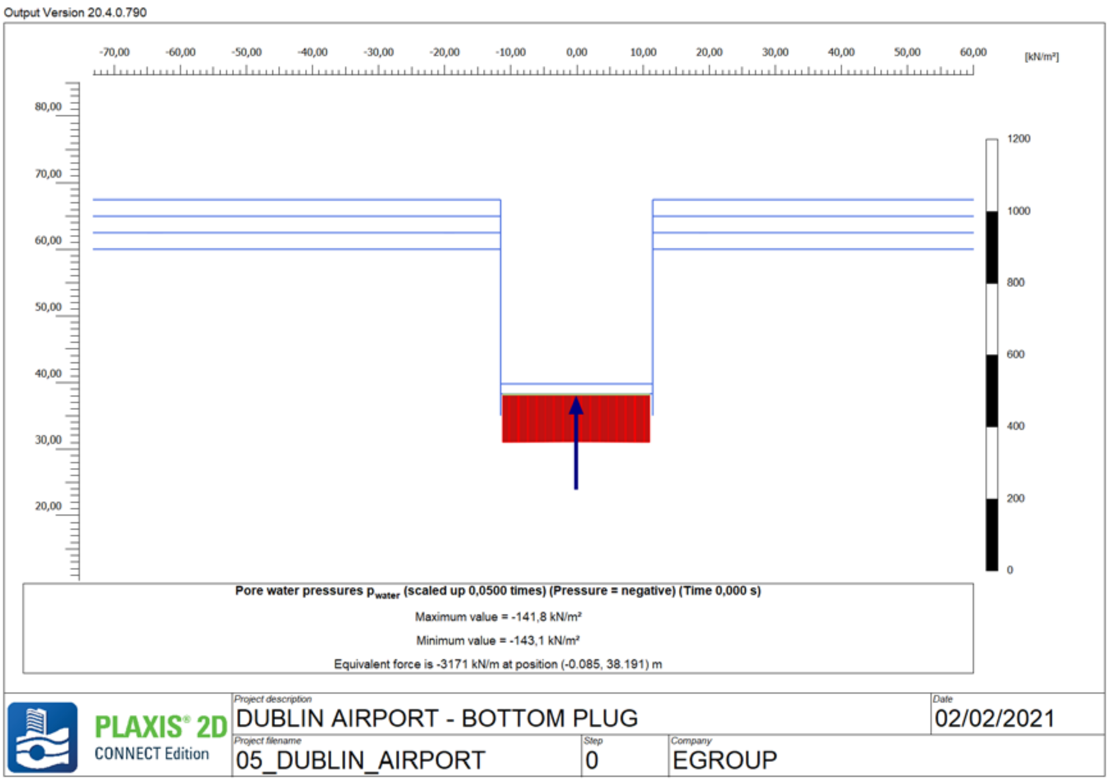


Figure 5-36. Pore water pressure under Bottom Plug. Dublin Airport Station.

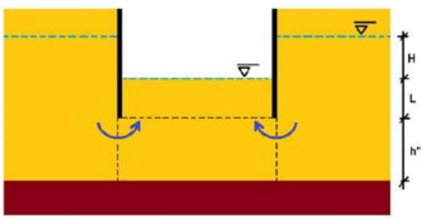
5.5 Dardistown

N	STATION NAME	TOP (m)	Qx (m)	QBL<10 m (m)	QBL > 10 m (m)	QBL > 10 m sand (m)	BoD (m)	CTO (m)
6	DARDISTOWN	61,50	60,00	51,50	48,30	45,30	41,00	37,20

Thickness					
Qx (m)	QBL<10 m (m)	QBL > 10 m (m)	QBL > 10 m sand (m)	BoD (m)	CTO (m)
0,00	0,50	3,20	3,00	4,30	3,80

K(Permeability)	Qx (m/s)	QBL<10 m (m/s)	QBL > 10 m (m/s)	QBL > 10 m sand (m/s)	BoD (m/s)	CTO (m/s)
Kx	7,65E-07	7,21E-07	7,15E-07	8,59E-06	2,90E-04	1,40E-06
Kv	7,65E-07	7,21E-07	7,15E-07	8,59E-06	2,90E-04	1,40E-07

Exc. (m)	W.L. (m)
51	52



$$k_{II} = \frac{H}{\sum_{1}^{m} \frac{H_{\alpha}}{k_{\alpha}}}$$

$$h'_{min} = \frac{ab}{2(a+b)}$$

$$k_I = \frac{\sum_{i=1}^{n} k_i \cdot H_i}{H}$$

Kh (m/s)	Kv (m/s)	H (m)	L (m)	a (m)	b (m)	h´ (m)	Vol (m3)	ro (m)	φ1 (m)	φ2 (m)	R (m)	Rf (m)	Qv (Dupuit formula) (m3/s/m)	Q Plaxis (m3/s/m)	Q Plaxis (m3/d/m)	Qt (m3/d)
8,65E-05	4,53E-07	1,00	5,00	23,00	75,00	8,80	1,73E+03	23,43	62,00	61,00	7,51	24,61	2,26E-06	5,30E-06	0,46	34,34

Q Plaxis (m3/s/m)	Q Plaxis (m3/d/m)	Qt (m3/d)	Water pressure under grout slab (kN/m2)
1,50E-07	0,01	0,97	25,75

Figure 5-37. Summary of results. Dardistown Station.

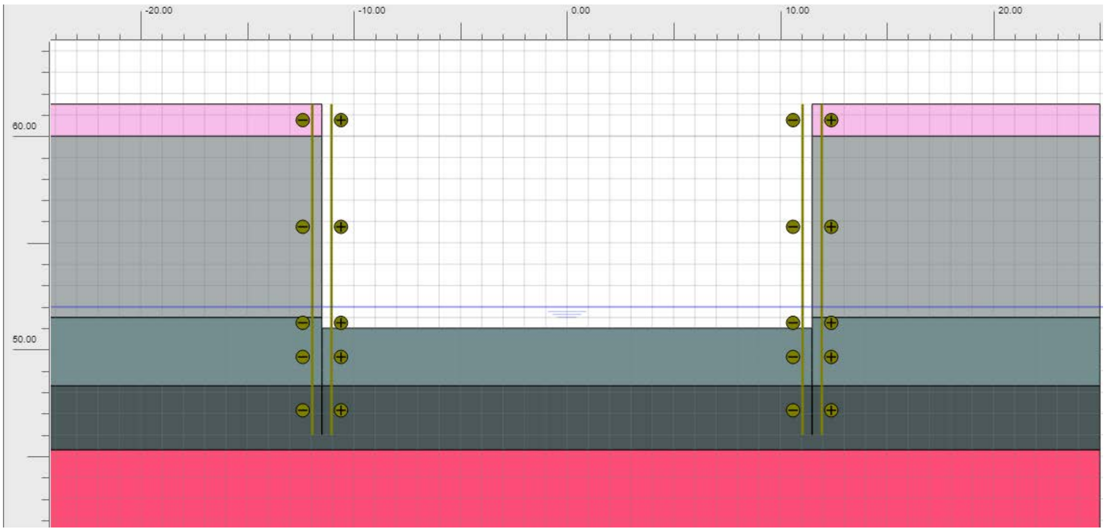


Figure 5-38. Illustration of Plaxis 2D Model. Dardistown Station.

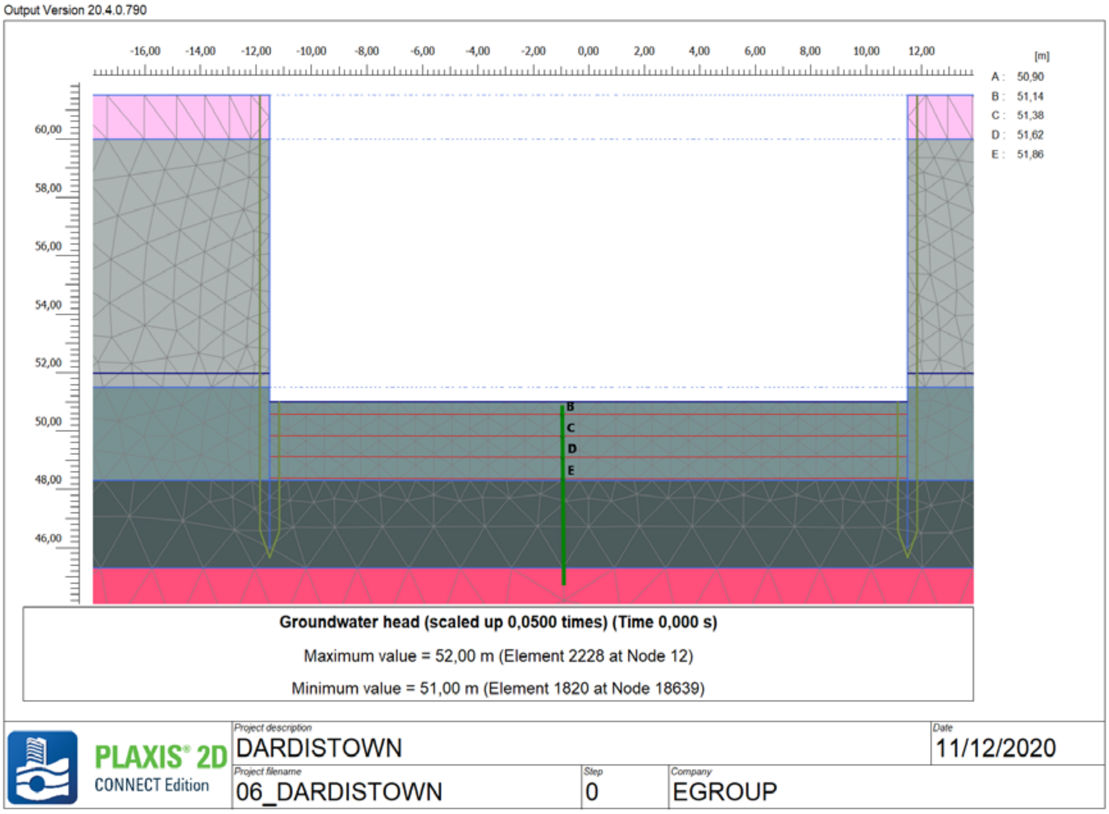


Figure 5-39. Illustration of groundwater head. Dardistown Station.

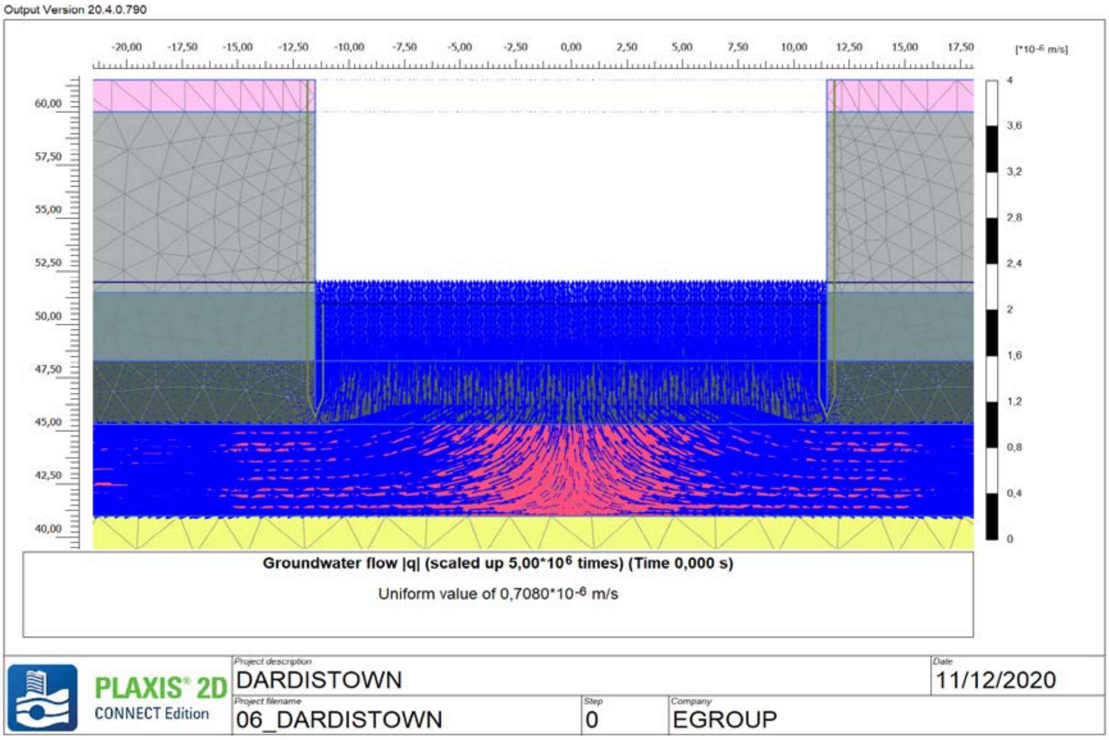


Figure 5-40. Illustration of groundwater flow. Dardistown Station.

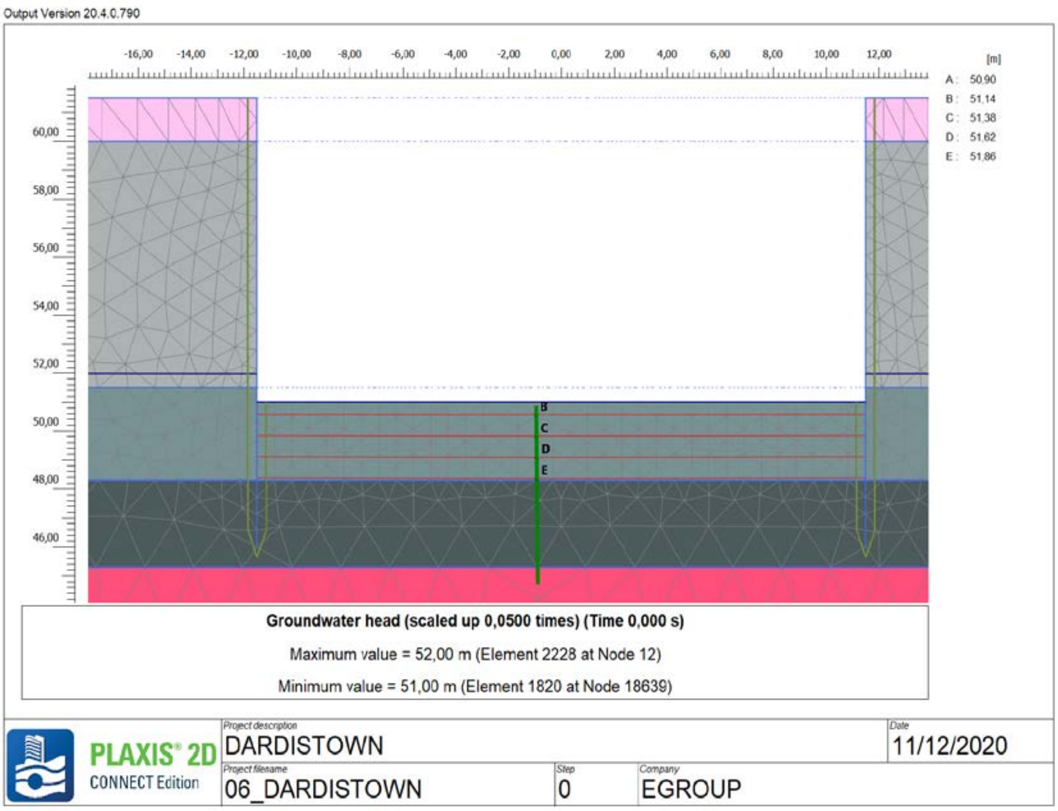


Figure 5-41. Water discharge ratio at the bottom of the excavation. Dardistown Station.

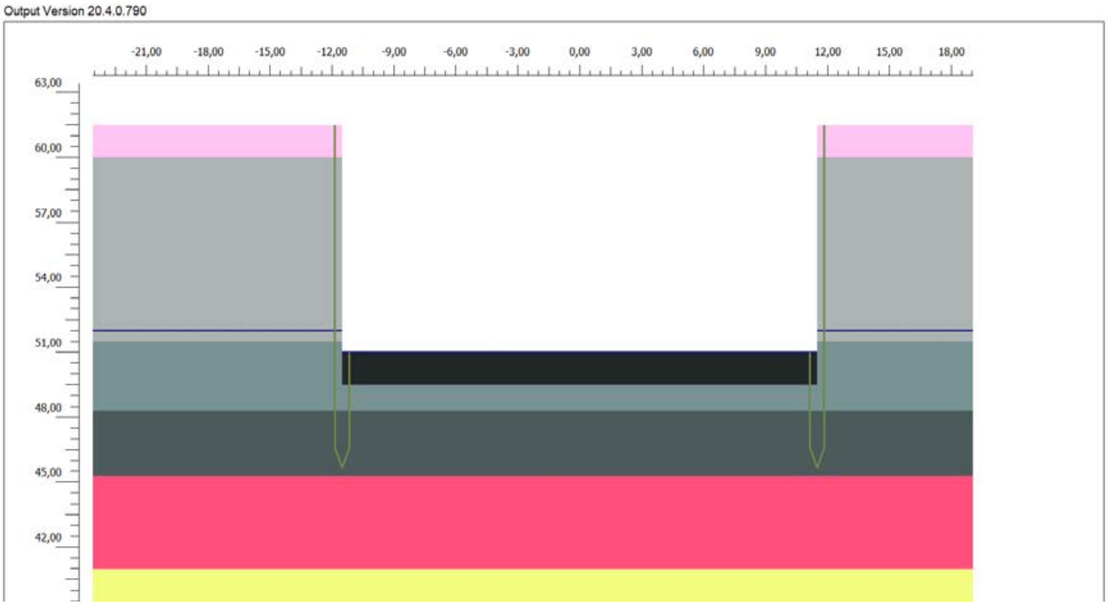


Figure 5-42. Bottom Plug geometry embedded in 2D model. Dardistown Station.

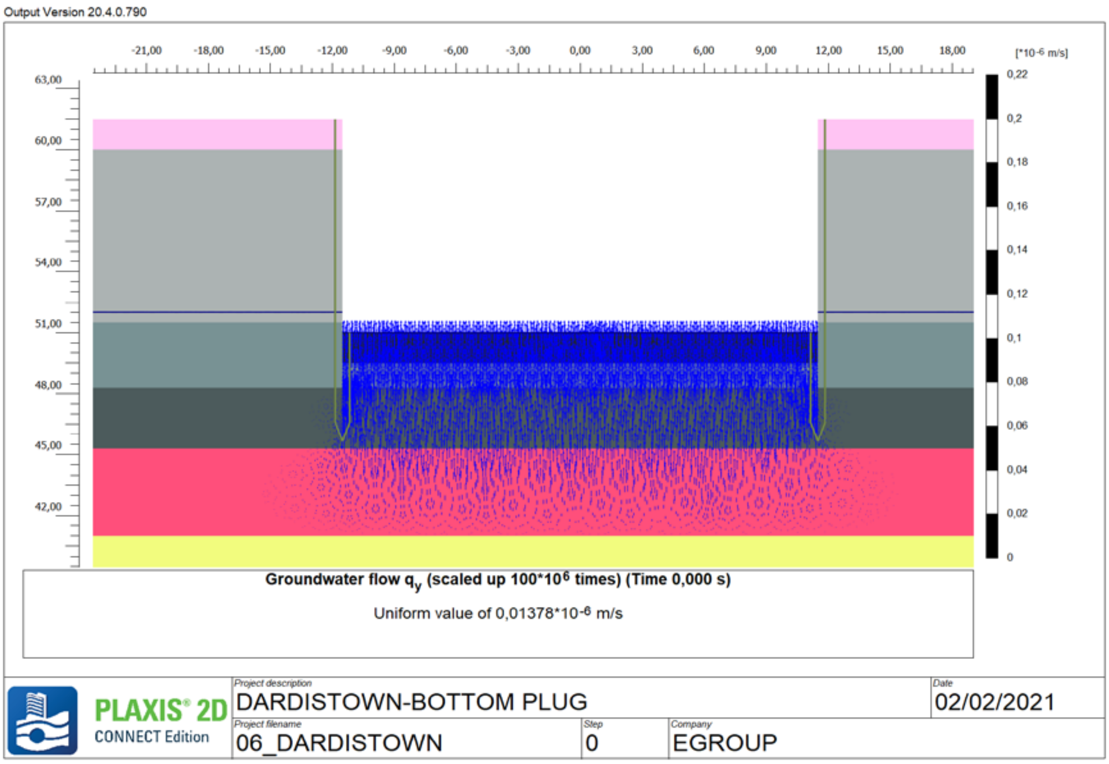


Figure 5-43. Groundwater flow (qy) with Bottom Plug. Dardistown Station.

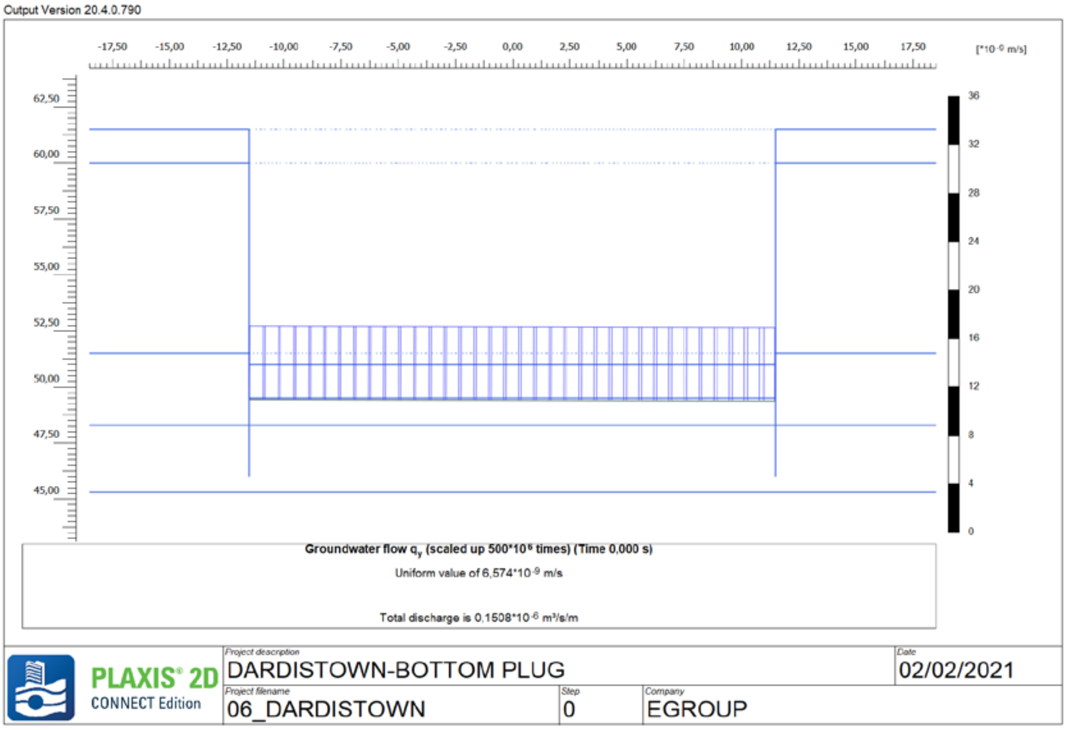


Figure 5-44. Water discharge ratio at the bottom of the excavation with Bottom Plug. Dardistown Station.

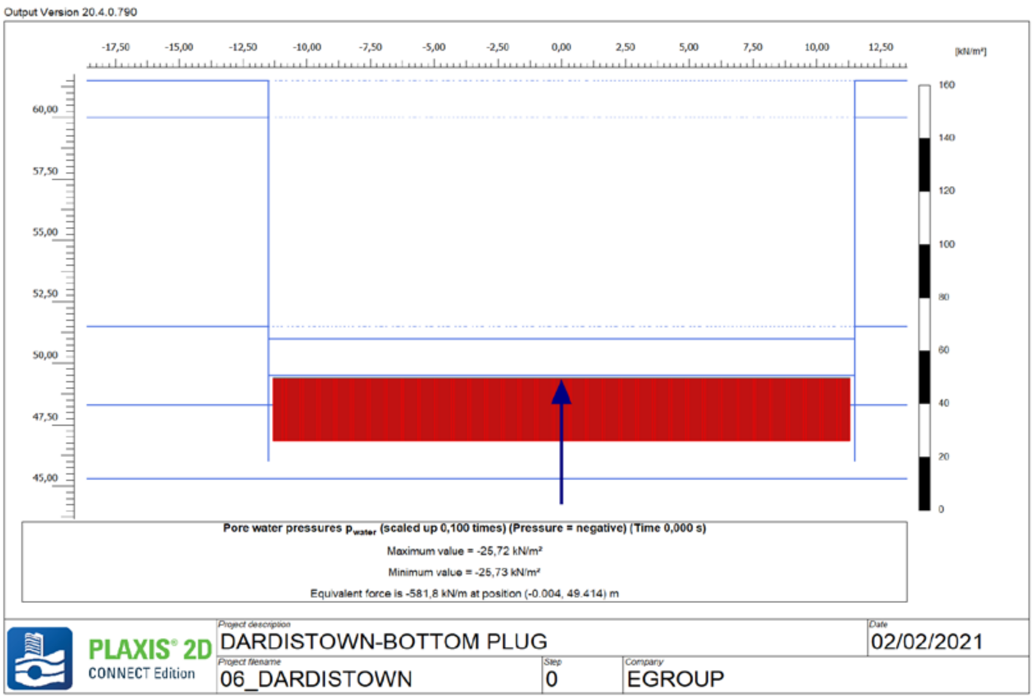


Figure 5-45. Pore water pressure under Bottom Plug. Dardistown Station.

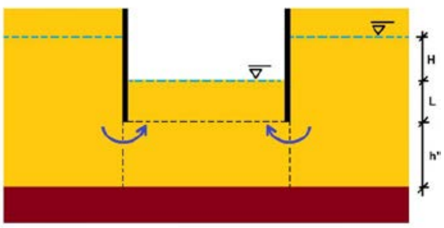
5.6 Northwood

N	STATION NAME	Levels TOP (m)	Qx (m)	QBR<10 m (m)	QBR > 10 m (m)	BoD (m)	CLU (m)
7	NORTHWOOD	60,00	58,80	50,00	39,80	37,80	23,06

Thickness	Qx (m)	QBR<10 m (m)	QBR > 10 m (m)	BoD (m)	CLU (m)
	0,00	4,40	10,20	2,00	14,74

K(Permeability)	Qx (m/s)	QBR<10 m (m/s)	QBR > 10 m (m/s)	BoD (m/s)	CLU (m/s)
Kx	7,65E-07	7,62E-07	6,64E-06	2,90E-04	4,70E-06
Kv	7,65E-07	7,62E-07	6,64E-06	2,90E-04	4,70E-07

Exc. (m)	W.L. (m)
39	55



$$k_{II} = \frac{H}{\sum_{1}^{m} \frac{H_a}{k_a}}$$

$$k_I = \frac{\sum_{i=1}^{n} k_i \cdot H_i}{H}$$

$$h'_{min} = \frac{ab}{2(a+b)}$$

Kh (m/s)	Kv (m/s)	H (m)	L (m)	a (m)	b (m)	h´ (m)	Vol (m3)	ro (m)	φ1 (m)	φ2 (m)	R (m)	Rf (m)	Qv (Dupuit formula) (m3/s/m)	Q Plaxis (m3/s/m)	Q Plaxis (m3/d/m)	Qt (m3/d)
2,30E-05	8,10E-07	16,00	6,00	23,00	147,00	9,94	5,41E+04	32,81	65,00	49,00	99,71	104,97	1,41E-05	1,80E-05	1,56	228,61

Q Plaxis (m3/s/m)	Q Plaxis (m3/d/m)	Qt (m3/d)	Water pressure under grout slab (kN/m2)
2,60E-06	0,22	33,02	150,00

Figure 5-46. Summary of results. Northwood Station.

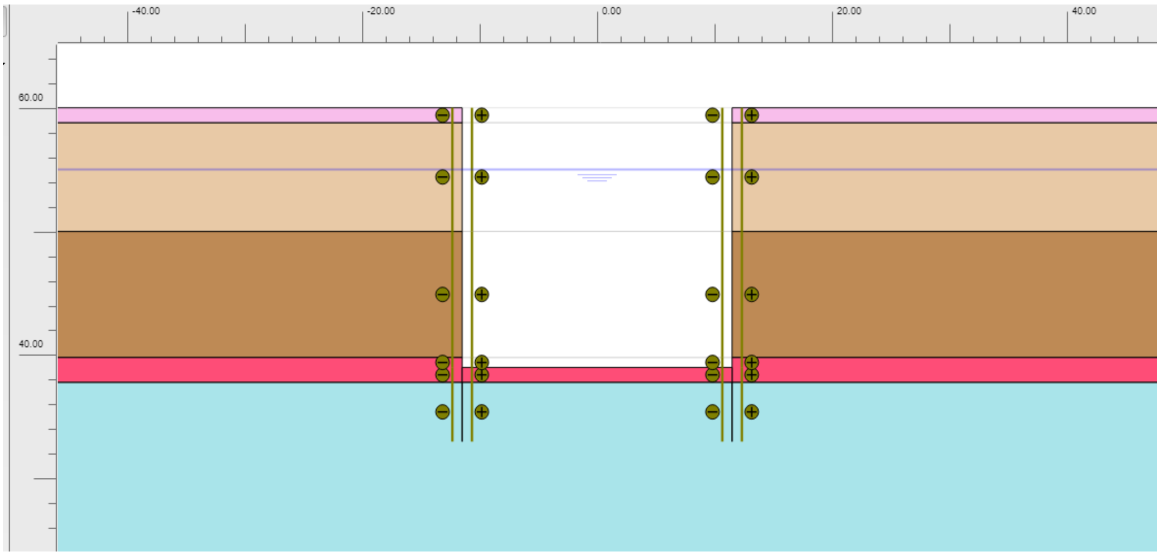


Figure 5-47. Illustration of Plaxis 2D Model. Northwood Station.

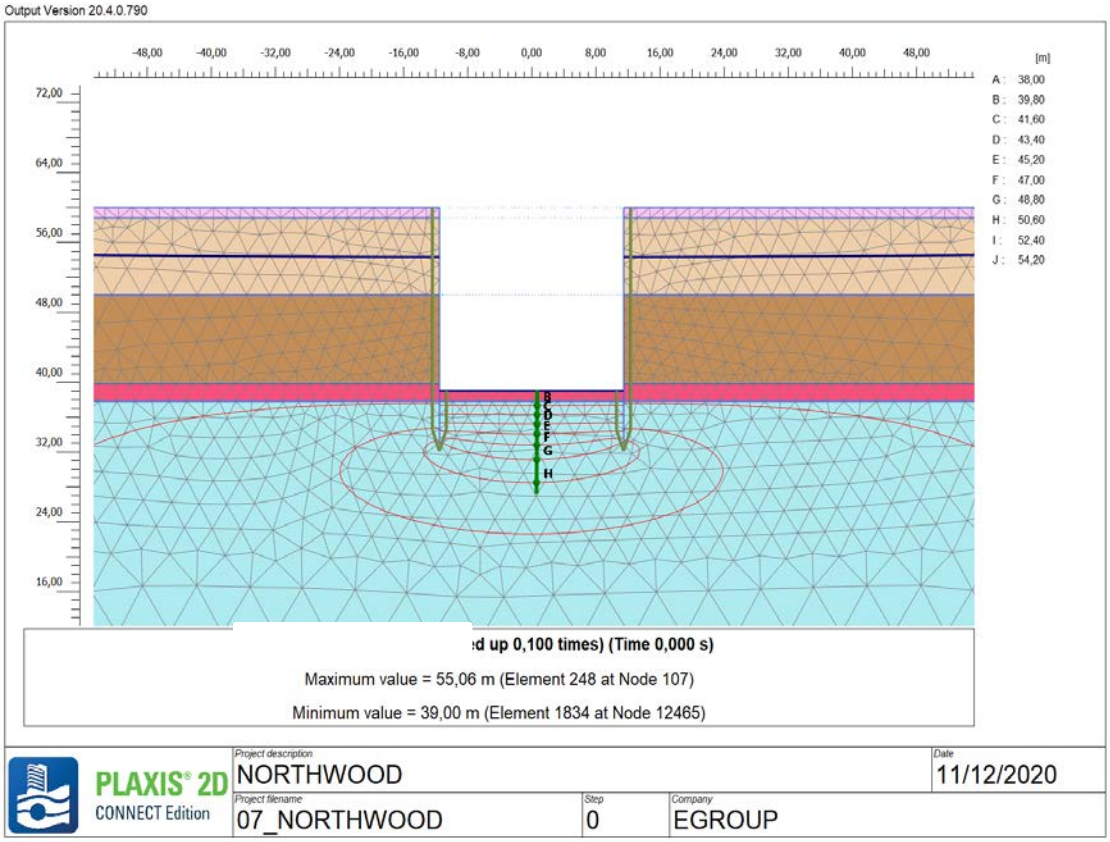


Figure 5-48. Illustration of groundwater head. Northwood Station.

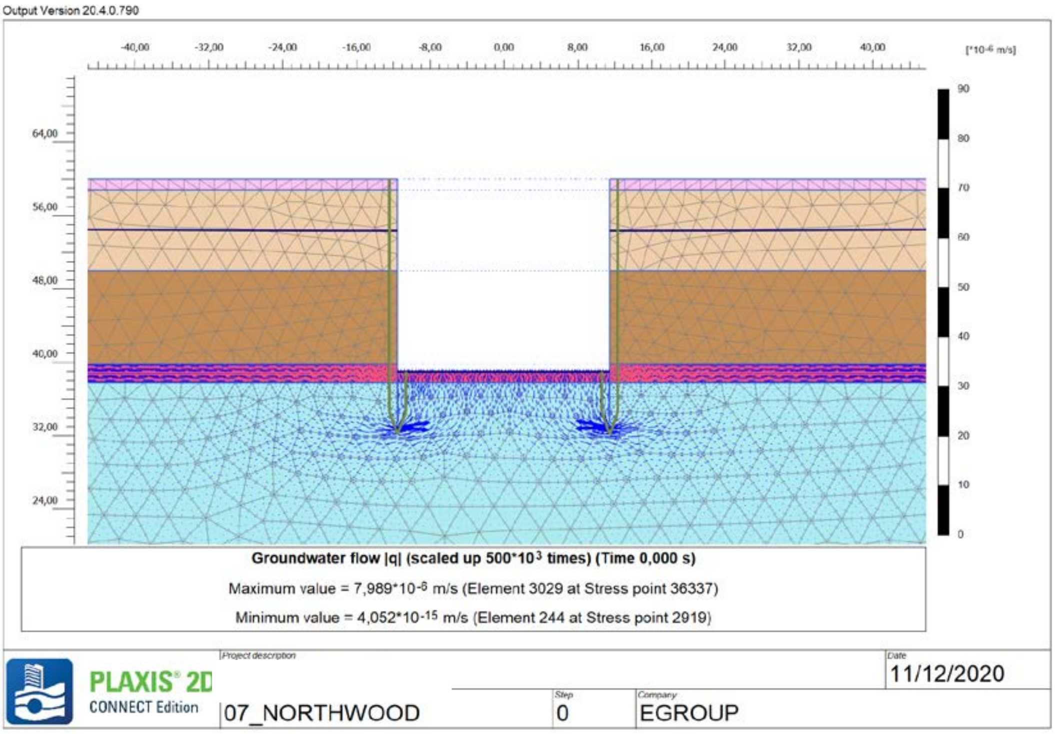


Figure 5-49. Illustration of groundwater flow. Northwood Station.

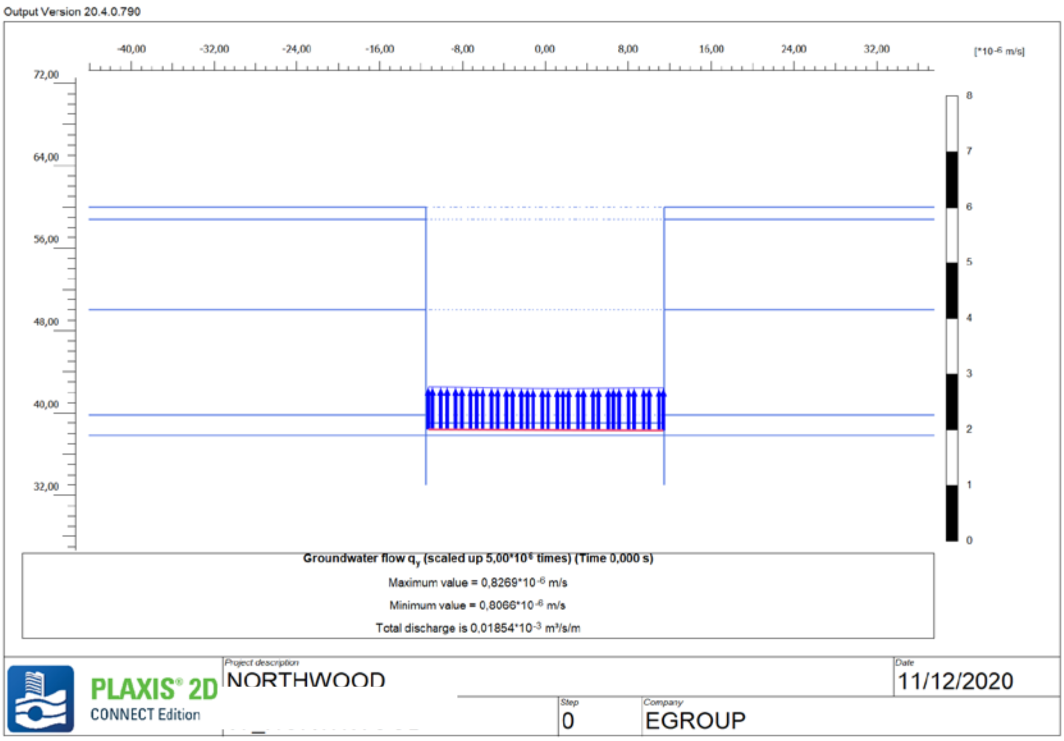


Figure 5-50. Water discharge ratio at the bottom of the excavation. Northwood Station.

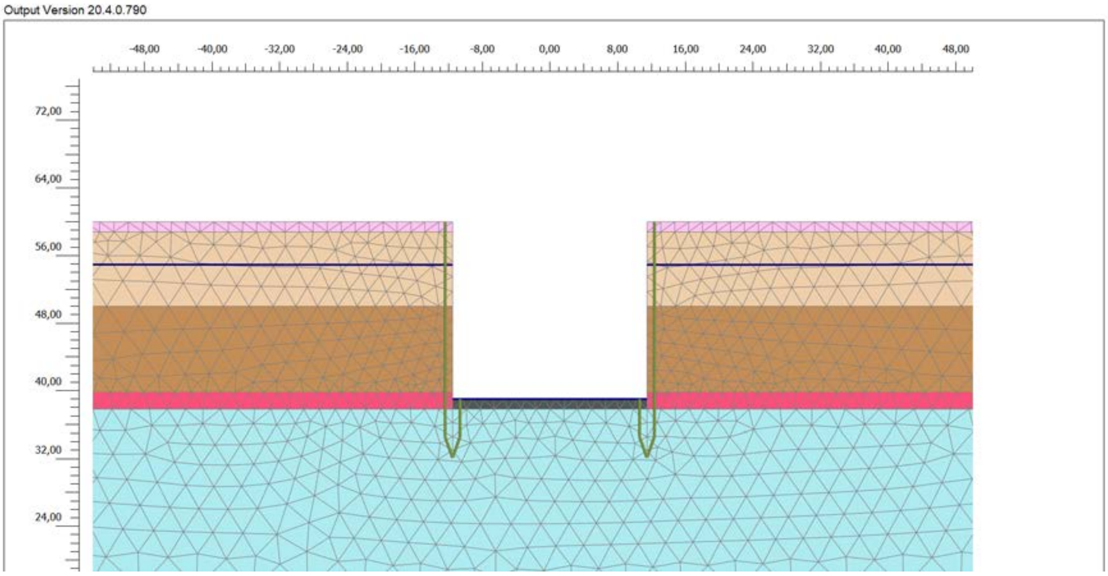


Figure 5-51. Bottom Plug geometry embedded in 2D model. Northwood Station

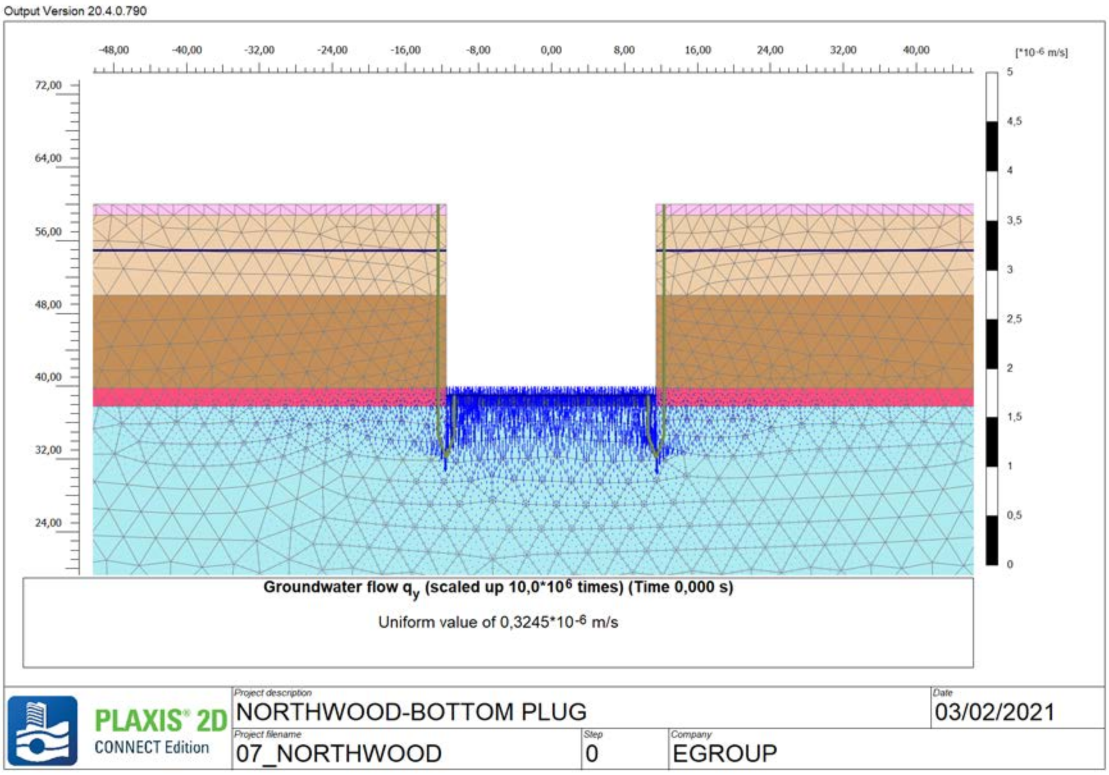


Figure 5-52. Groundwater flow (qy) with Bottom Plug. Northwood Station

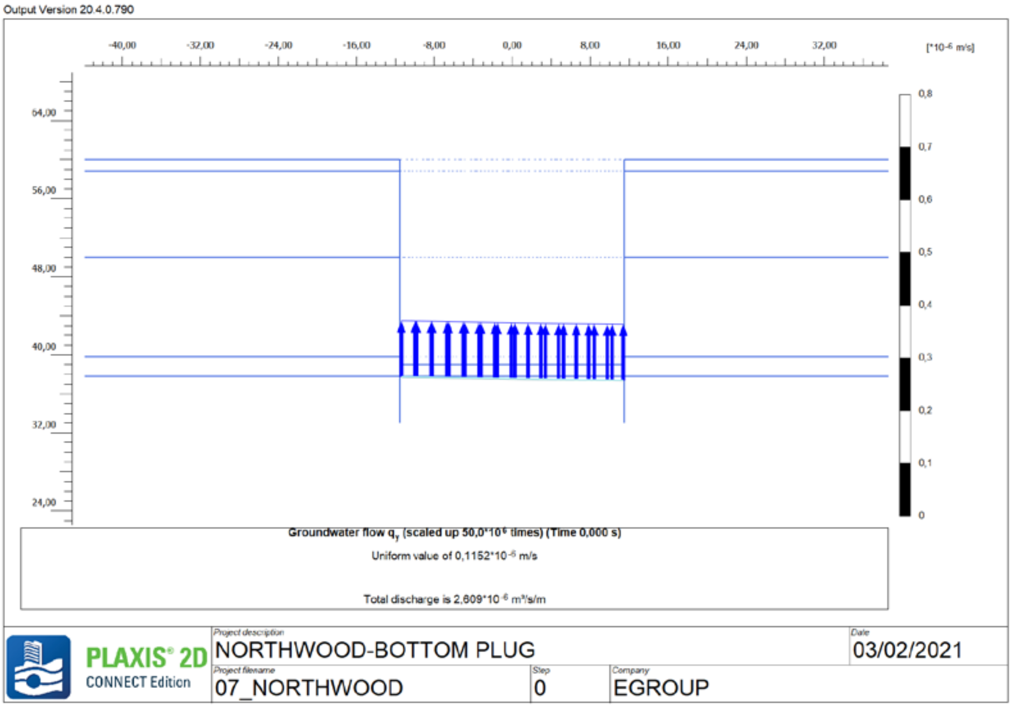


Figure 5-53. Water discharge ratio at the bottom of the excavation with Bottom Plug. Northwood Station

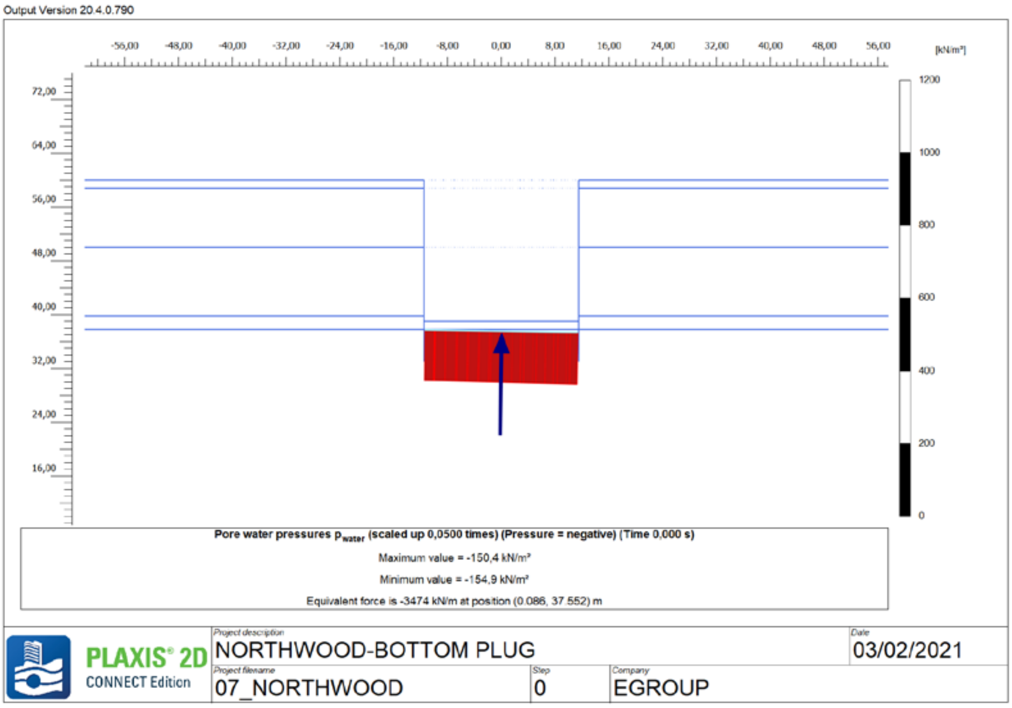


Figure 5-54. Pore water pressure under Bottom Plug. Northwood Station

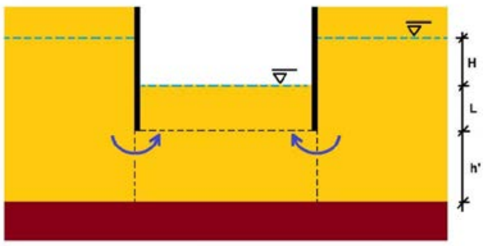
5.7 Ballymun

N	STATION NAME	Levels									
		TOP	Qx	QBR<10 m	QBR<10 m sand	QBR<10 m	QBR>10 m	QBR>10 m sand	QBR>10 m	BoD	CLU
		(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
8	BALLYMUN	62,50	60,50	57,50	57,00	52,50	48,50	45,80	43,50	39,50	21,40

Thickness								
Qx	QBR<10 m	QBR<10 m sand	QBR<10 m	QBR>10 m	QBR>10 m sand	QBR>10 m	BoD	CLU
(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
0,00	0,00	0,00	2,25	4,00	2,70	2,30	4,00	18,10

	K(Permeability)								
	Qx	QBR<10 m	QBR<10 m sand	QBR<10 m	QBR>10 m	QBR>10 m sand	QBR>10 m	BoD	CLU
	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)
Kx	7,65E-07	7,62E-07	2,90E-06	7,62E-07	6,64E-06	8,59E-06	6,64E-06	2,90E-04	4,70E-06
Kv	7,65E-07	7,62E-07	2,90E-06	7,62E-07	6,64E-06	8,59E-06	6,64E-06	2,90E-04	4,70E-07

Exc.	W.L.
(m)	(m)
33,5	54,5



$$k_{II} = \frac{H}{\sum_{1}^{m} \frac{H_{\alpha}}{k_{\alpha}}}$$

$$h'_{min} = \frac{ab}{2(a+b)}$$

$$k_I = \frac{\sum_{i=1}^{n} k_i \cdot H_i}{H}$$

Kh	Kv	H	L	a	b	h´	Vol	ro	φ1	φ2	R	Rf	Qv (Dupuit formula)	Q Plaxis	Q Plaxis	Qt
(m/s)	(m/s)	(m)	(m)	(m)	(m)	(m)	(m3)	(m)	(m)	(m)	(m)	(m)	(m3/s/m)	(m3/s/m)	(m3/d/m)	(m3/d)
3,93E-05	7,80E-07	21,00	2,50	23,00	116,00	9,60	5,60E+04	29,14	54,50	33,50	148,29	151,13	9,54E-06	3,00E-05	2,59	300,67

Q Plaxis	Q Plaxis	Qt	Water pressureunder grout slab
(m3/s/m)	(m3/d/m)	(m3/d)	(kN/m2)
2,96E-06	0,26	29,67	210,00

Figure 5-55. Summary of results. Ballymun Station.

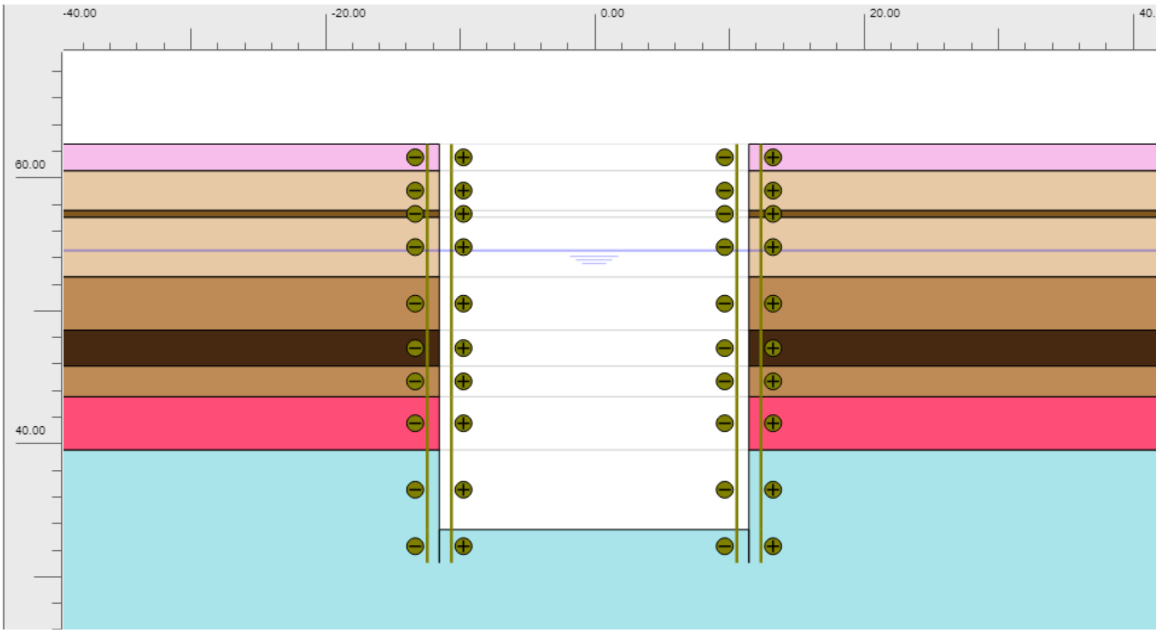


Figure 5-56. Illustration of Plaxis 2D Model. Ballymun Station.

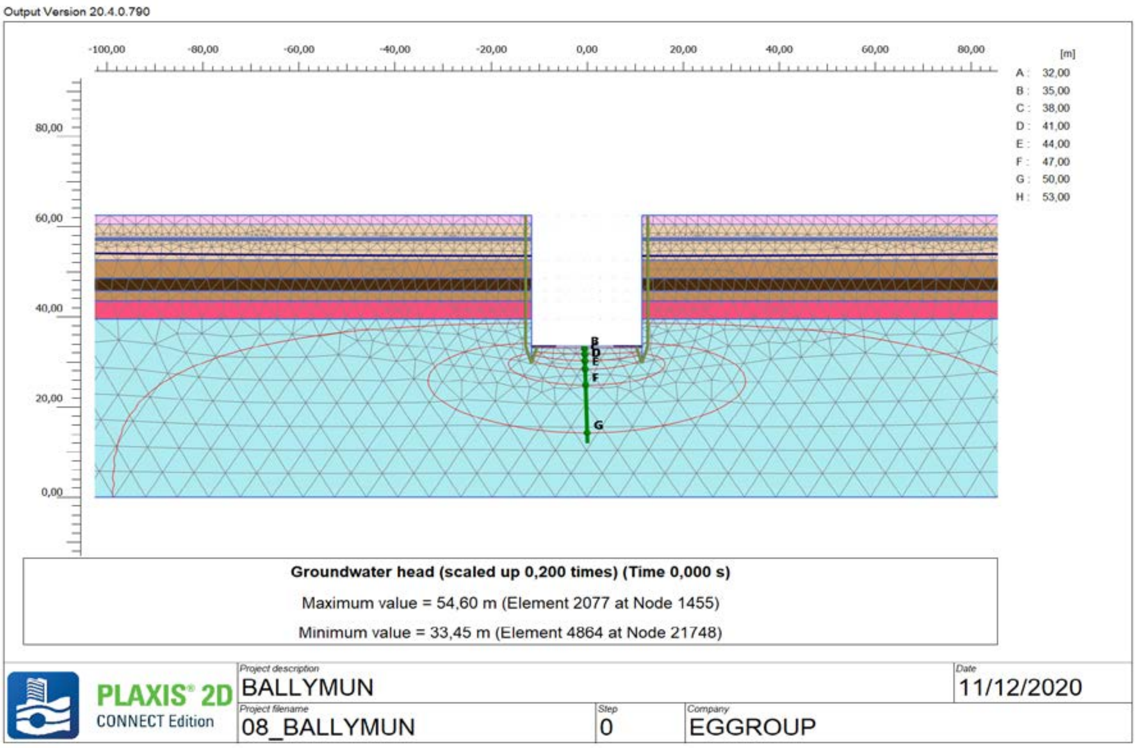


Figure 5-57. Illustration of groundwater head. Ballymun Station.

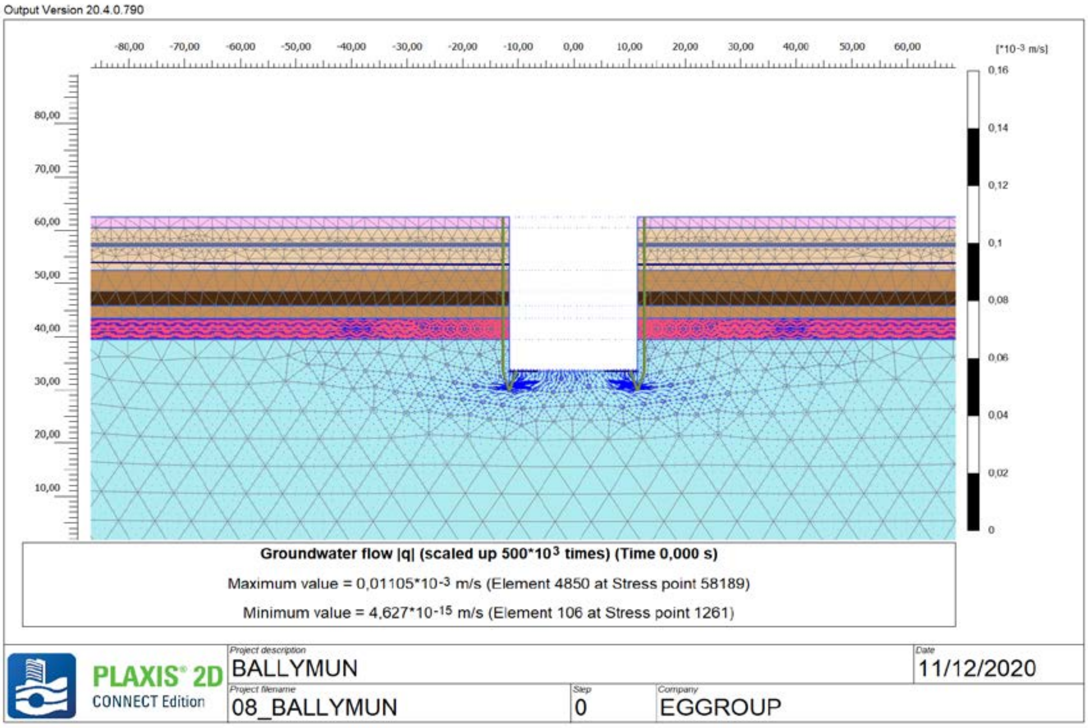


Figure 5-58. Illustration of groundwater flow. Ballymun Station.

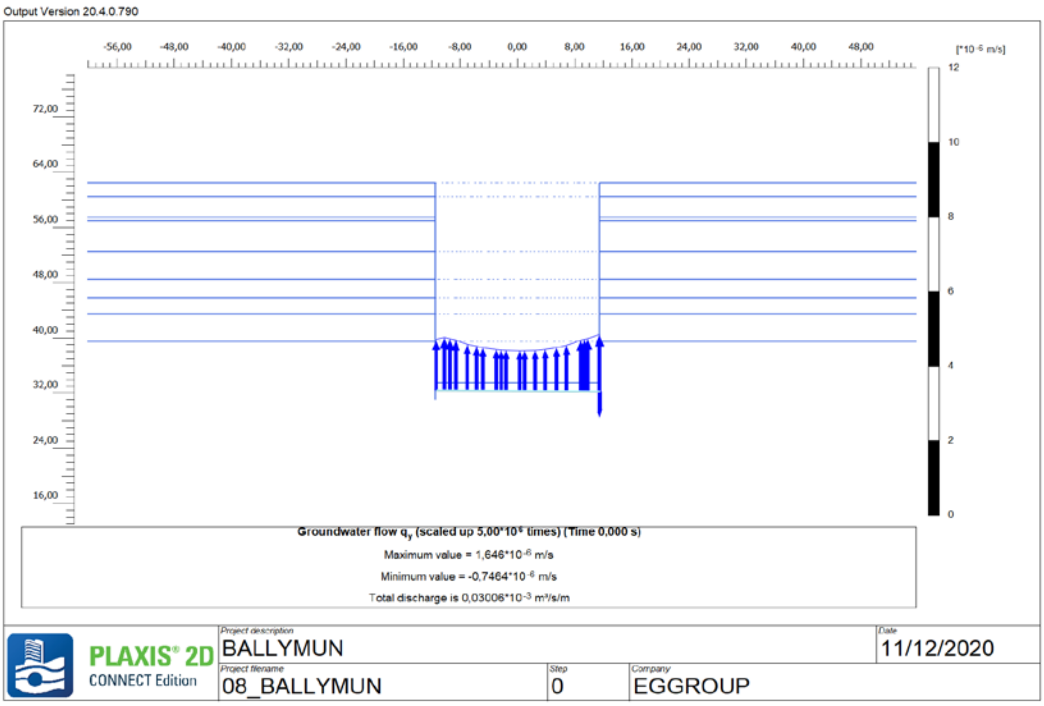


Figure 5-59. Water discharge ratio at the bottom of the excavation. Ballymun Station.

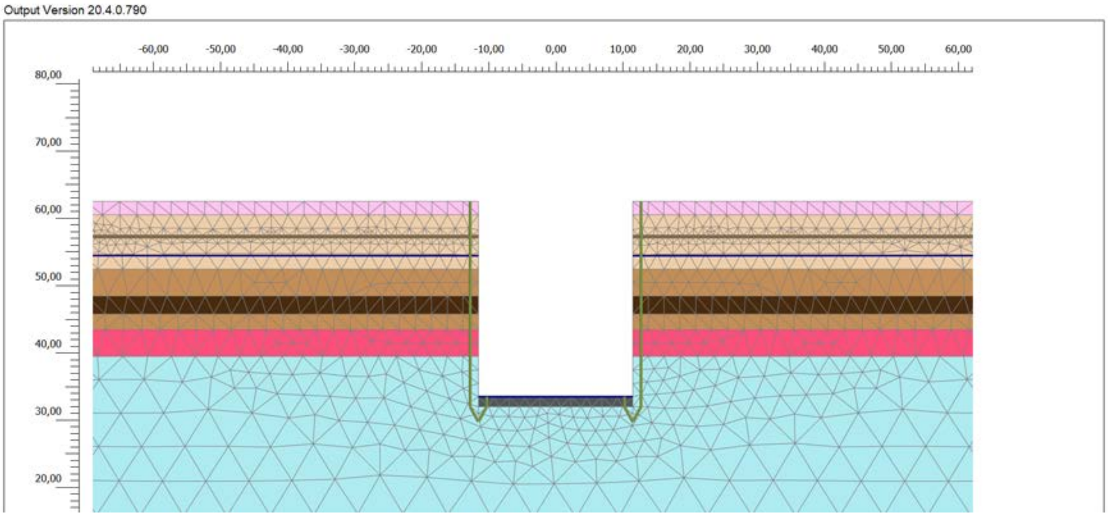


Figure 5-60. Bottom Plug geometry embedded in 2D model. Ballymun Station.

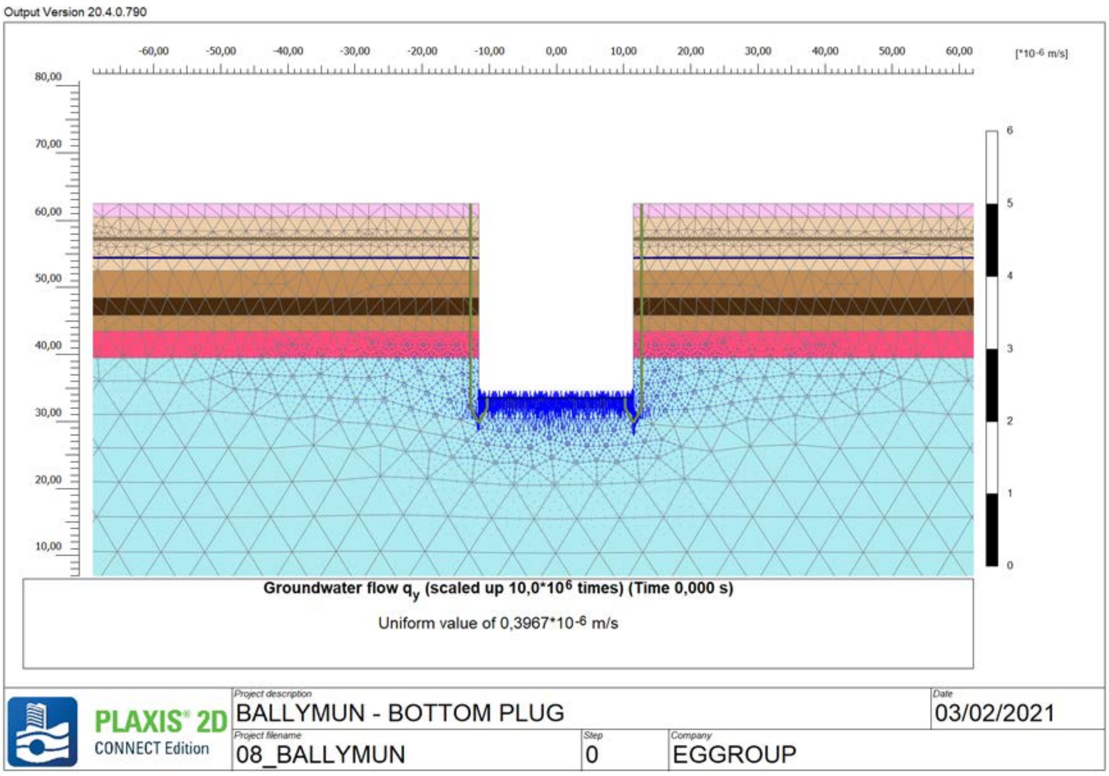


Figure 5-61. Groundwater flow (qy) with Bottom Plug. Ballymun Station.

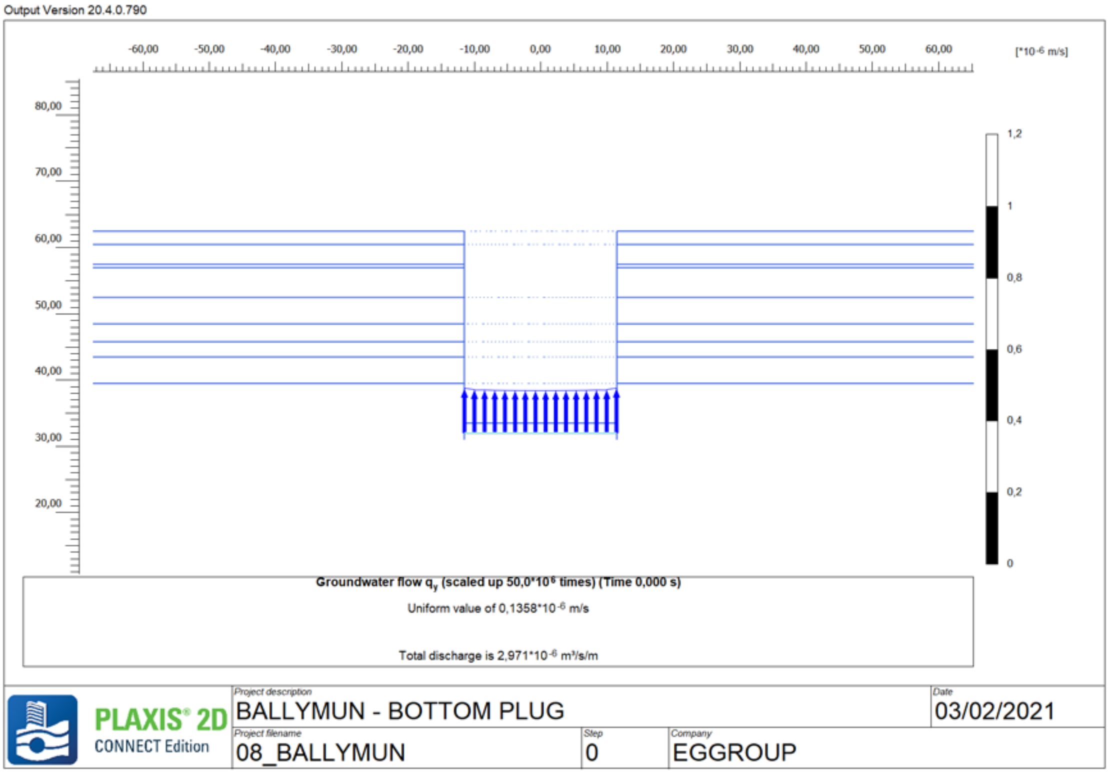


Figure 5-62. Water discharge ratio at the bottom of the excavation with Bottom Plug. Ballymun Station.

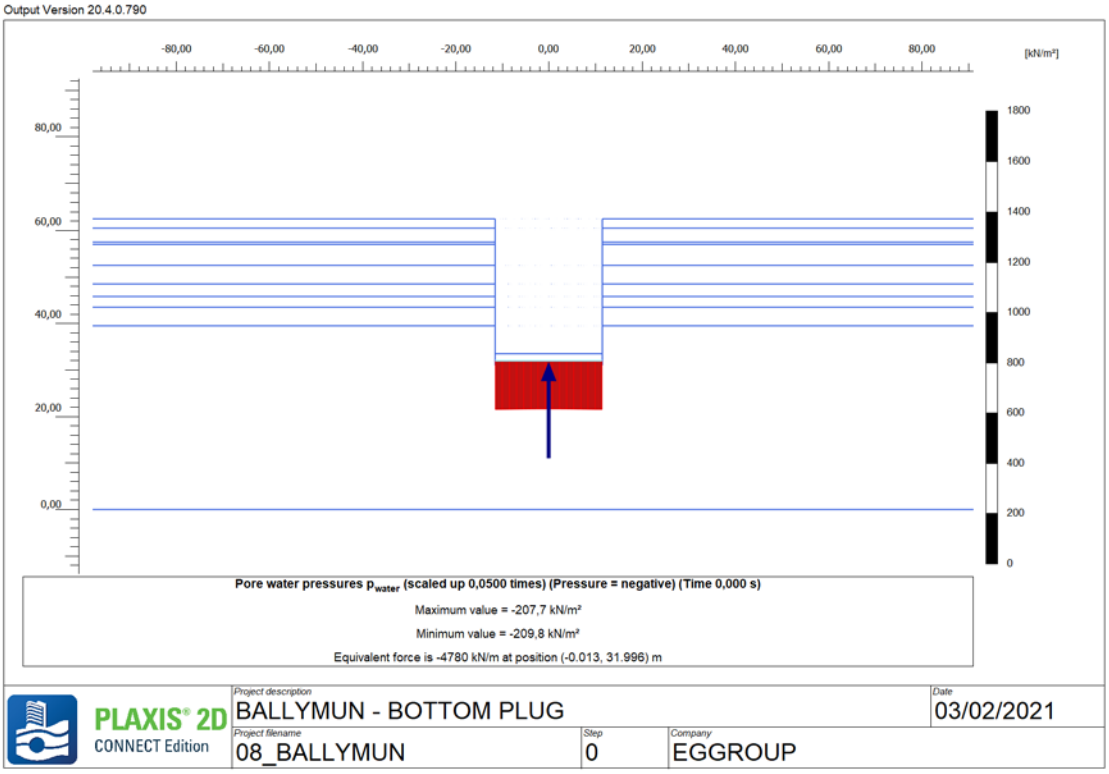


Figure 5-63. Pore water pressure under Bottom Plug. Ballymun Station.

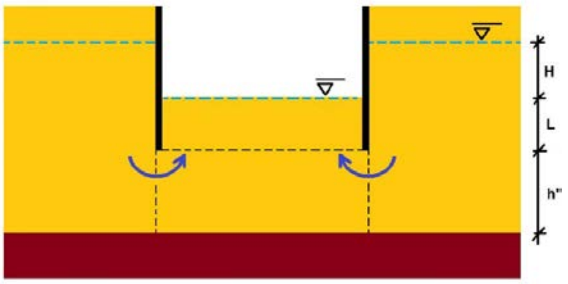
5.8 Collins avenue

N	STATION NAME	Levels								
		TOP	Qx	QBR<10 m	QBR<10 m sand	QBR<10 m	QBR>10 m	QBR>10 m sand	BoD	CLU
		(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
9	COLLINS AV.	51,5	50	48,5	47,3	43,5	41,5	38,2	27,6	8,90

Thickness							
Qx	QBR<10 m	QBR<10 m sand	QBR<10 m	QBR>10 m	QBR>10 m sand	BoD	CLU
(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
0	0	0	2,85	2	3,3	10,6	18,697122

	K(Permeability)							
	Qx	QBR<10 m	QBR<10 m sand	QBR<10 m	QBR>10 m	QBR>10 m sand	BoD	CLU
	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)
Kx	7,65E-07	7,62E-07	2,90E-06	7,62E-07	6,64E-06	8,59E-06	2,90E-04	4,70E-06
Kv	7,65E-07	7,62E-07	2,90E-06	7,62E-07	6,64E-06	8,59E-06	2,90E-04	4,70E-07

Exc.	W.L.
(m)	(m)
23,2	43,5



$$k_{II} = \frac{H}{\sum_{1}^{m} \frac{H_u}{k_u}}$$

$$k_I = \frac{\sum_{i=1}^{n} k_i \cdot H_i}{H}$$

$$h'_{min} = \frac{ab}{2(a+b)}$$

Kh	Kv	H	L	a	b	h´	Vol	ro	φ1	φ2	R	Rf	Qv (Dupuit formula)	Q Plaxis	Q Plaxis	Qt
(m/s)	(m/s)	(m)	(m)	(m)	(m)	(m)	(m3)	(m)	(m)	(m)	(m)	(m)	(m3/s/m)	(m3/s/m)	(m3/d/m)	(m3/d)
1,71E-04	8,46E-07	20,30	4,70	23,00	116,00	9,60	5,42E+04	29,14	43,50	23,20	211,22	213,22	5,37E-06	2,00E-05	1,73	200,45

Q Plaxis	Q Plaxis	Qt	Water pressureunder grout slab
(m3/s/m)	(m3/d/m)	(m3/d)	(kN/m2)
2,76E-06	0,24	27,66	197,00

Figure 5-64. Summary of results. Collins Avenue Station.

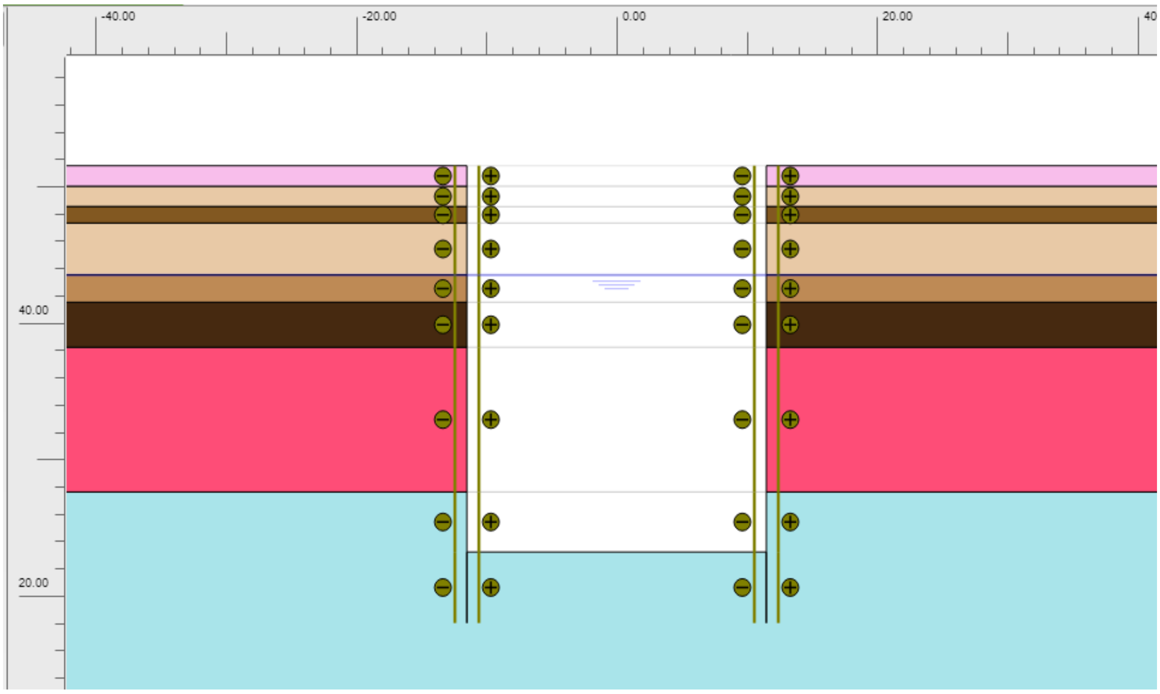


Figure 5-65. Illustration of Plaxis 2D Model. Collins Avenue Station.

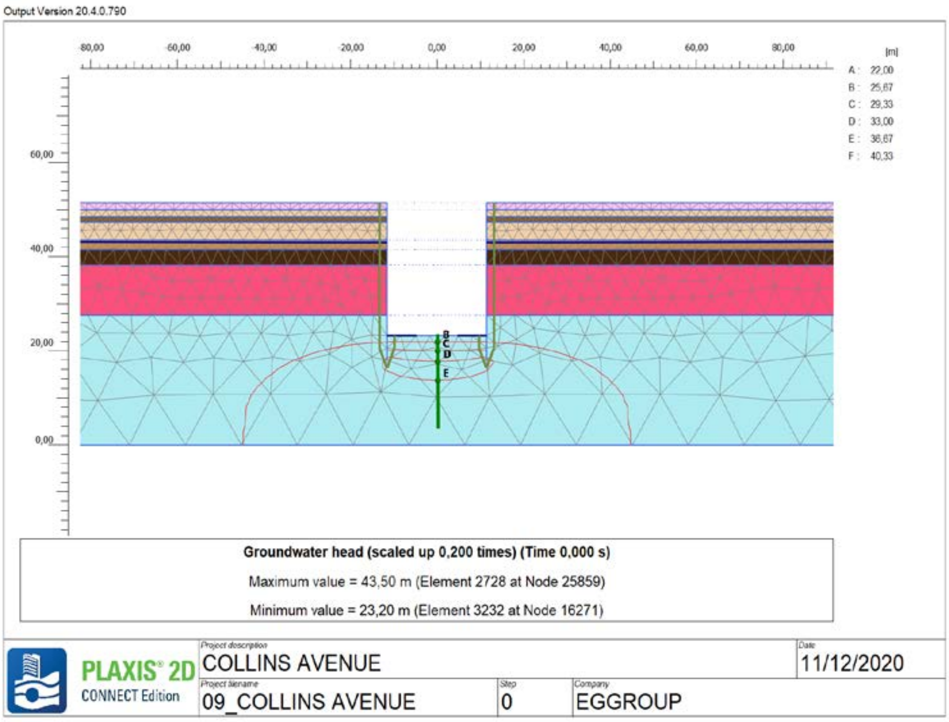


Figure 5-66. Illustration of groundwater head. Collins Avenue Station.

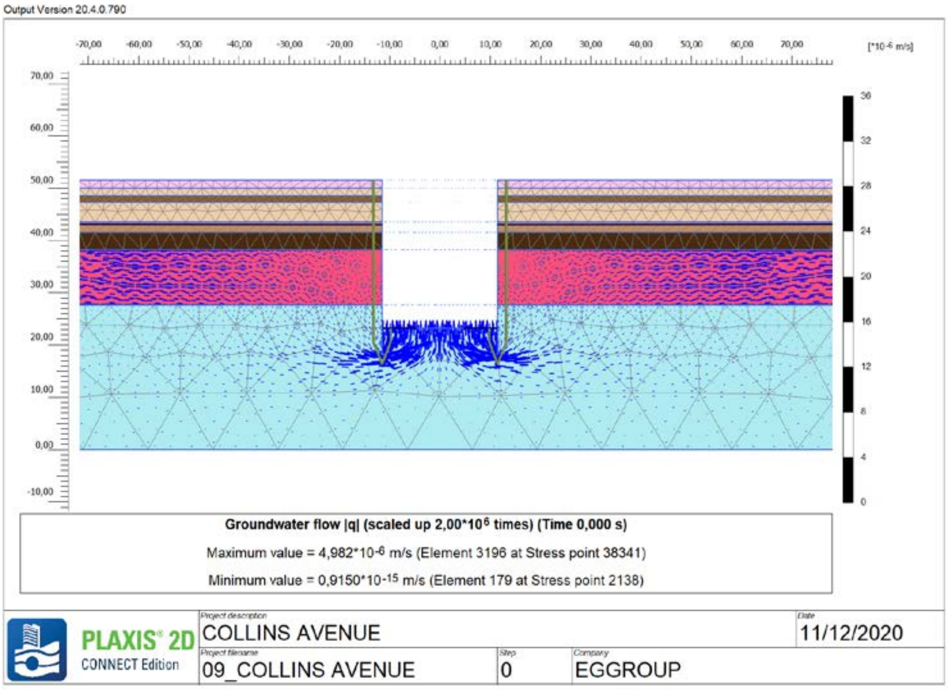


Figure 5-67. Illustration of groundwater flow. Collins Avenue Station.

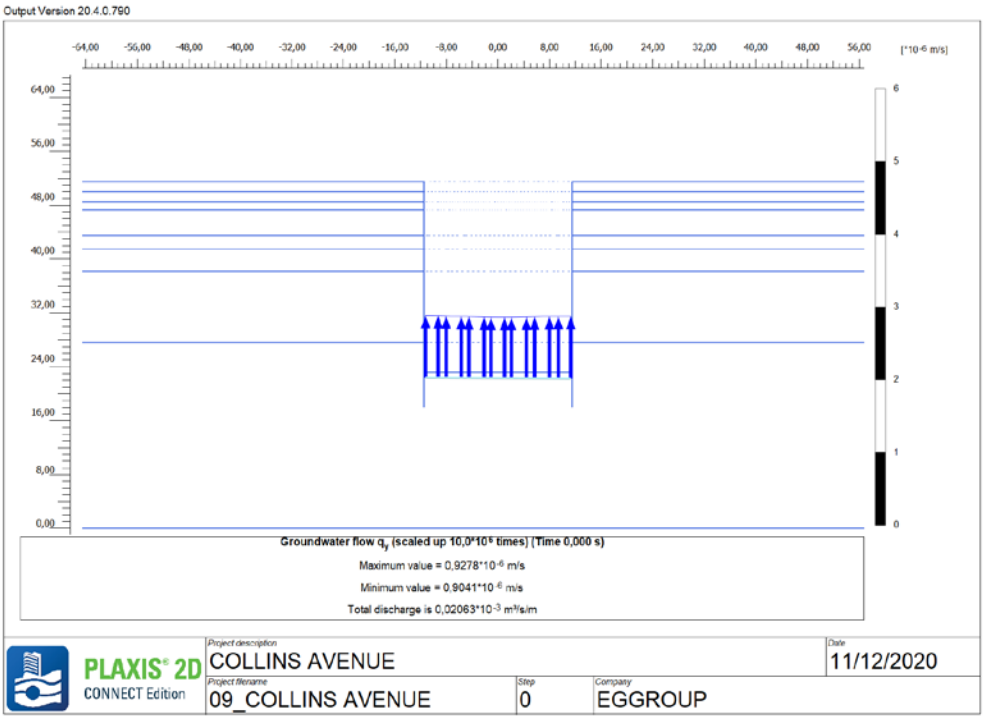


Figure 5-68. Water discharge ratio at the bottom of the excavation. Collins Avenue Station.

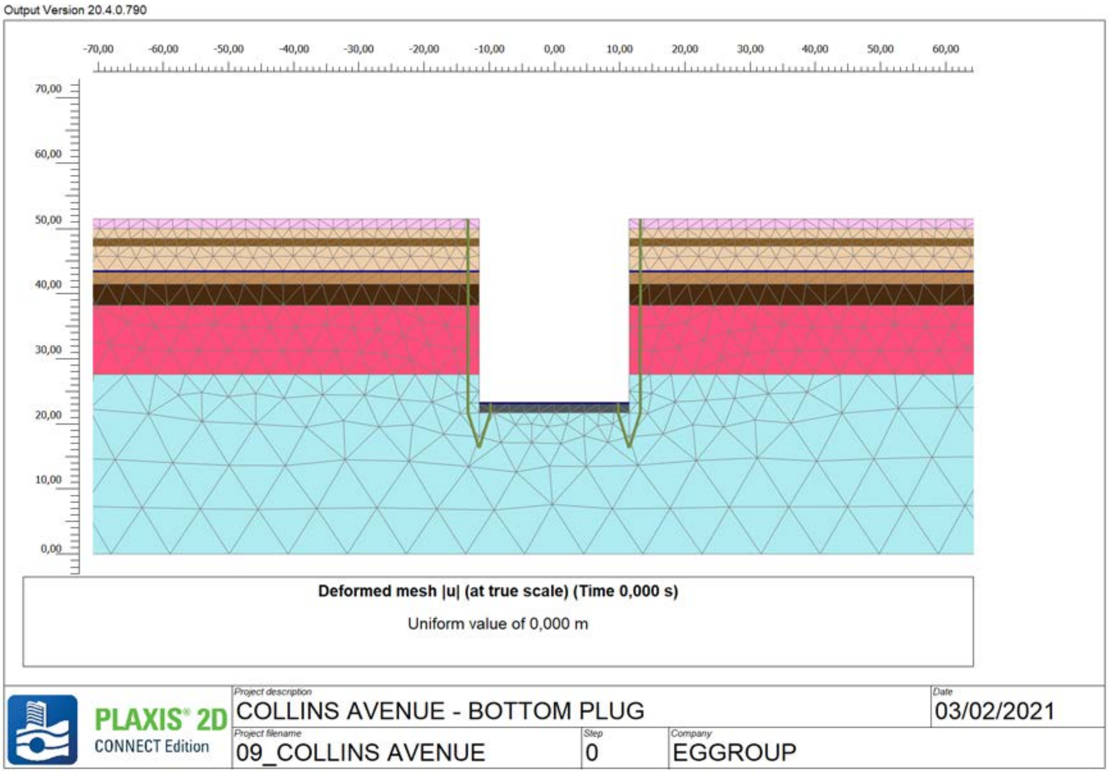


Figure 5-69. Bottom Plug geometry embedded in 2D model. Collins Avenue Station.

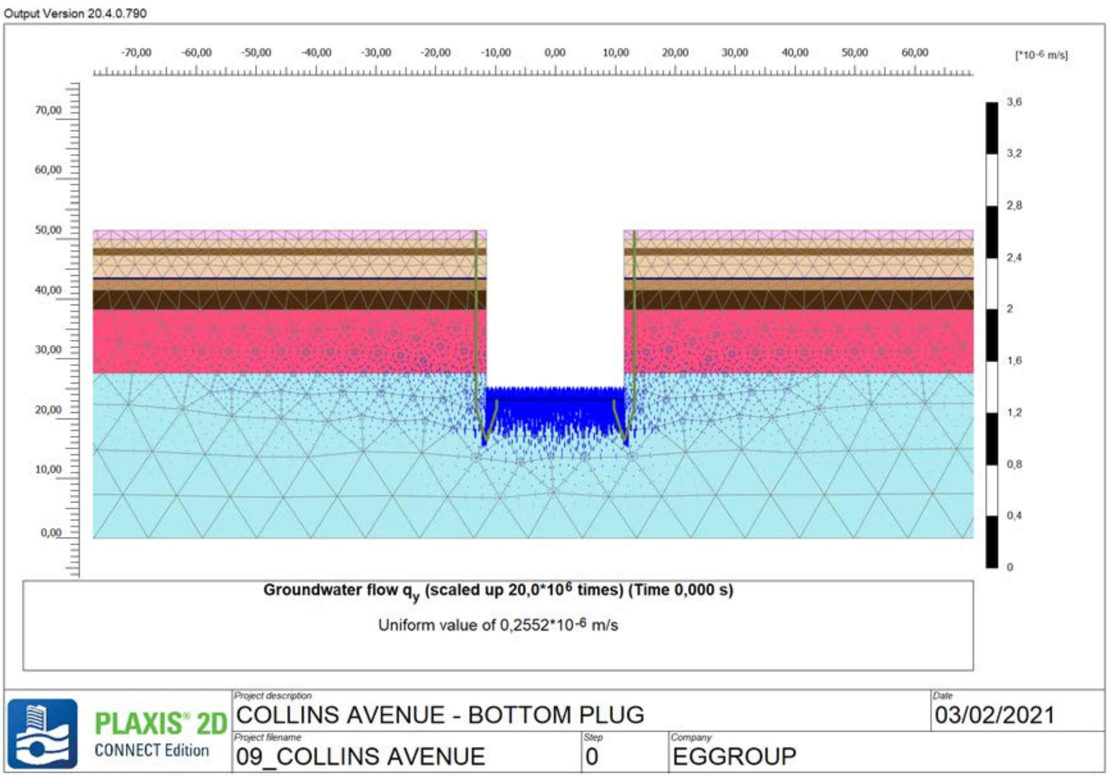


Figure 5-70. Groundwater flow (qy) with Bottom Plug. Collins Avenue Station.

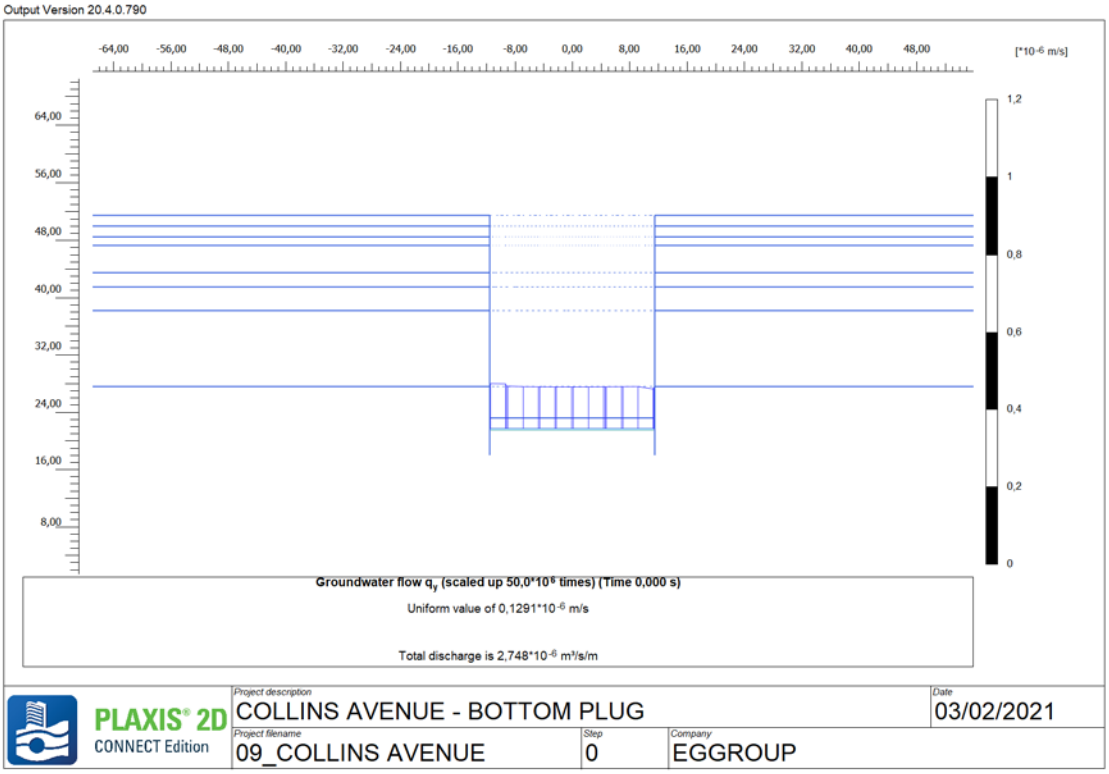


Figure 5-71. Water discharge ratio at the bottom of the excavation with Bottom Plug. Collins Avenue Station.

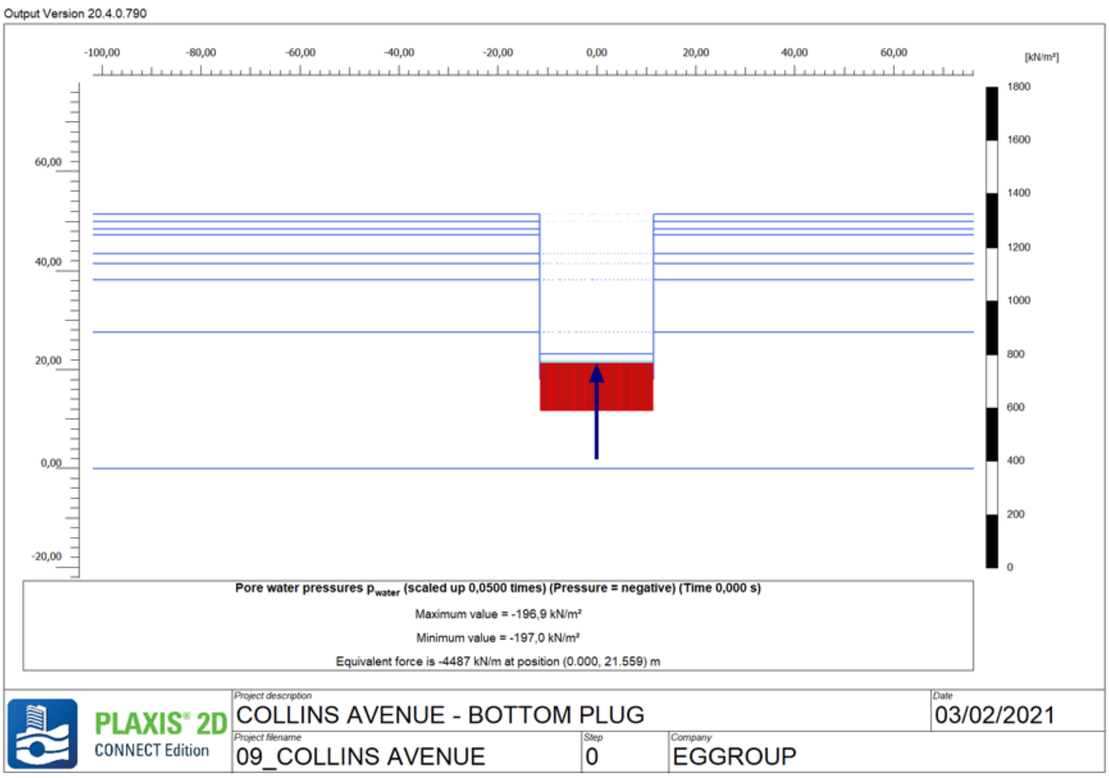


Figure 5-72. Pore water pressure under Bottom Plug. Collins Avenue Station.

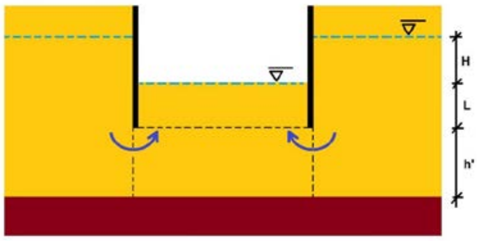
5.9 Griffith park

N	STATION NAME	Levels				
		TOP	Qx	QBR<10 m	BoD	CLU
		(m)	(m)	(m)	(m)	(m)
10	GRIFFITH PARK	18,50	16,00	9,30	3,30	-24,11

thickness			
Qx	QBR<10 m	BoD	CLU
(m)	(m)	(m)	(m)
0,00	5,36	6,00	27,41

	K(Permeability)			
	Qx	QBR<10 m	BoD	CLU
	(m/s)	(m/s)	(m/s)	(m/s)
Kx	7,65E-07	7,62E-07	2,90E-04	4,70E-06
Kv	7,65E-07	7,62E-07	2,90E-04	4,70E-07

Exc.	W.L.
(m)	(m)
-10	13,5



$$k_{II} = \frac{H}{\sum_{1}^{m} \frac{H_a}{k_a}}$$

$$k_I = \frac{\sum_{i=1}^{n} k_i \cdot H_i}{H}$$

$$h'_{min} = \frac{ab}{2(a+b)}$$

Kh	Kv	H	L	a	b	h´	Vol	ro	φ1	φ2	R	Rf	Qv (Dupuit formula)	Q Plaxis	Q Plaxis	Qt
(m/s)	(m/s)	(m)	(m)	(m)	(m)	(m)	(m3)	(m)	(m)	(m)	(m)	(m)	(m3/s/m)	(m3/s/m)	(m3/d/m)	(m3/d)
4,83E-05	5,93E-07	23,50	4,50	23,00	117,00	9,61	6,32E+04	29,27	63,50	40,00	163,10	165,71	8,70E-06	2,60E-05	2,25	262,83

Q Plaxis	Q Plaxis	Qt	Water pressure under grout slab
(m3/s/m)	(m3/d/m)	(m3/d)	(kN/m2)
3,22E-06	0,28	32,55	229,00

Figure 5-73. Summary of results. Griffith Park Station.

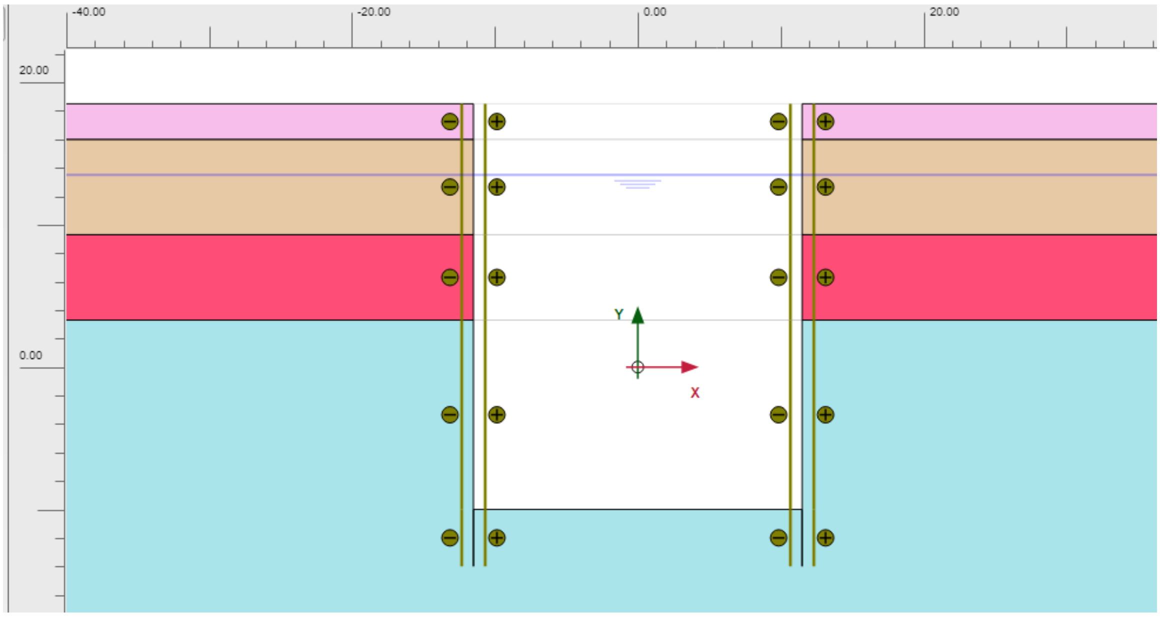


Figure 5-74. Illustration of Plaxis 2D Model. Griffith Park Station.

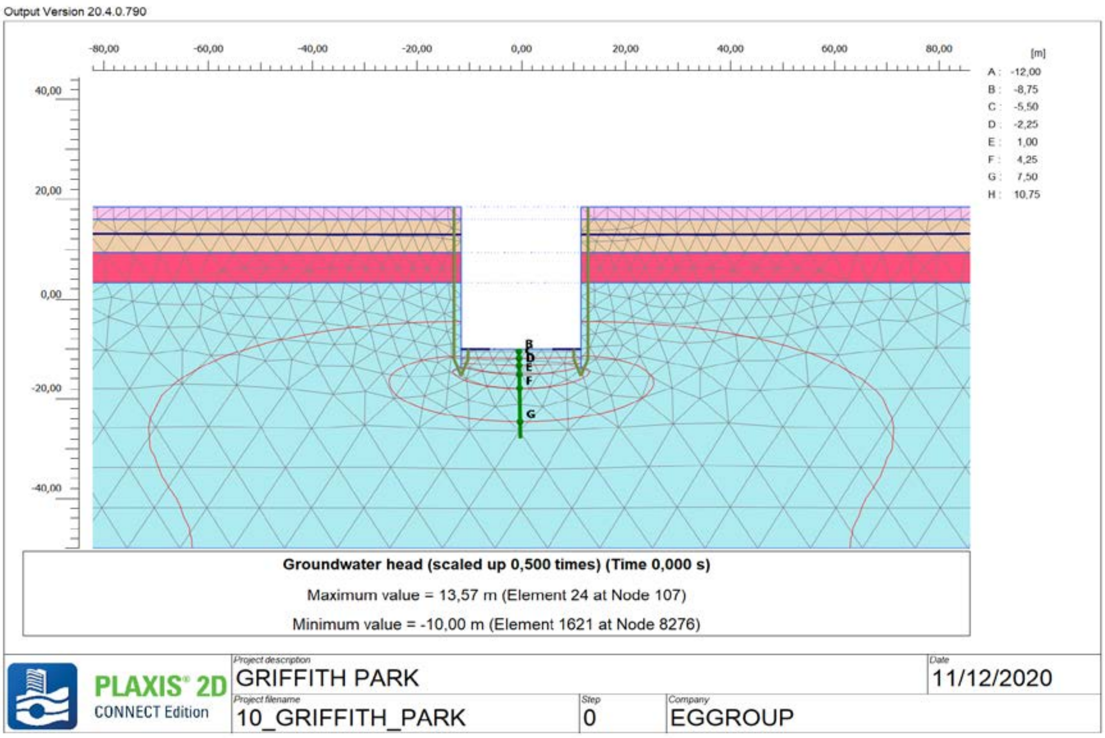


Figure 5-75. Illustration of groundwater head. Griffith Park Station.

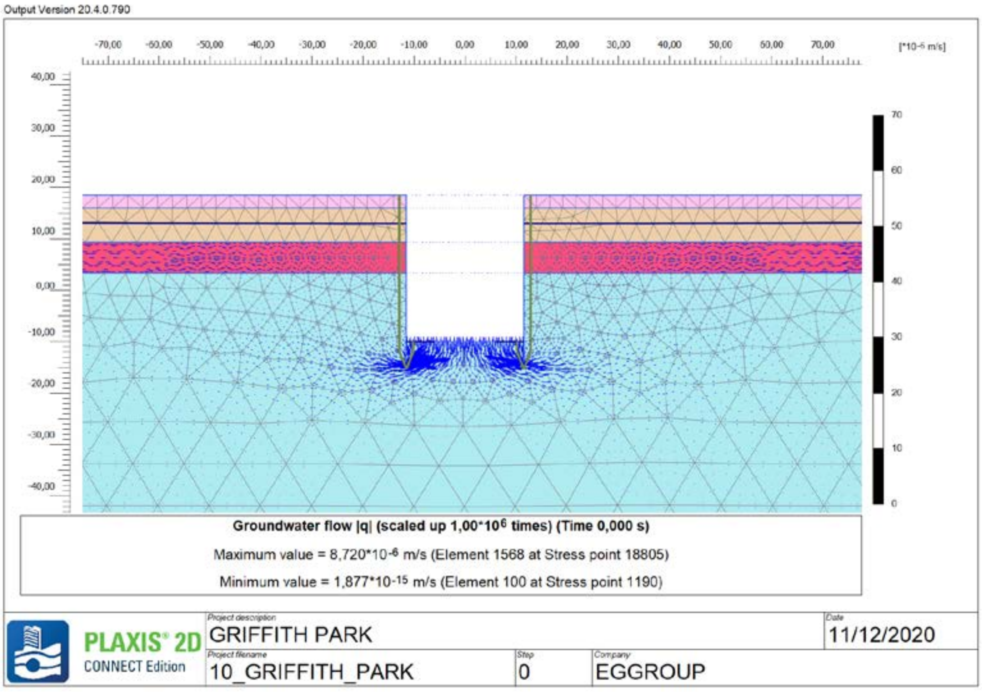


Figure 5-76. Illustration of groundwater flow. Griffith Park Station.

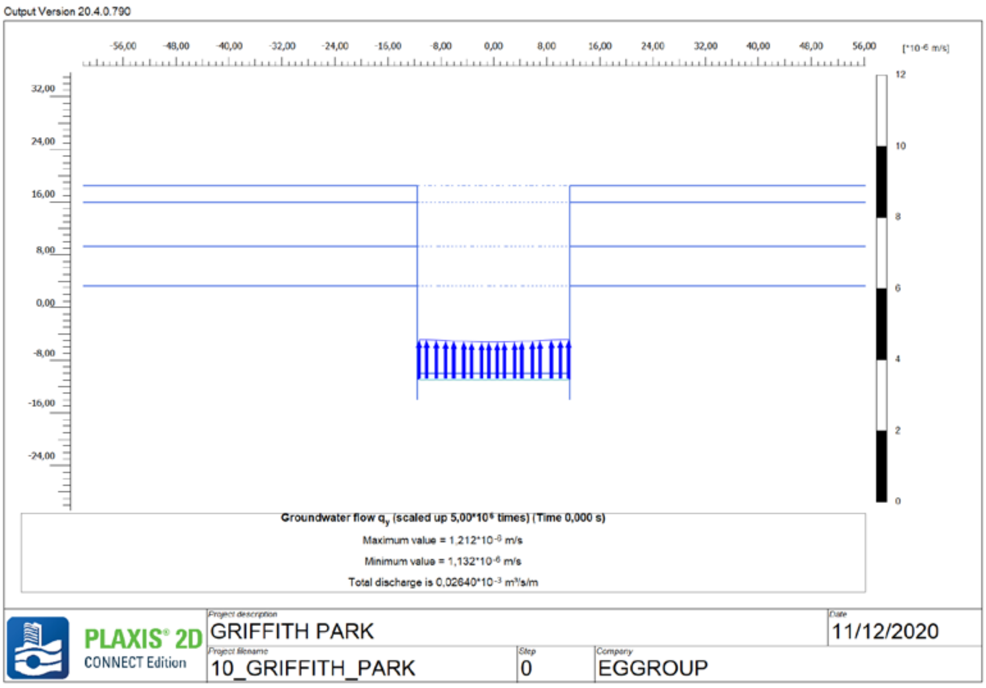


Figure 5-77. Water discharge ratio at the bottom of the excavation. Griffith Park Station.

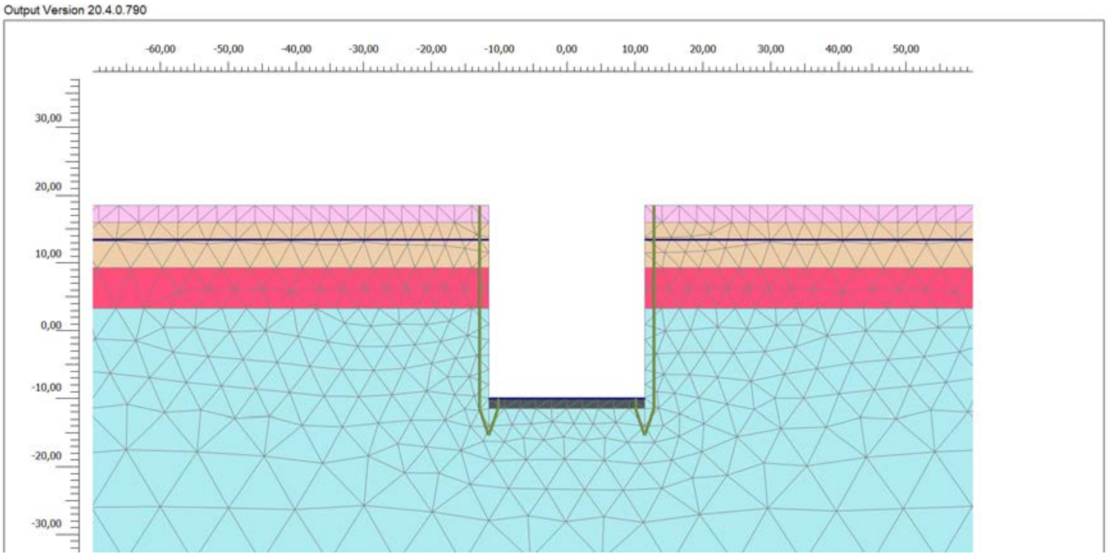


Figure 5-78. Bottom Plug geometry embedded in 2D model. Griffith Park Station.

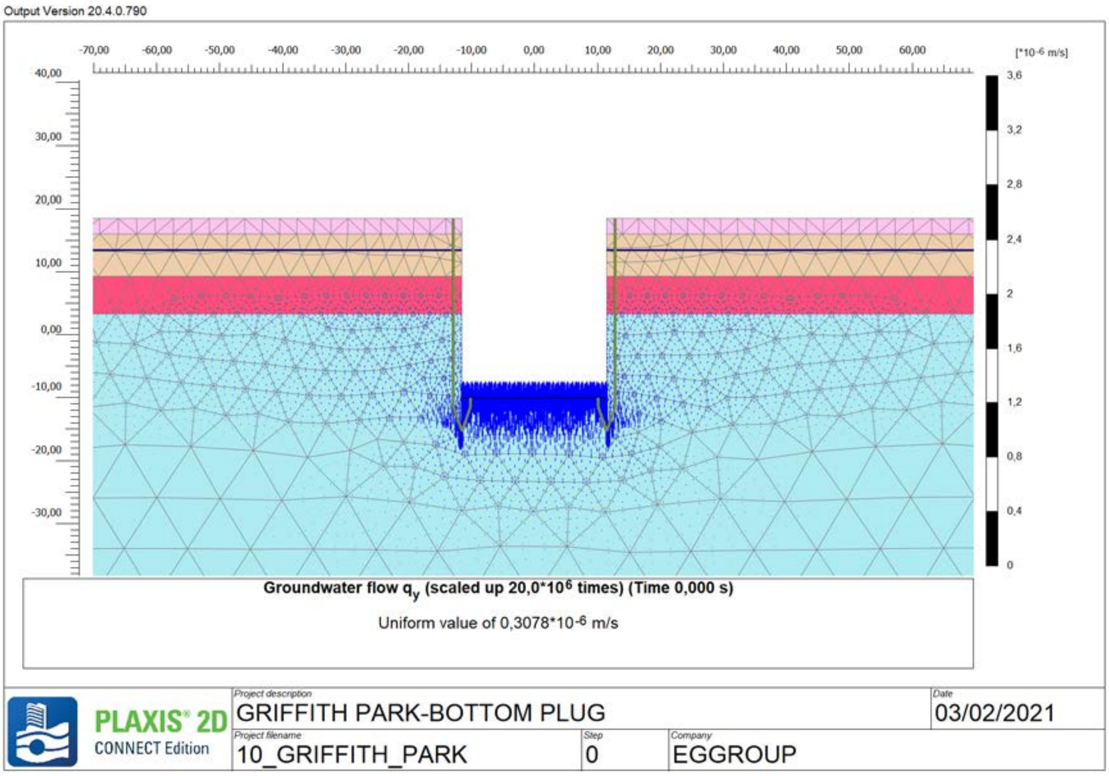


Figure 5-79. Groundwater flow (qy) with Bottom Plug. Griffith Park Station.

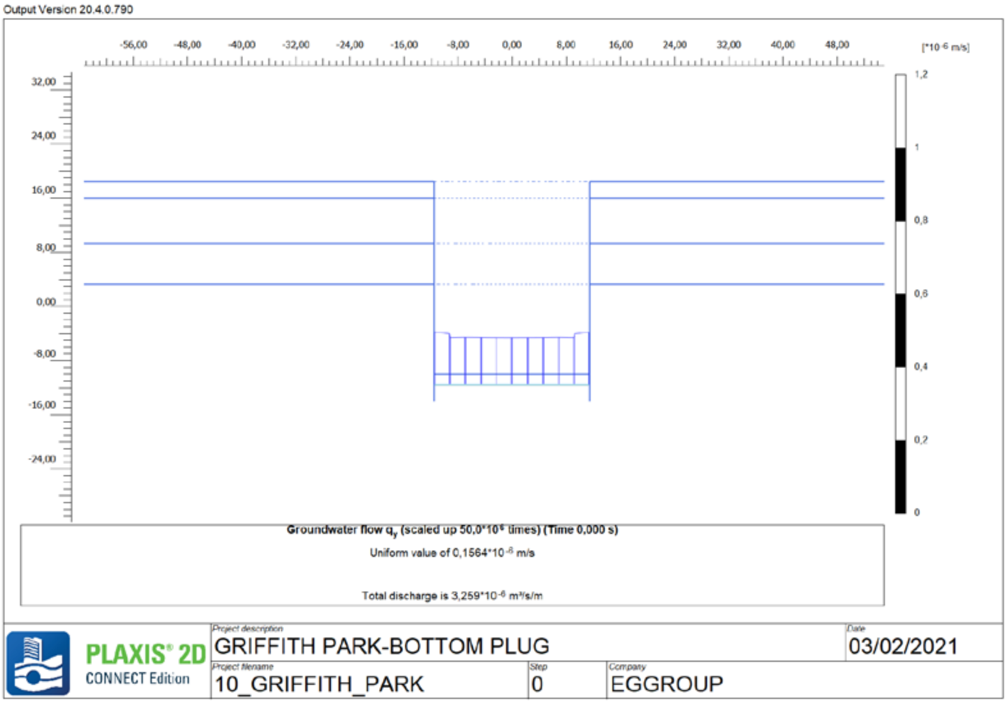


Figure 5-80. Water discharge ratio at the bottom of the excavation with Bottom Plug. Griffith Park Station.

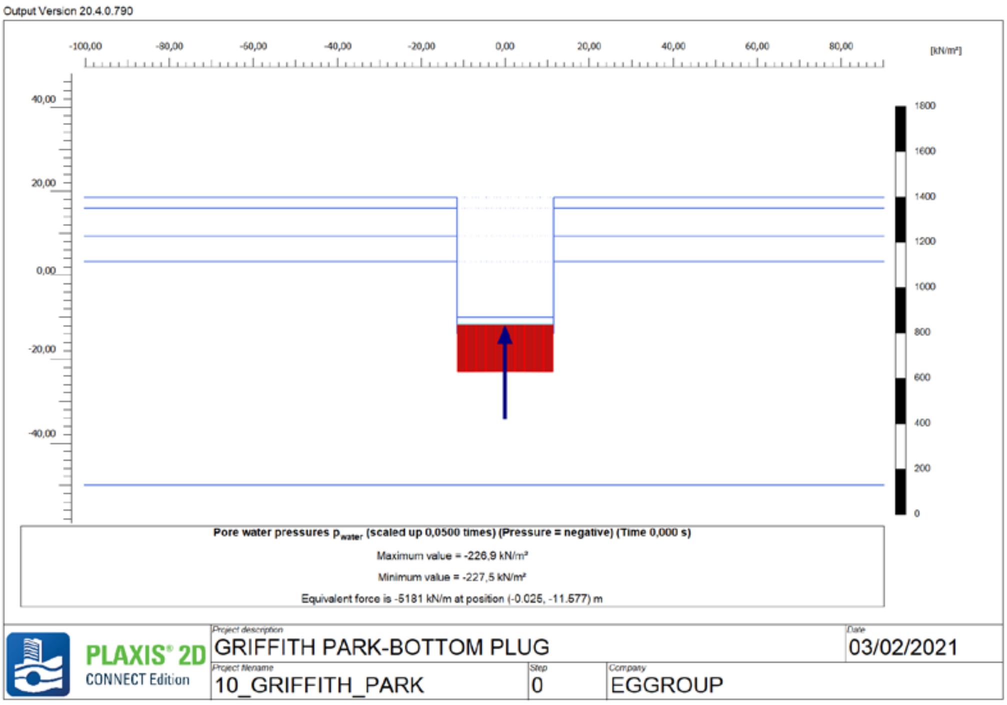


Figure 5-81. Pore water pressure under Bottom Plug. Griffith Park Station.

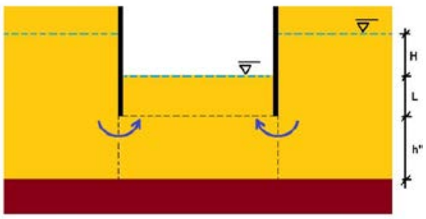
5.10 Glasnevin

N	STATION NAME	Levels							
		TOP	Qx	QBR<10 m	QBR>10 m	QBR>10 m sand	QBR>10 m	BoD	CLU
		(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
11	GLASNEVIN	25	22,3	15	8,7	6	-3,9	-7,7	-17,28

thickness						
Qx	QBR<10 m	QBR>10 m	QBR>10 m sand	QBR>10 m	BoD	CLU
(m)	(m)	(m)	(m)	(m)	(m)	(m)
0,00	5,11	6,30	2,70	9,90	3,80	9,58

	K(Permeability)						
	Qx	QBR<10 m	QBR>10 m	QBR>10 m sand	QBR>10 m	BoD	CLU
	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)
Kx	7,65E-07	7,62E-07	6,64E-06	8,59E-06	6,64E-06	2,90E-04	4,70E-06
Kv	7,65E-07	7,62E-07	6,64E-06	8,59E-06	6,64E-06	2,90E-04	4,70E-07

Exc.	W.L.
(m)	(m)
-4	19,3



$$k_{II} = \frac{H}{\sum_{1}^{m} \frac{H_{\alpha}}{k_{\alpha}}}$$

$$h'_{min} = \frac{ab}{2(a+b)}$$

$$k_I = \frac{\sum_{i=1}^{n} k_i \cdot H_i}{H}$$

Kh	Kv	H	L	a	b	h´	Vol	ro	φ1	φ2	R	Rf	Qv (Dupuit formula)	Q Plaxis	Q Plaxis	Qt
(m/s)	(m/s)	(m)	(m)	(m)	(m)	(m)	(m3)	(m)	(m)	(m)	(m)	(m)	(m3/s/m)	(m3/s/m)	(m3/d/m)	(m3/d)
3,43E-05	1,25E-06	23,30	4,00	23,00	96,00	9,28	5,14E+04	26,51	69,30	46,00	178,93	180,88	1,86E-05	7,24E-05	6,26	600,68

Q Plaxis	Q Plaxis	Qt	Water pressure under grout slab
(m3/s/m)	(m3/d/m)	(m3/d)	(kN/m2)
3,41E-06	0,29	28,28	238,00

Figure 5-82. Summary of results. Glasnevin Station.

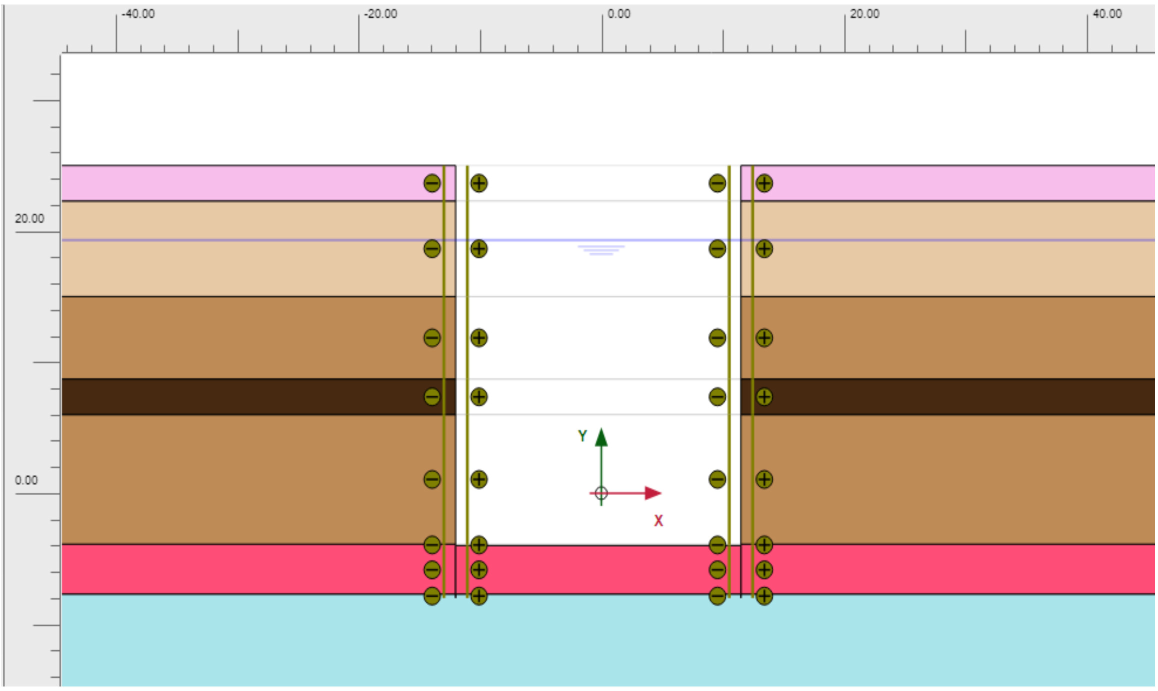


Figure 5-83. Illustration of Plaxis 2D Model. Glasnevin Station.

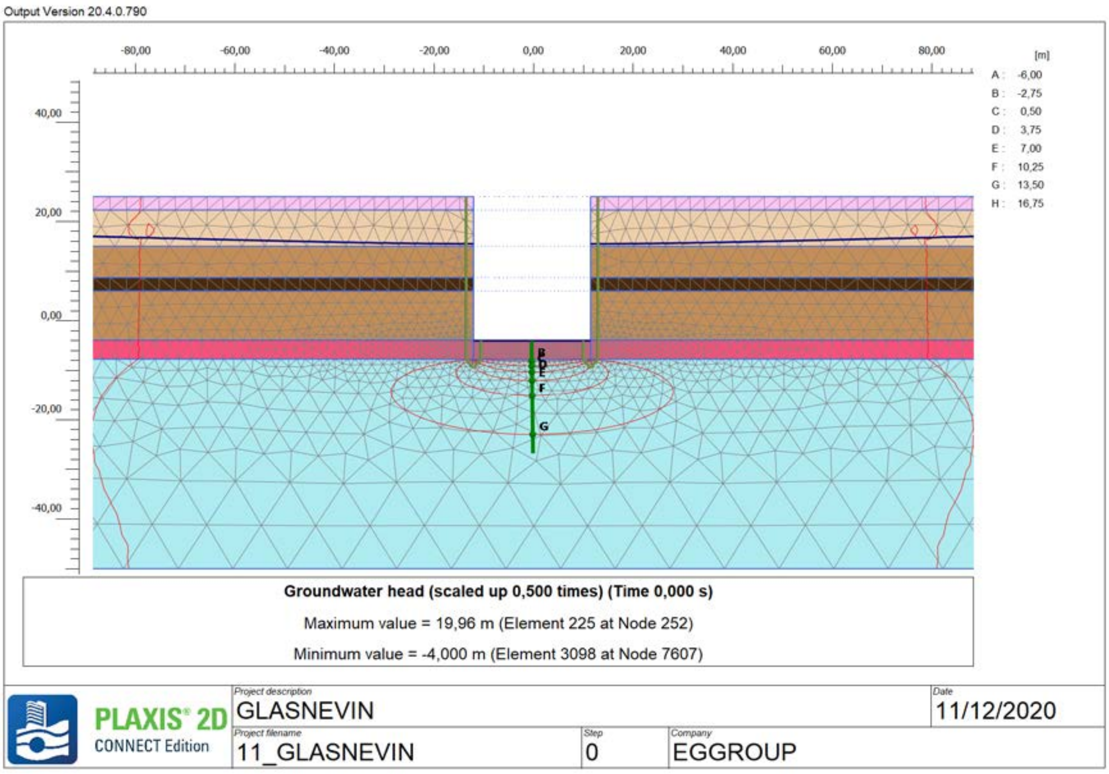


Figure 5-84. Illustration of groundwater head. Glasnevin Station.

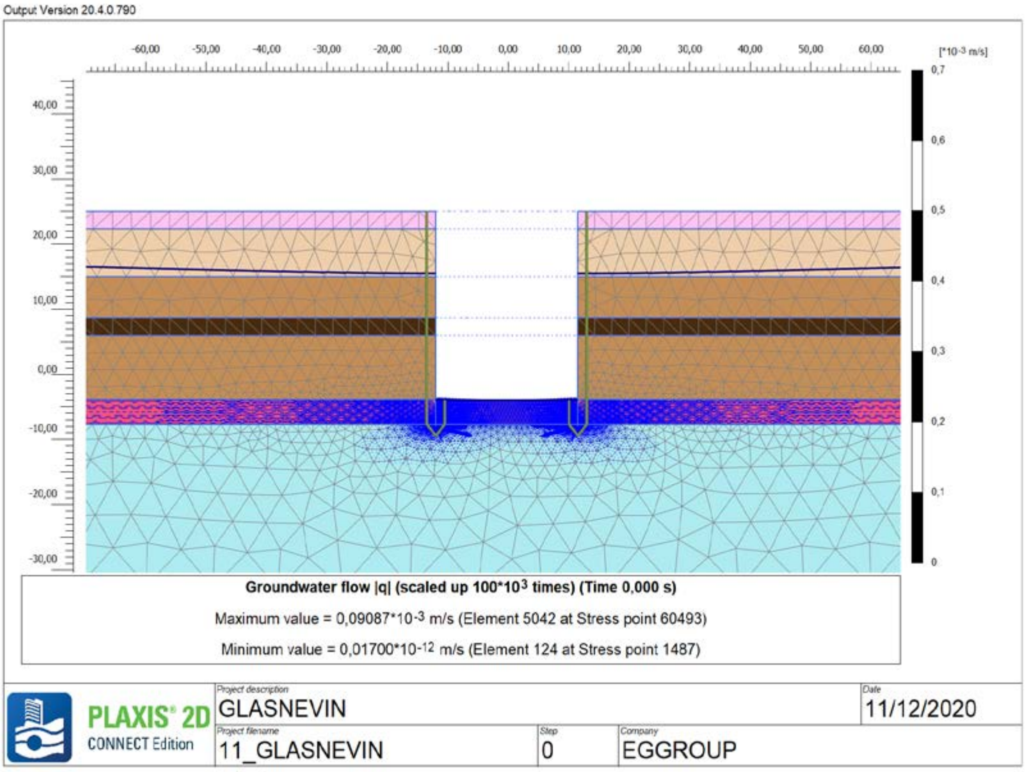


Figure 5-85. Illustration of groundwater flow. Glasnevin Station.

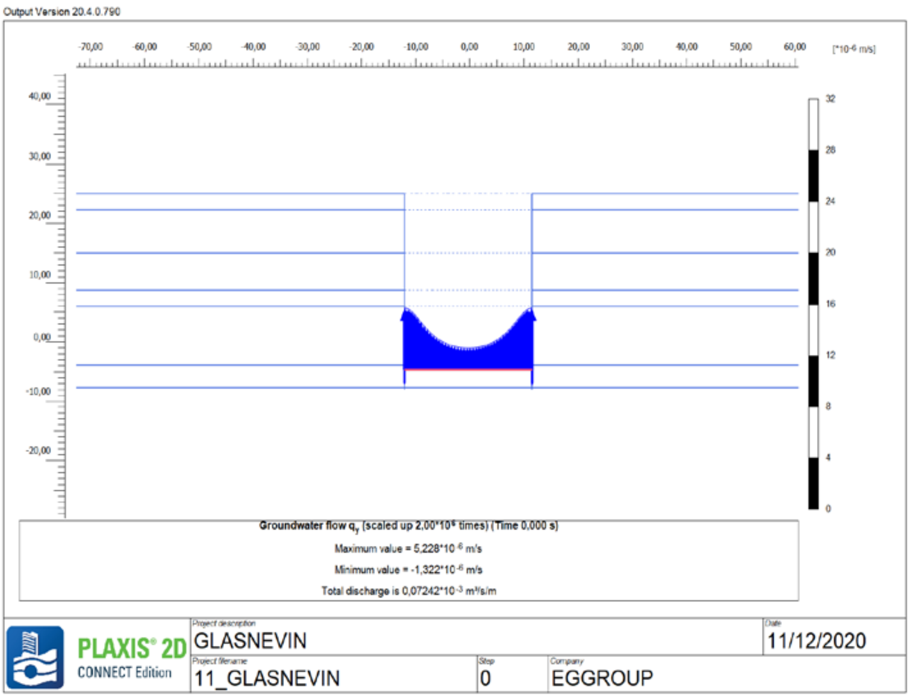


Figure 5-86. Water discharge ratio at the bottom of the excavation. Glasnevin Station.

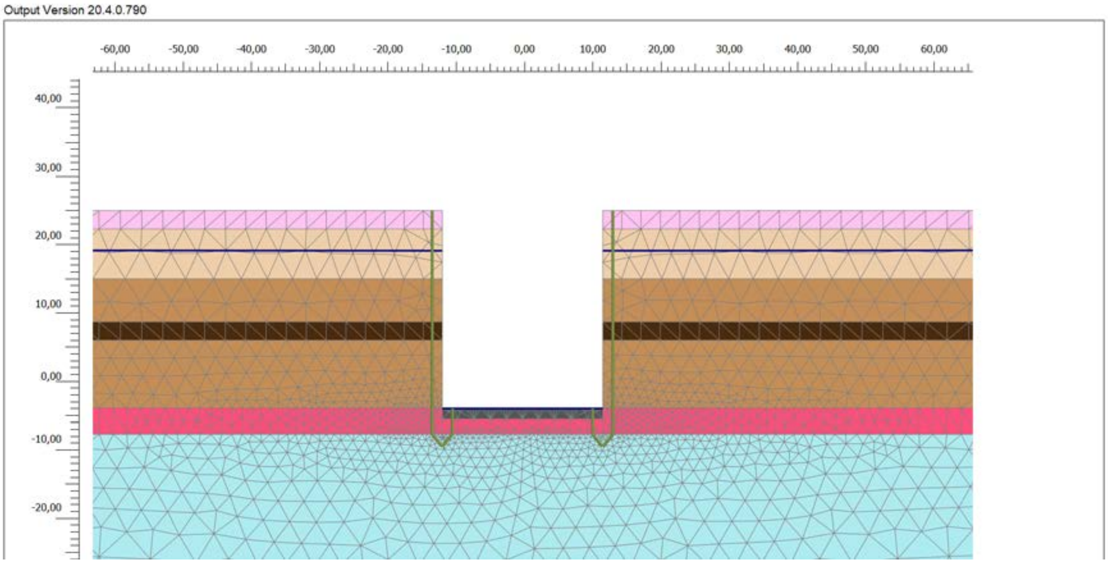


Figure 5-87. Bottom Plug geometry embedded in 2D model. Glasnevin Station.

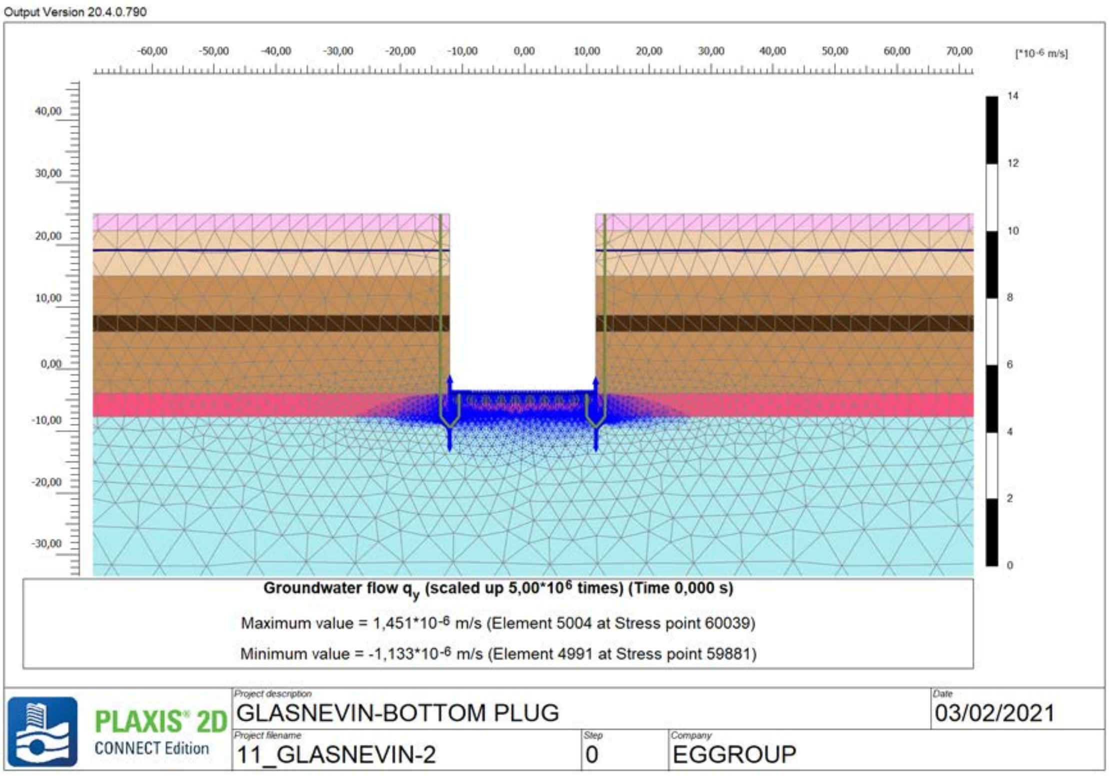


Figure 5-88. Groundwater flow (qy) with Bottom Plug. Glasnevin Station.

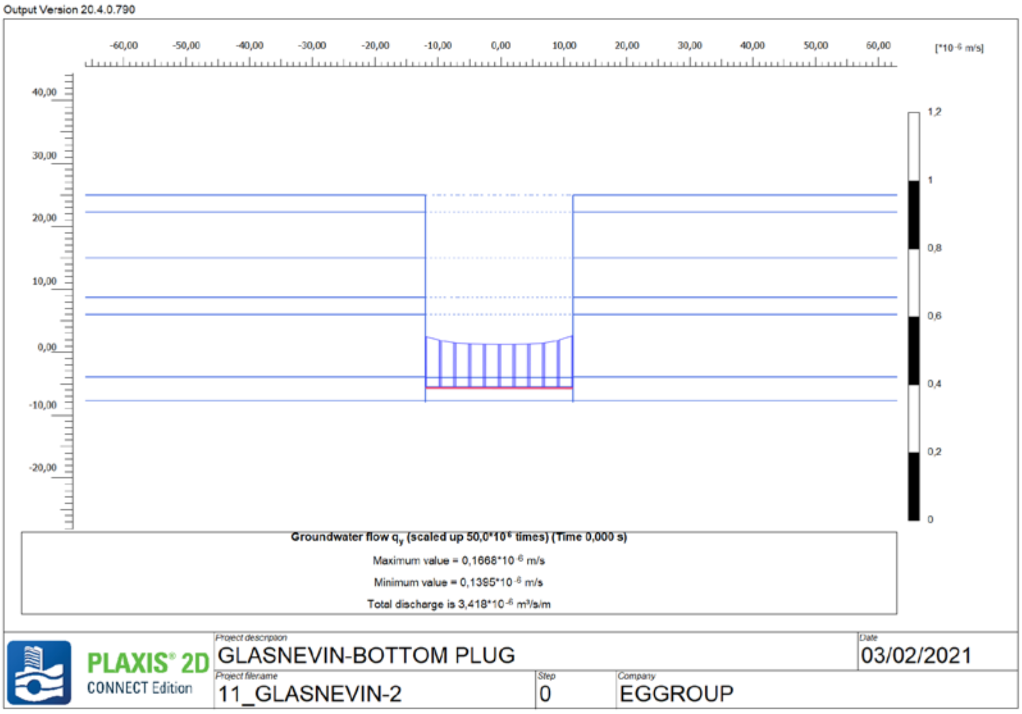


Figure 5-89. Water discharge ratio at the bottom of the excavation with Bottom Plug. Glasnevin Station.

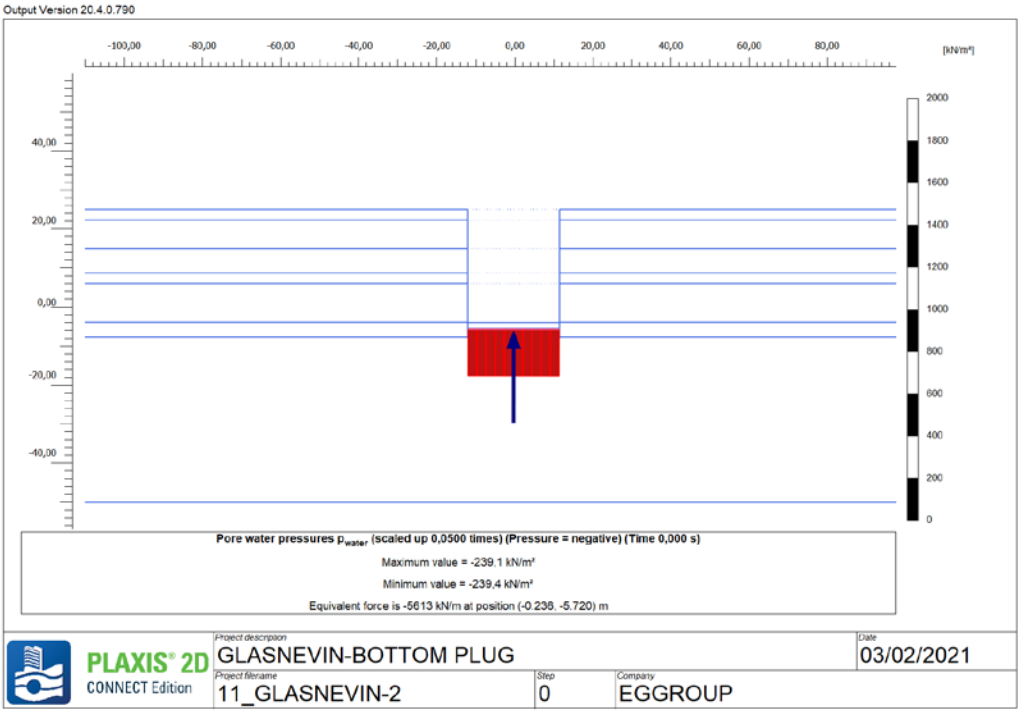


Figure 5-90. Pore water pressure under Bottom Plug. Glasnevin Station.

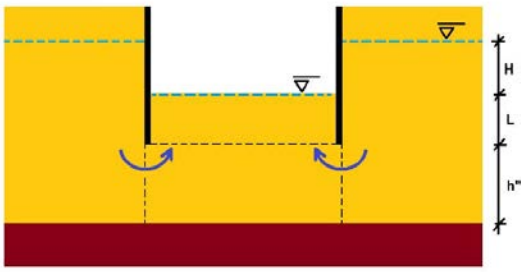
5.11 Mater

N	STATION NAME	Levels							
		TOP	Qx	QBR<10 m	QBR<10 m sand	QBR>10 m sand	QBR>10 m	BoD	CLU
		(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
12	MATER	22	19,4	15,8	12	5,8	-0,5	-5,1	-20,54

thickness						
Qx	QBR<10 m	QBR<10 m sand	QBR>10 m sand	QBR>10 m	BoD	CLU
(m)	(m)	(m)	(m)	(m)	(m)	(m)
1,95	3,6	3,8	6,2	6,3	4,6	15,4407407

	K(Permeability)						
	Qx	QBR<10 m	QBR<10 m sand	QBR>10 m sand	QBR>10 m	BoD	CLU
	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)
Kx	7,65E-07	7,62E-07	2,90E-06	8,59E-06	6,64E-06	2,90E-04	4,70E-06
Kv	7,65E-07	7,62E-07	2,90E-06	8,59E-06	6,64E-06	2,90E-04	4,70E-07

Exc.	W.L.
(m)	(m)
-6,3	21



$$k_{II} = \frac{H}{\sum_{1}^{m} \frac{H_a}{k_a}}$$

$$h'_{min} = \frac{ab}{2(a+b)}$$

$$k_I = \frac{\sum_{i=1}^{n} k_i \cdot H_i}{H}$$

Kh	Kv	H	L	a	b	h´	Vol	ro	φ1	φ2	R	Rf	Qv (Dupuit formula)	Q Plaxis	Q Plaxis	Qt
(m/s)	(m/s)	(m)	(m)	(m)	(m)	(m)	(m3)	(m)	(m)	(m)	(m)	(m)	(m3/s/m)	(m3/s/m)	(m3/d/m)	(m3/d)
3,62E-05	9,71E-07	27,30	4,70	23,00	112,00	9,54	7,03E+04	28,64	71,00	43,70	199,46	201,50	1,51E-05	3,10E-05	2,68	299,98

Q Plaxis	Q Plaxis	Qt	Water pressure under grout slab
(m3/s/m)	(m3/d/m)	(m3/d)	(kN/m2)
3,73E-06	0,32	36,09	261,00

Figure 5-91. Summary of results. Mater Station.

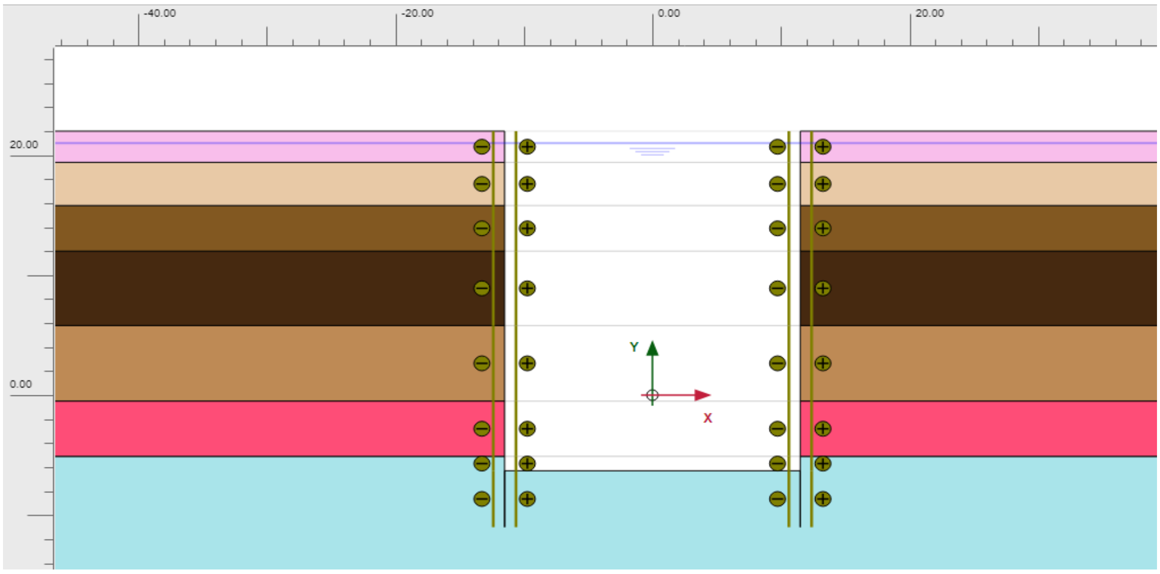


Figure 5-92. Illustration of Plaxis 2D Model. Mater Station.

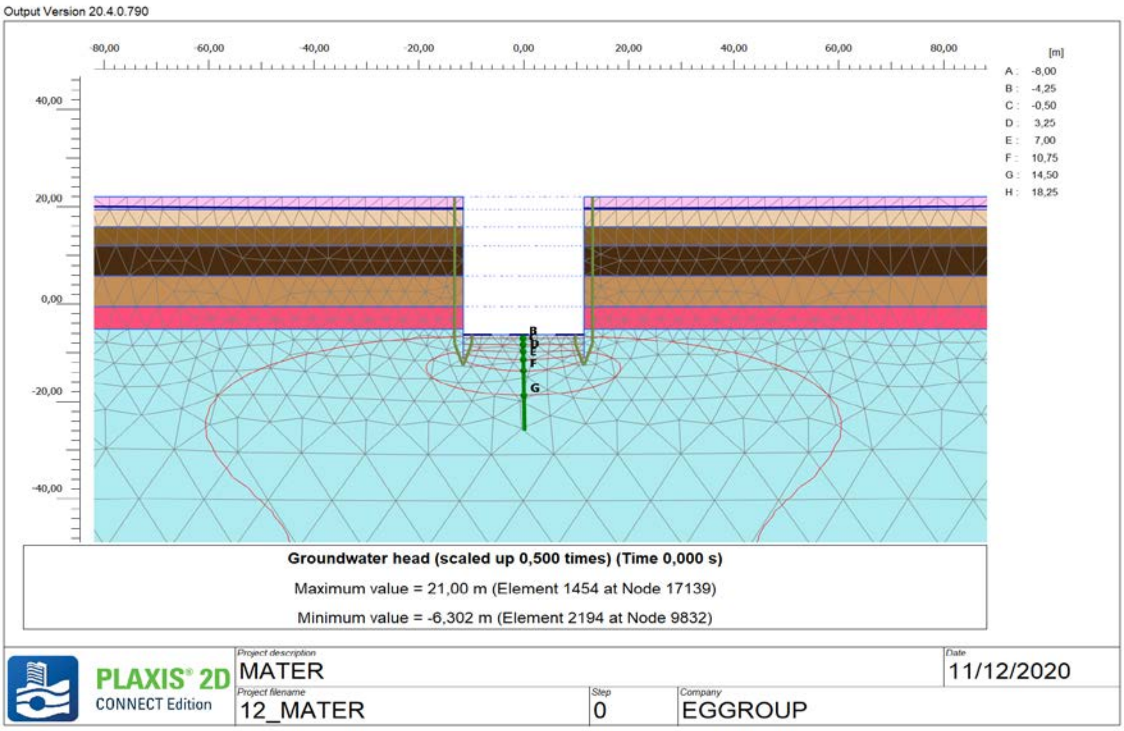


Figure 5-93. Illustration of groundwater head. Mater Station.

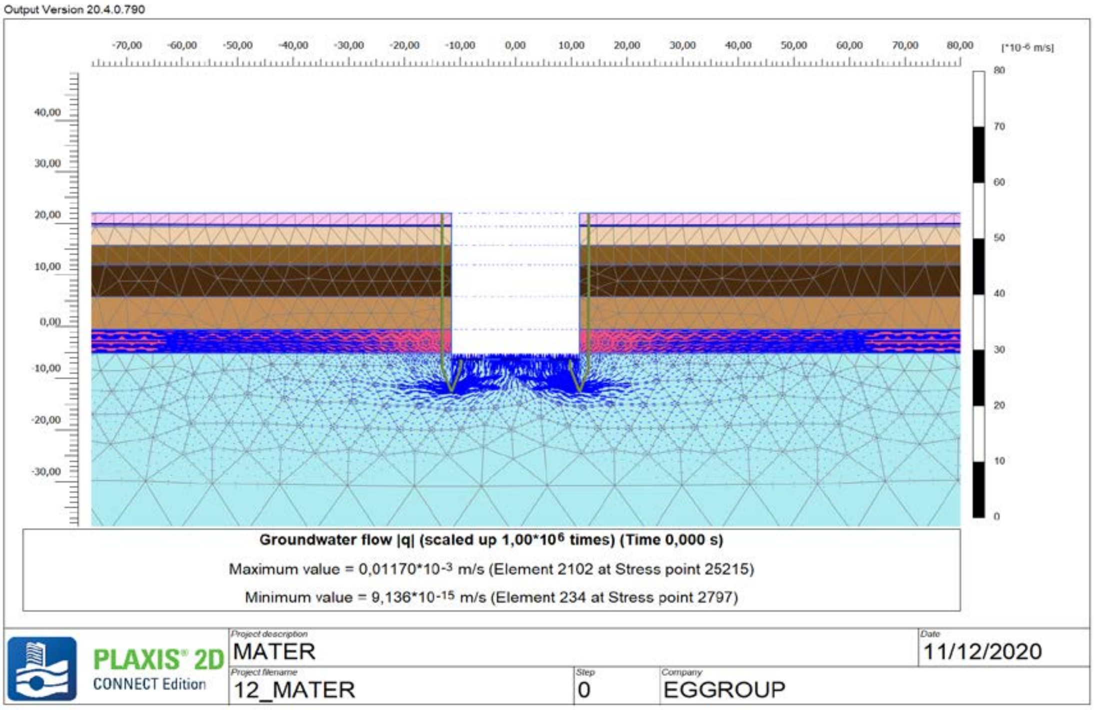


Figure 5-94. Illustration of groundwater flow Mater Station.

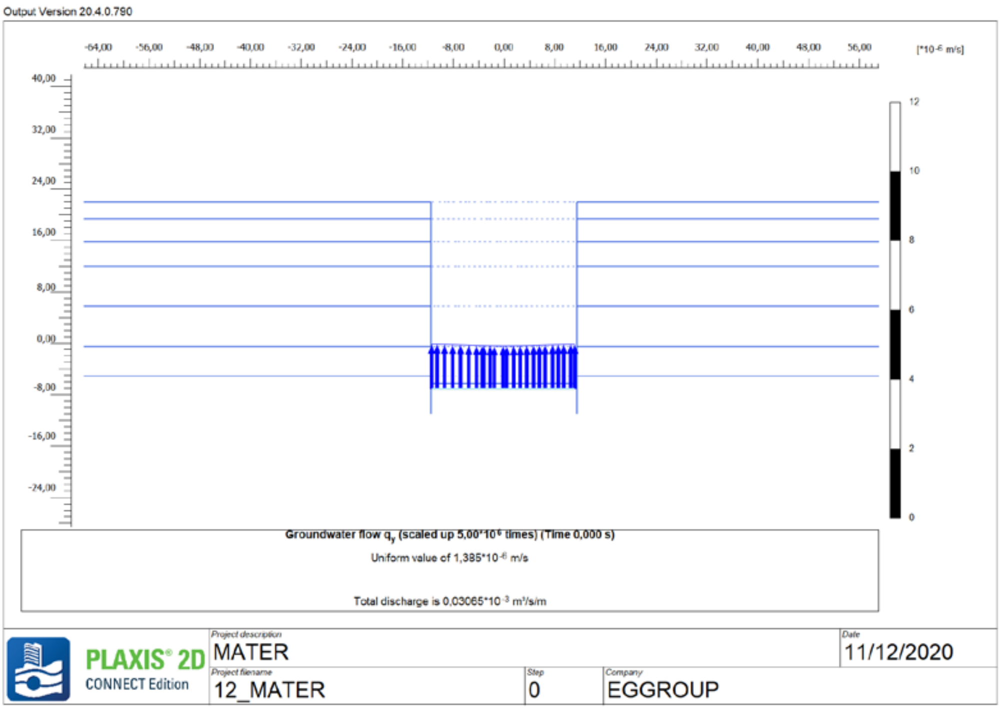


Figure 5-95. Water discharge ratio at the bottom of the excavation. Mater Station.

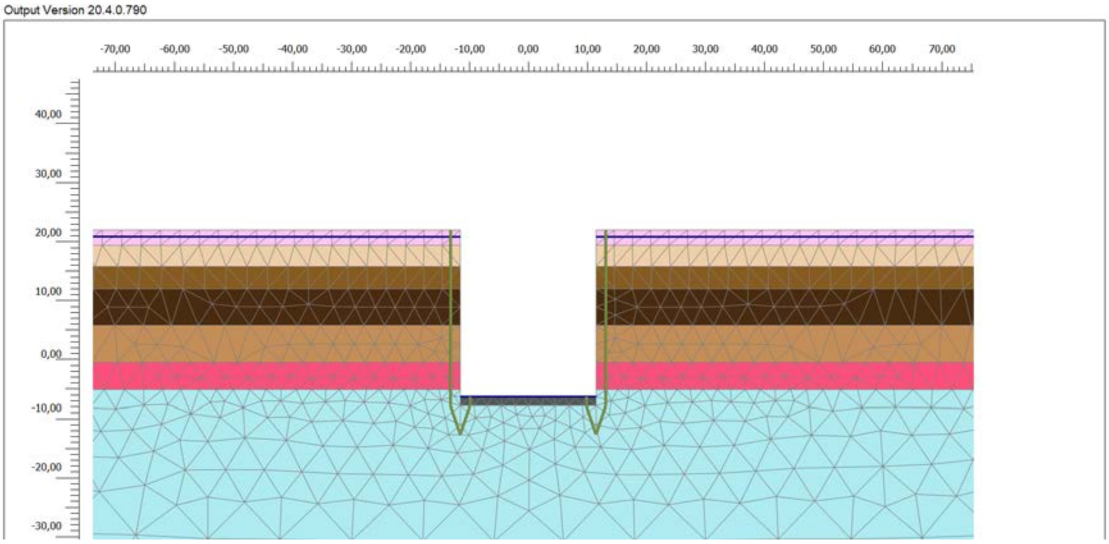


Figure 5-96. Bottom Plug geometry embedded in 2D model. Mater Station.

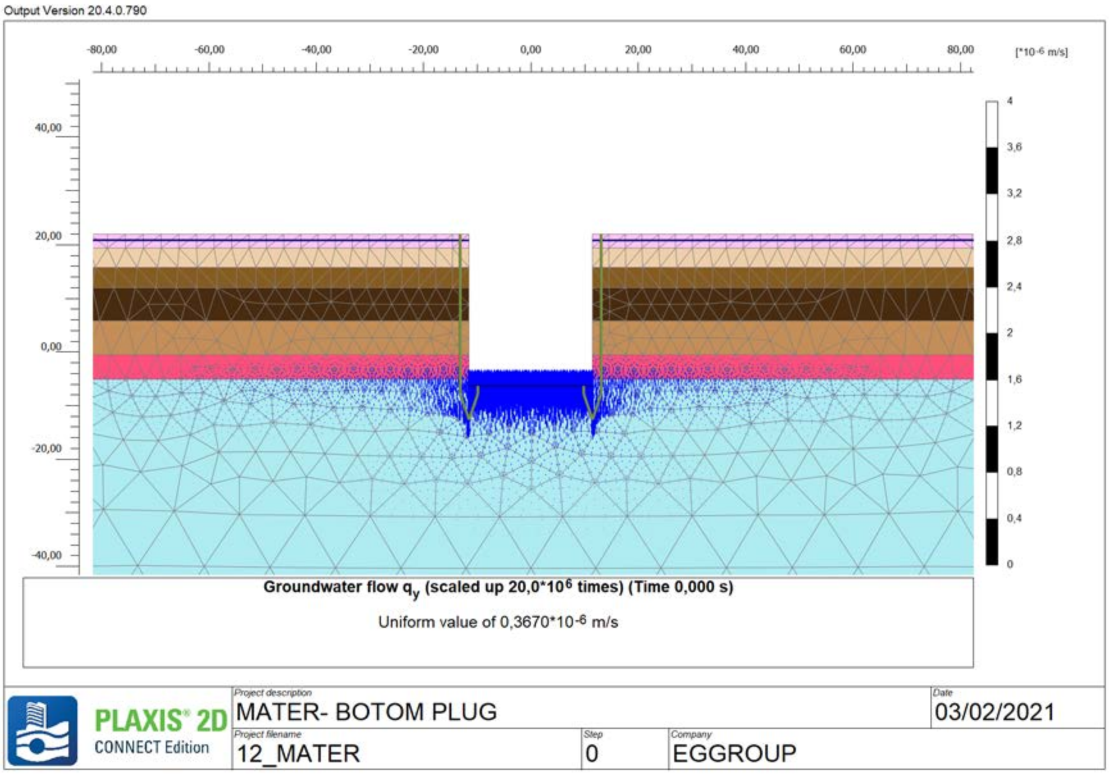


Figure 5-97. Groundwater flow (qy) with Bottom Plug. Mater Station.

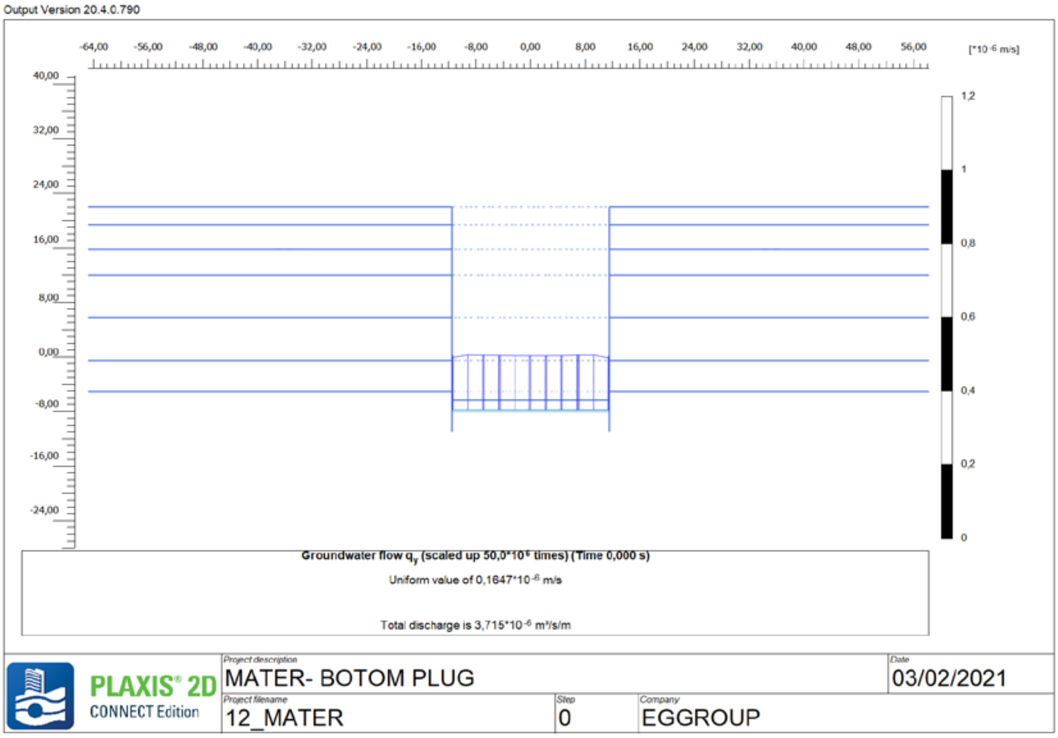


Figure 5-98. Water discharge ratio at the bottom of the excavation with Bottom Plug. Mater Station.

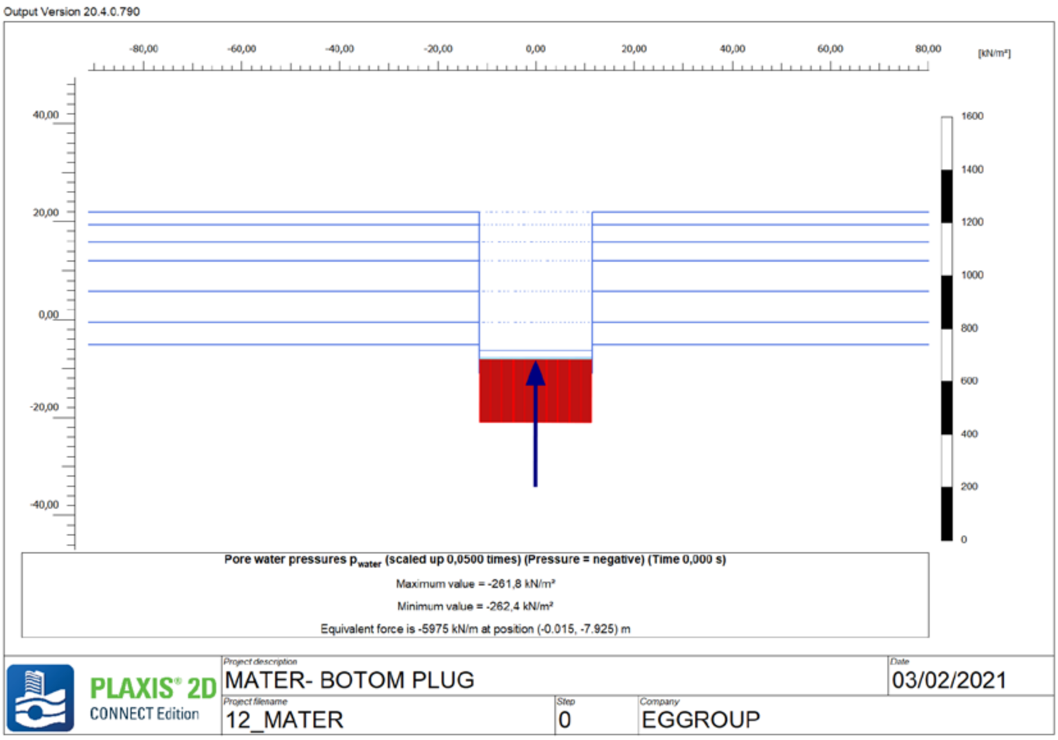


Figure 5-99. Pore water pressure under Bottom Plug. Mater Station.

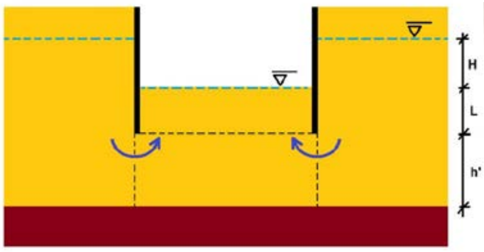
5.12 O´Conell Street

N	STATION NAME	INITIAL STA	END STA	Levels							
				TOP	Qx	QBR<10 m sand	QBR>10 m sand	QBR>10 m	QBR>10 m sand	BoD	CLU
				(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
13	O'CONNELL ST.	16+630	16+695	5,00	0,80	-5,00	-7,20	-14,00	-16,20	-20,10	-40,54

	thickness						
	Qx	QBR<10 m sand	QBR>10 m sand	QBR>10 m	QBR>10 m sand	BoD	CLU
	(m)	(m)	(m)	(m)	(m)	(m)	(m)
	0,00	5,80	2,20	6,80	2,20	3,90	20,44

	K(Permeability)						
	Qx	QBR<10 m sand	QBR>10 m sand	QBR>10 m	QBR>10 m sand	BoD	CLU
	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)
Kx	7,65E-07	2,90E-06	8,59E-06	6,64E-06	8,59E-06	2,90E-04	4,70E-06
Kv	7,65E-07	2,90E-06	8,59E-06	6,64E-06	8,59E-06	2,90E-04	4,70E-07

Exc.	W.L.
(m)	(m)
-24	1



$$k_{II} = \frac{H}{\sum_{1}^{m} \frac{H_a}{k_a}}$$

$$h'_{min} = \frac{ab}{2(a+b)}$$

$$k_I = \frac{\sum_{i=1}^{n} k_i \cdot H_i}{H}$$

Kh	Kv	H	L	a	b	h´	Vol	ro	φ1	φ2	R	Rf	Qv (Dupuit formula)	Q Plaxis	Q Plaxis	Qt
(m/s)	(m/s)	(m)	(m)	(m)	(m)	(m)	(m3)	(m)	(m)	(m)	(m)	(m)	(m3/s/m)	(m3/s/m)	(m3/d/m)	(m3/d)
3,21E-05	8,79E-07	25,00	7,00	23,00	112,00	9,54	6,44E+04	28,64	81,00	56,00	172,84	175,20	1,72E-05	2,20E-05	1,90	212,89

Q Plaxis	Q Plaxis	Qt	Water pressure under grout slab
(m3/s/m)	(m3/d/m)	(m3/d)	(kN/m2)
3,30E-06	0,29	31,93	238,00

Figure 5-100. Summary of results. O'Connell Street Station.

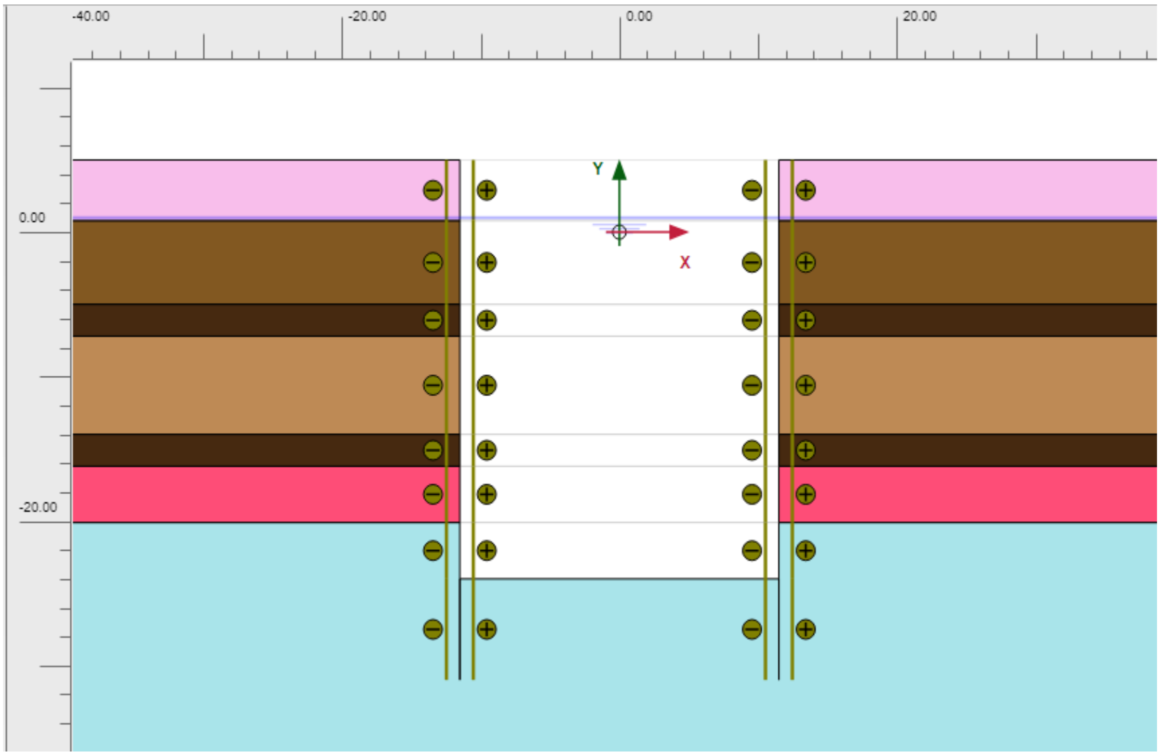


Figure 5-101. Illustration of Plaxis 2D Model. O'Connell Street Station.

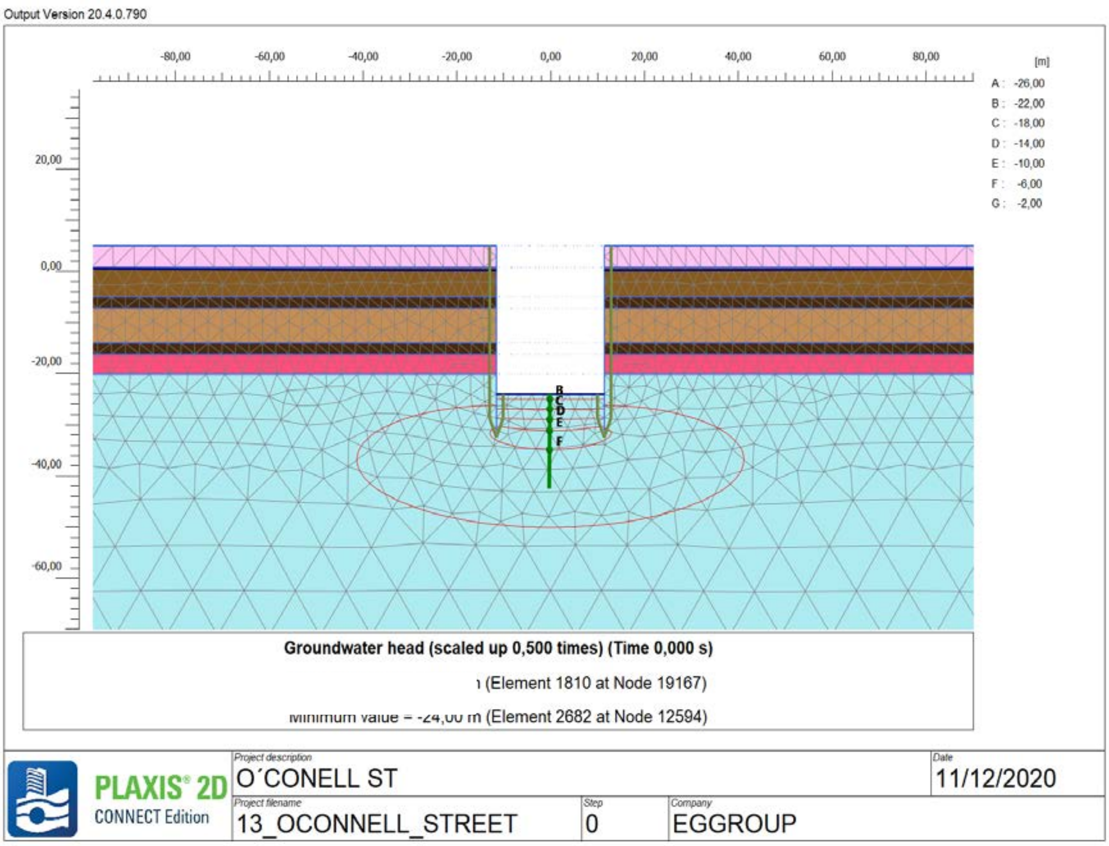


Figure 5-102. Illustration of groundwater head. O'Connell Street Station.

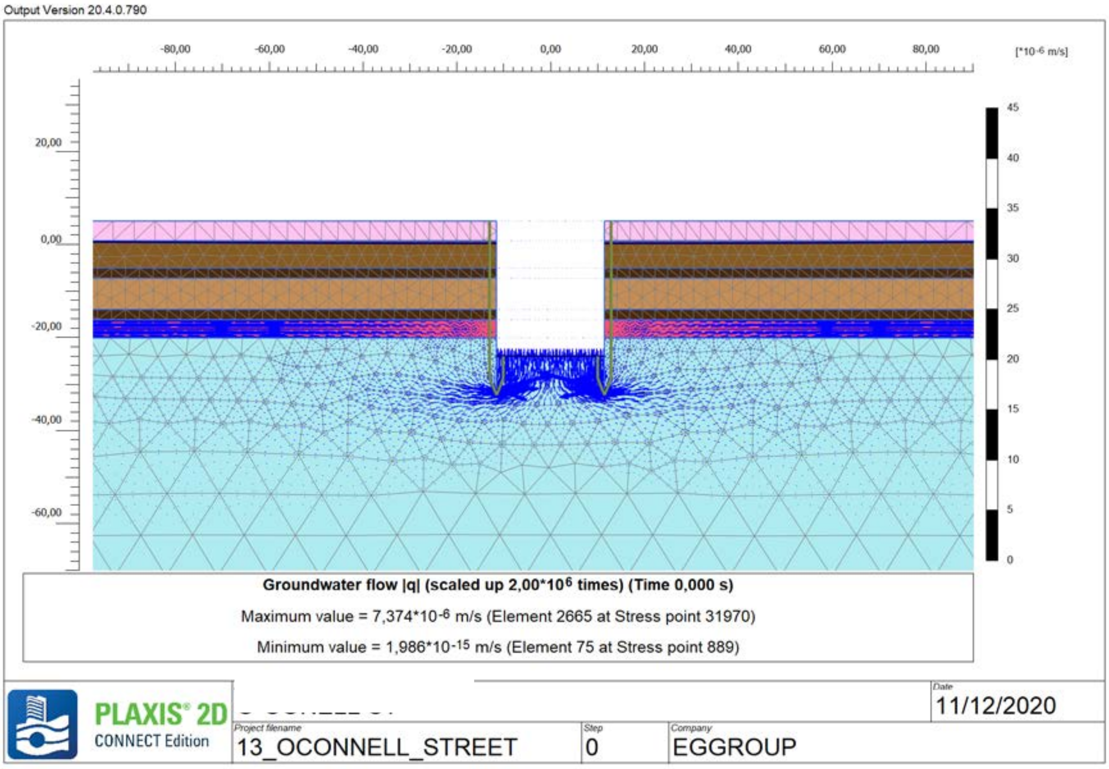


Figure 5-103. Illustration of groundwater flow. O'Connell Street Station.

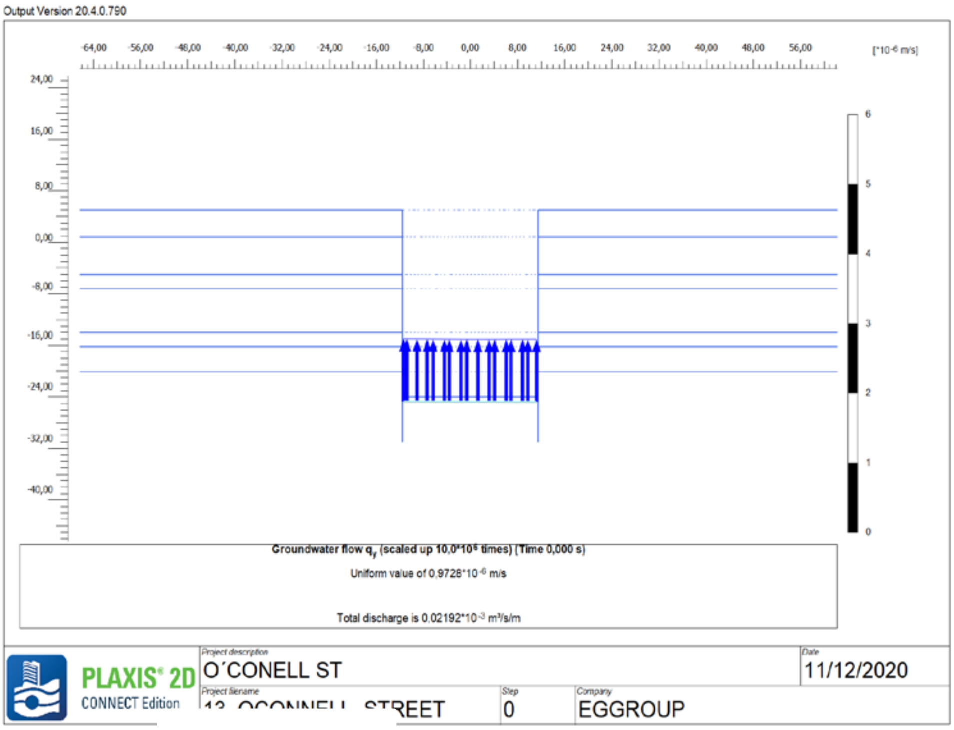


Figure 5-104. Water discharge ratio at the bottom of the excavation. O'Connell Street Station.

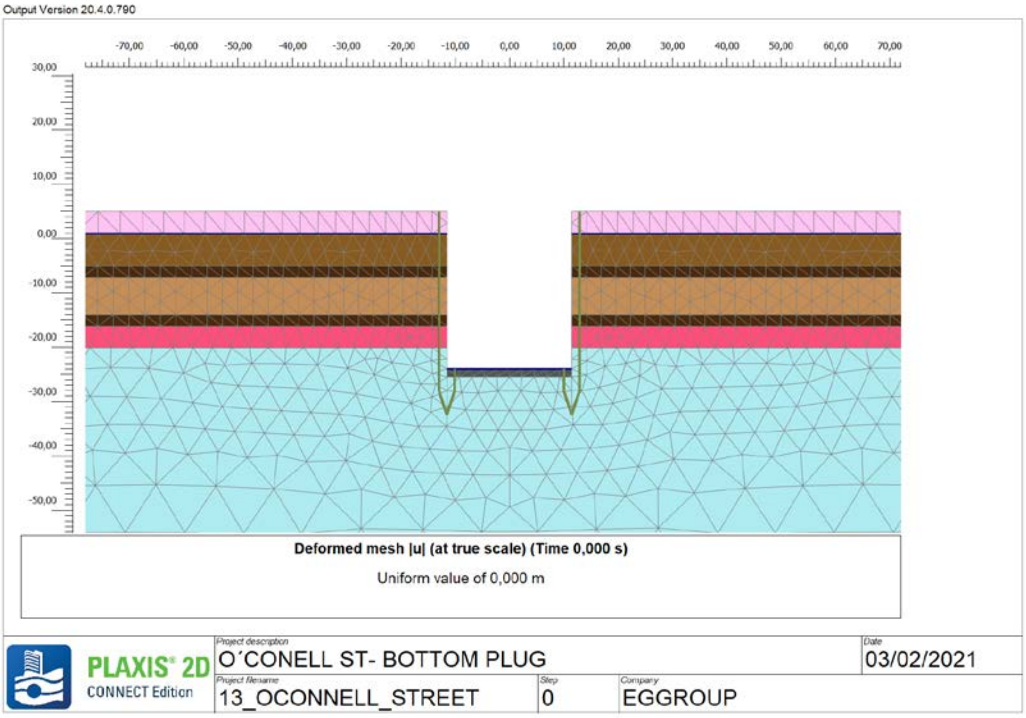


Figure 5-105. Bottom Plug geometry embedded in 2D model. O'Connell Street Station.

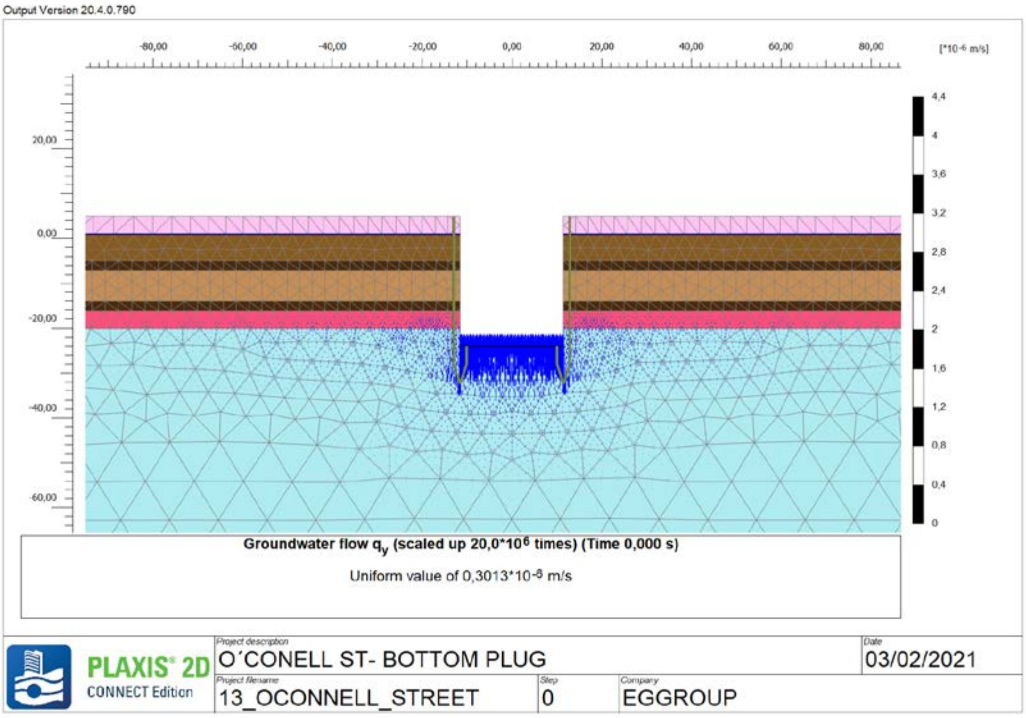


Figure 5-106. Groundwater flow (qy) with Bottom Plug. O'Connell Street Station.

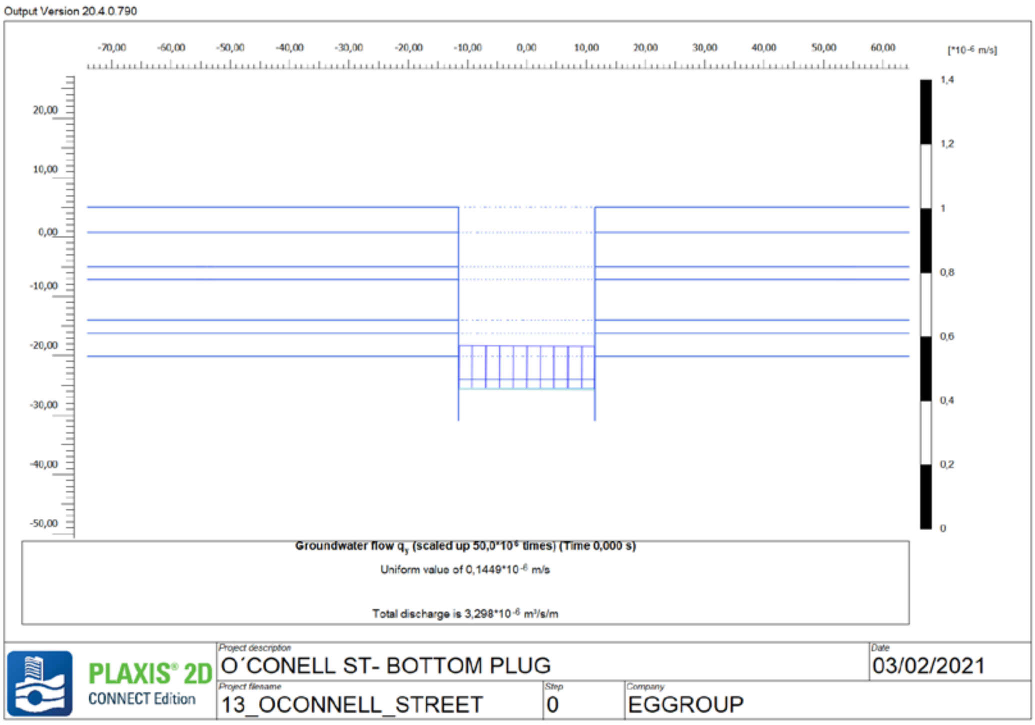


Figure 5-107. Water discharge ratio at the bottom of the excavation with Bottom Plug. O'Connell Street Station.

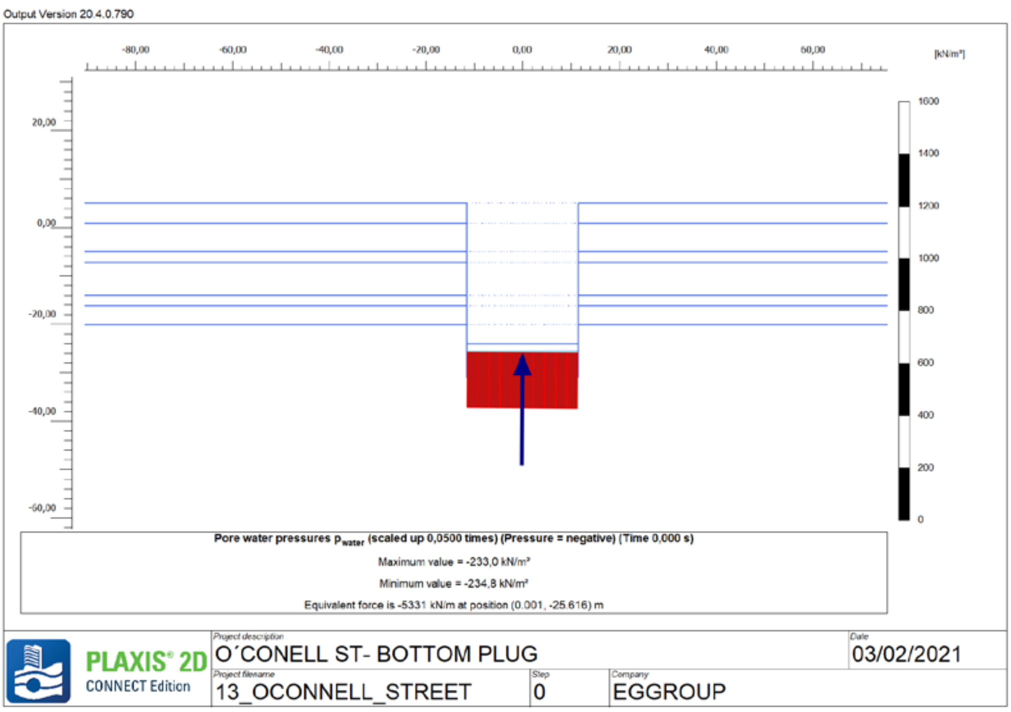


Figure 5-108. Pore water pressure under Bottom Plug. O'Connell Street Station.

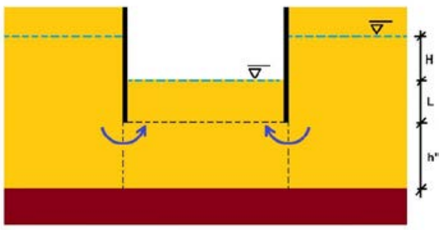
5.13 Tara

N	STATION NAME	TARA B				
		TOP	Qx	QAG	BoD	CLU
		(m)	(m)	(m)	(m)	(m)
14	TARA	3,5	0,8	-1	-7,2	-39,85

thickness			
Qx	QAG	BoD	CLU
(m)	(m)	(m)	(m)
0	1,8	6,2	32,6507246

	K(Permeability)			
	Qx	QAG	BoD	CLU
	(m/s)	(m/s)	(m/s)	(m/s)
Kx	7,65E-07	1,37E-05	2,90E-04	4,70E-06
Kv	7,65E-07	1,37E-05	2,90E-04	4,70E-07

Exc.	W.L.
(m)	(m)
-25,3	-0,2



$$k_{II} = \frac{H}{\sum_{1}^{m} \frac{H_u}{k_u}}$$

$$h'_{min} = \frac{ab}{2(a+b)}$$

$$k_i = \frac{\sum_{i=1}^{n} k_i \cdot H_i}{H}$$

Kh	Kv	s	emp	a	b	hmin	Vol	ro	φ1	φ2	R	Rf	Qv (Dupuit formula)	Q Plaxis	Q Plaxis	Qt
(m/s)	(m/s)	(m)	(m)	(m)	(m)	(m)	(m3)	(m)	(m)	(m)	(m)	(m)	(m3/s/m)	(m3/s/m)	(m3/d/m)	(m3/d)
4,86E-05	5,84E-07	25,10	4,00	26,00	112,00	10,55	7,31E+04	30,45	79,80	54,70	173,80	176,45	1,12E-05	2,60E-05	2,25	251,60

Q Plaxis	Q Plaxis	Qt	Water pressure under grout slab
(m3/s/m)	(m3/d/m)	(m3/d)	(kN/m2)
3,76E-06	0,32	36,38	251,00

Figure 5-109. Summary of results. Tara Station.

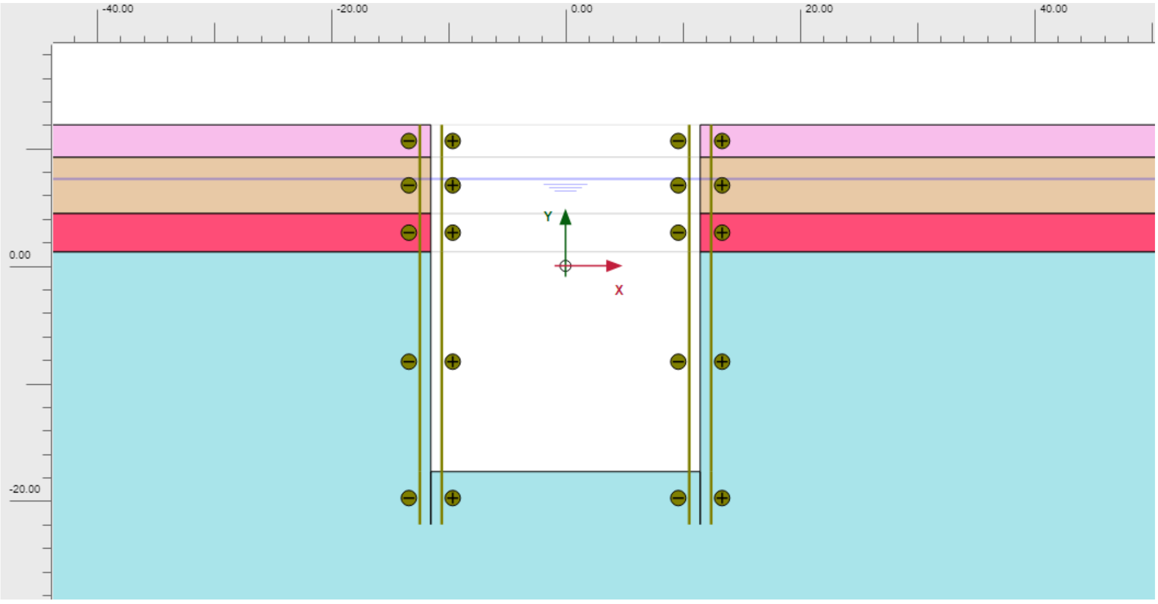


Figure 5-110. Illustration of Plaxis 2D Model. Tara Station.

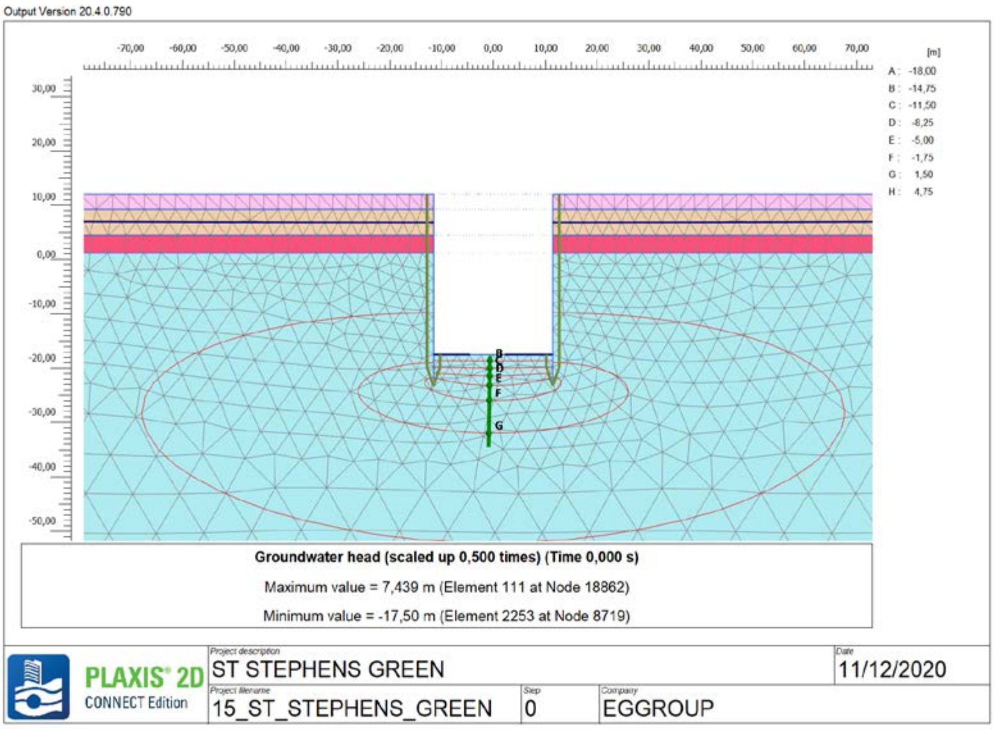


Figure 5-111. Illustration of groundwater head. Tara Station.

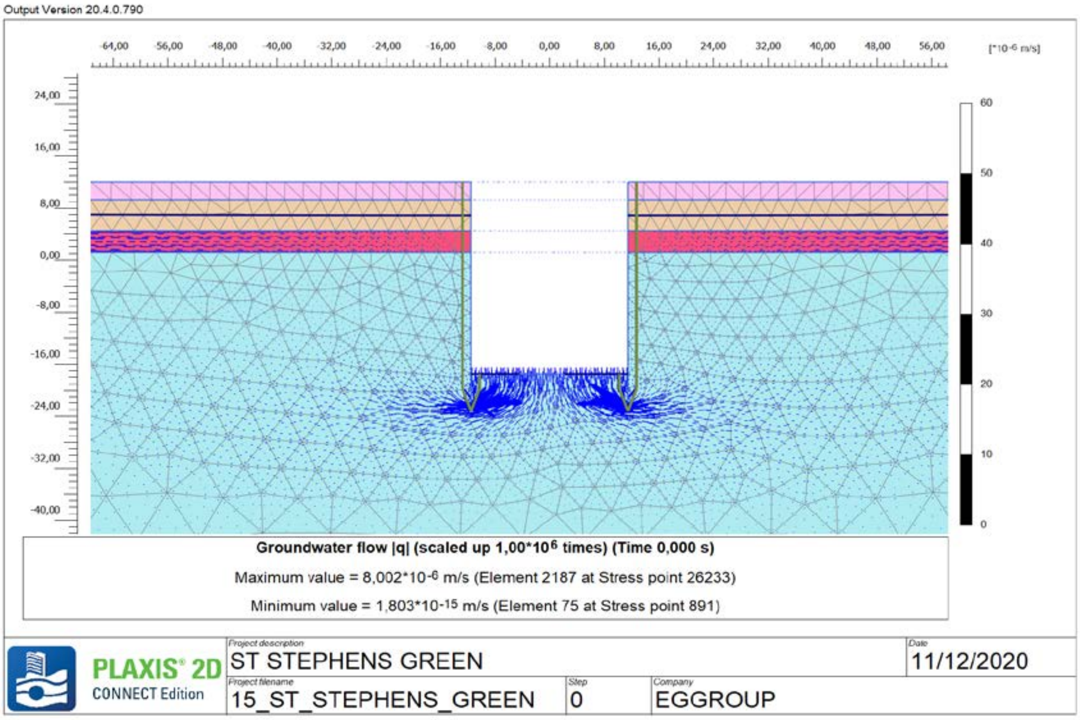


Figure 5-112. Illustration of groundwater flow. Tara Station.

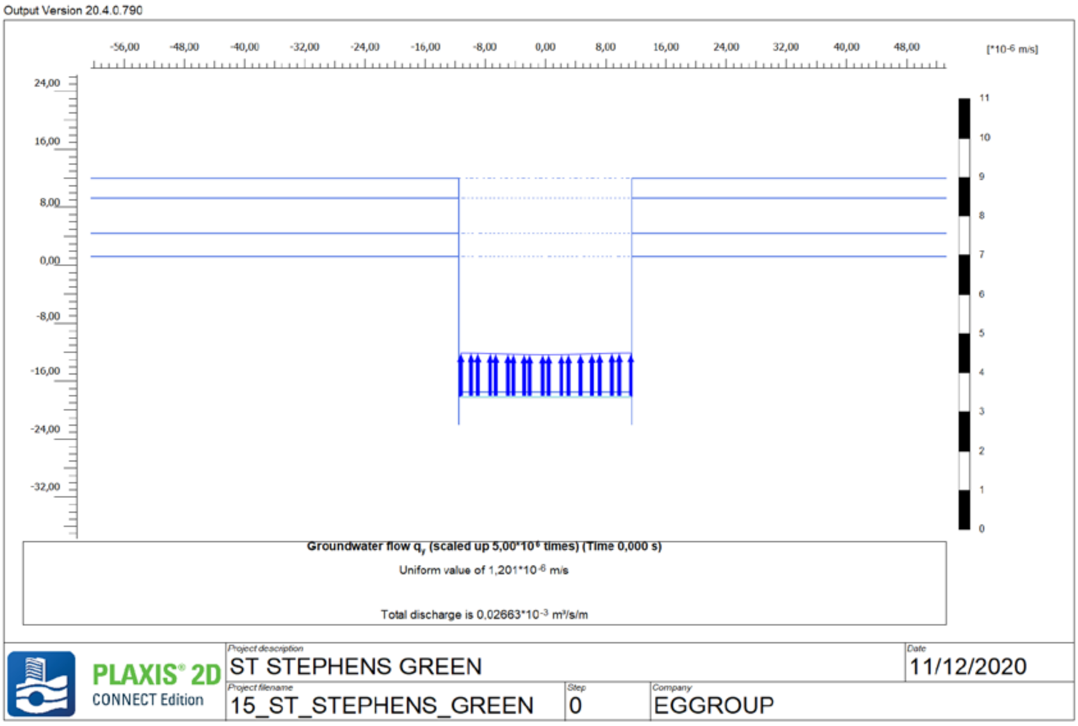


Figure 5-113. Water discharge ratio at the bottom of the excavation. Tara Station.

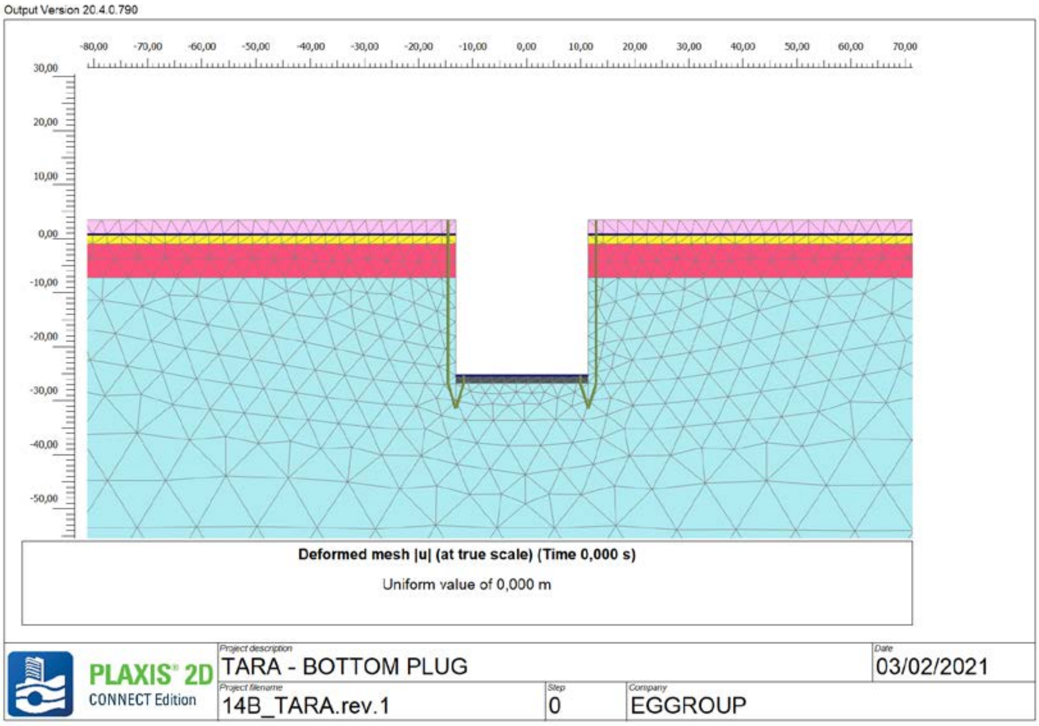


Figure 5-114. Bottom Plug geometry embedded in 2D model. Tara Station.

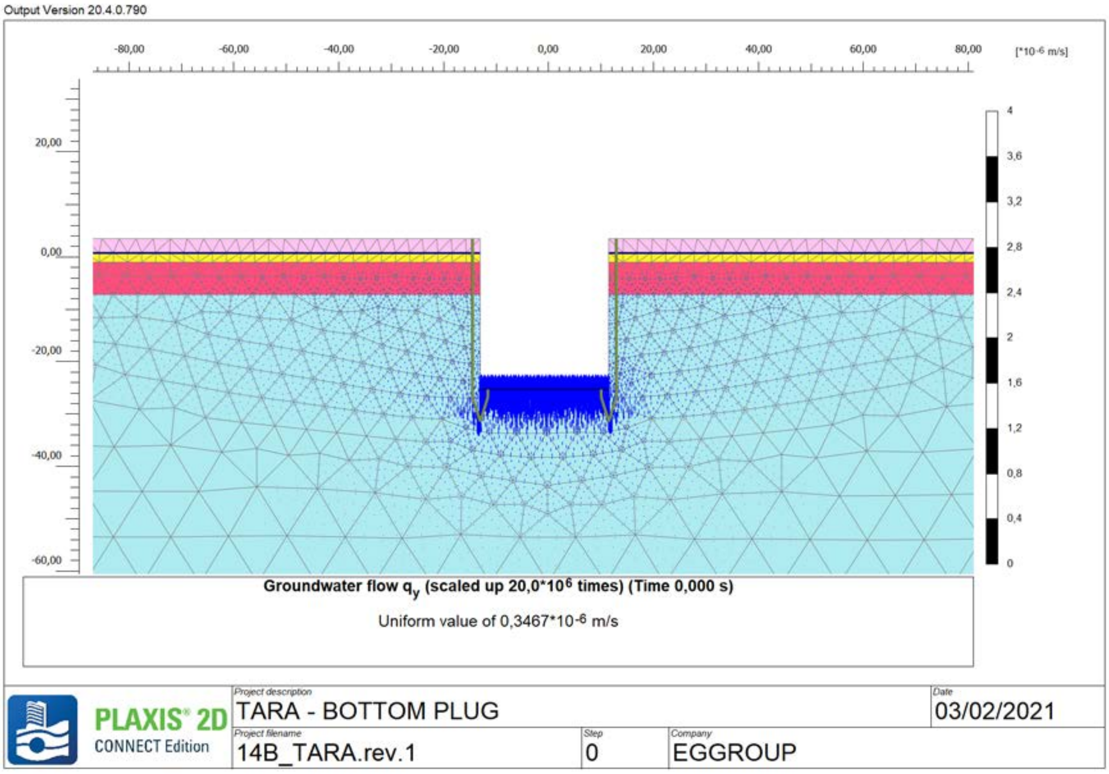


Figure 5-115. Groundwater flow (qy) with Bottom Plug. Tara Station.

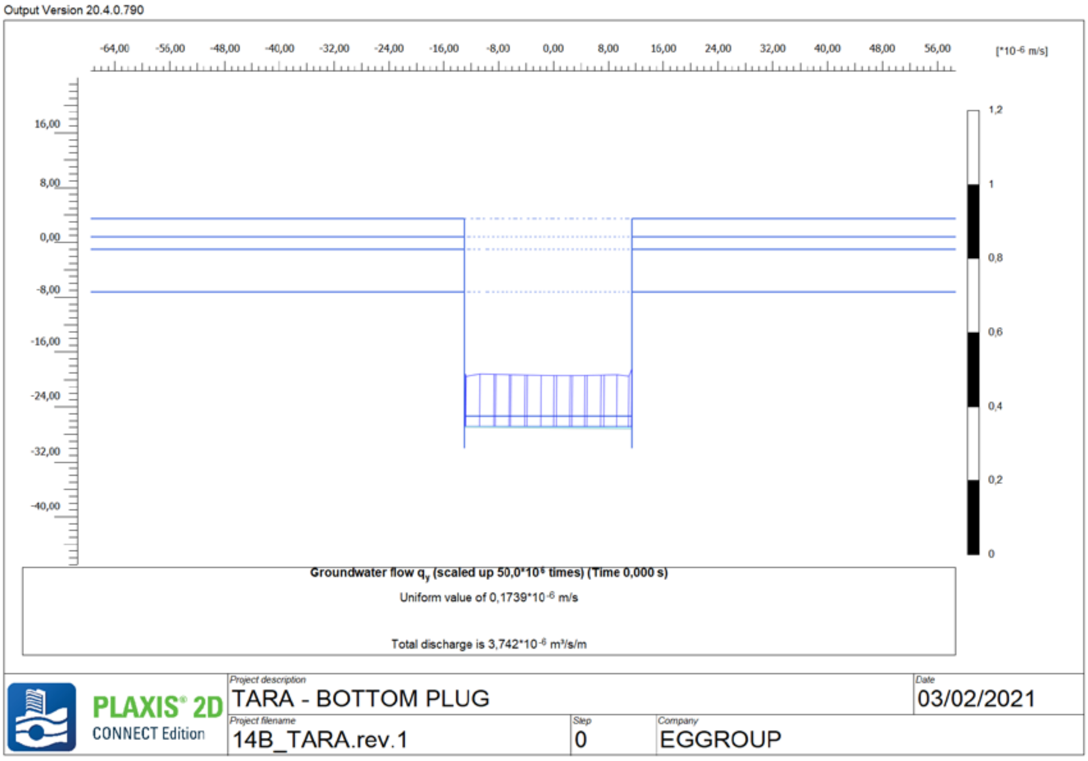


Figure 5-116. Water discharge ratio at the bottom of the excavation with Bottom Plug. Tara Station.

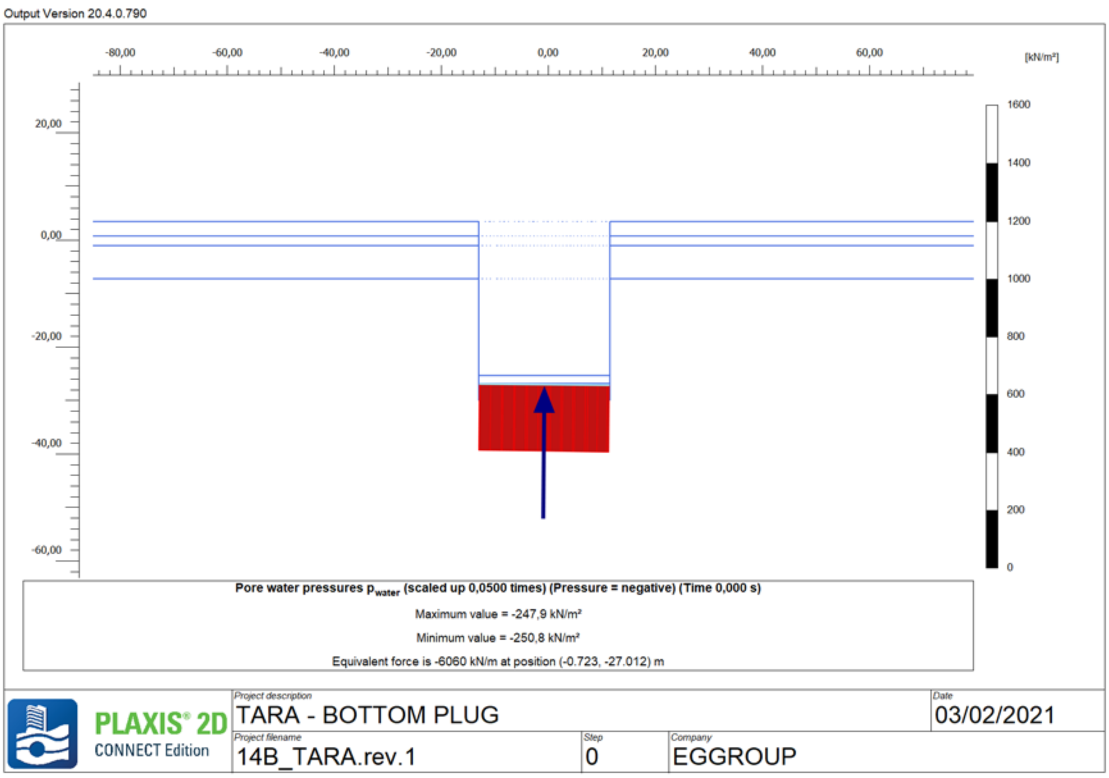


Figure 5-117. Pore water pressure under Bottom Plug. Tara Station.

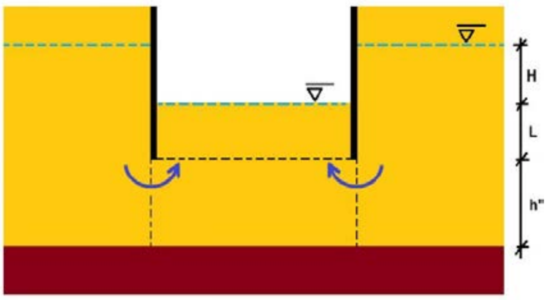
5.14 Stephens Green

N	STATION NAME	TOP (m)	Qx (m)	QBR<10 m (m)	BoD (m)	CLU (m)
15	ST. STEPHEN'S GREEN	12	9,25	4,45	1,2	-31,53

thickness	Qx (m)	QBR<10 m (m)	BoD (m)	CLU (m)
	0	3,6	3,25	32,729942

K(Permeability)	Qx (m/s)	QBR<10 m (m/s)	BoD (m/s)	CLU (m/s)
Kx	7,65E-07	7,62E-07	2,90E-04	4,70E-06
Kv	7,65E-07	7,62E-07	2,90E-04	4,70E-07

Exc. (m)	W.L. (m)
-17,5	7,4



$$k_{II} = \frac{H}{\sum_{1}^{m} \frac{H_\alpha}{k_\alpha}}$$

$$h'_{min} = \frac{ab}{2(a+b)}$$

$$k_i = \frac{\sum_{i=1}^{n} k_i \cdot H_i}{H}$$

Kh (m/s)	Kv (m/s)	H (m)	L (m)	a (m)	b (m)	h´ (m)	Vol (m3)	ro (m)	φ1 (m)	φ2 (m)	R (m)	Rf (m)	Qv (m3/s/m)	Q Plaxis (m3/s/m)	Q Plaxis (m3/d/m)	Qt (m3/d)
2,78E-05	5,32E-07	24,90	4,50	23,00	111,26	9,53	6,37E+04	28,54	87,40	62,50	146,46	149,22	1,33E-05	2,70E-05	2,33	259,55

Q Plaxis (m3/s/m)	Q Plaxis (m3/d/m)	Qt (m3/d)	Water pressure under grout slab (kN/m2)
3,40E-06	0,29	32,68	238,00

Figure 5-118. Summary of results. ST Stephens Green Station.

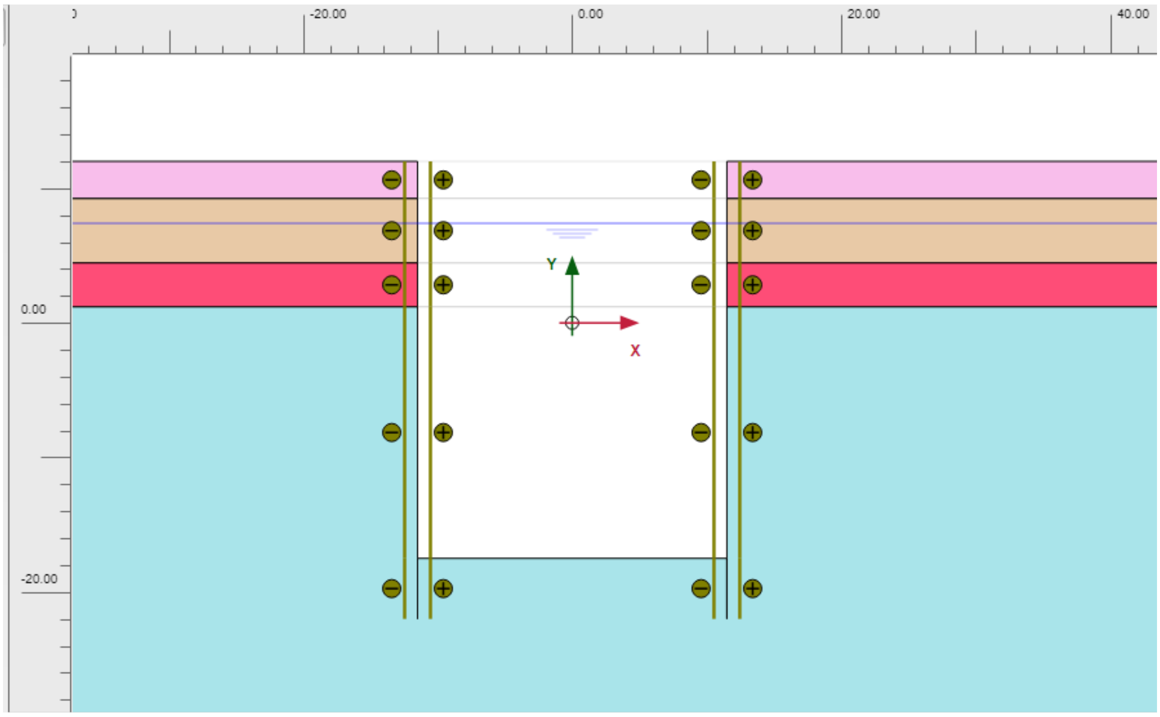


Figure 5-119. Illustration of Plaxis 2D Model. ST Stephens Green Station.

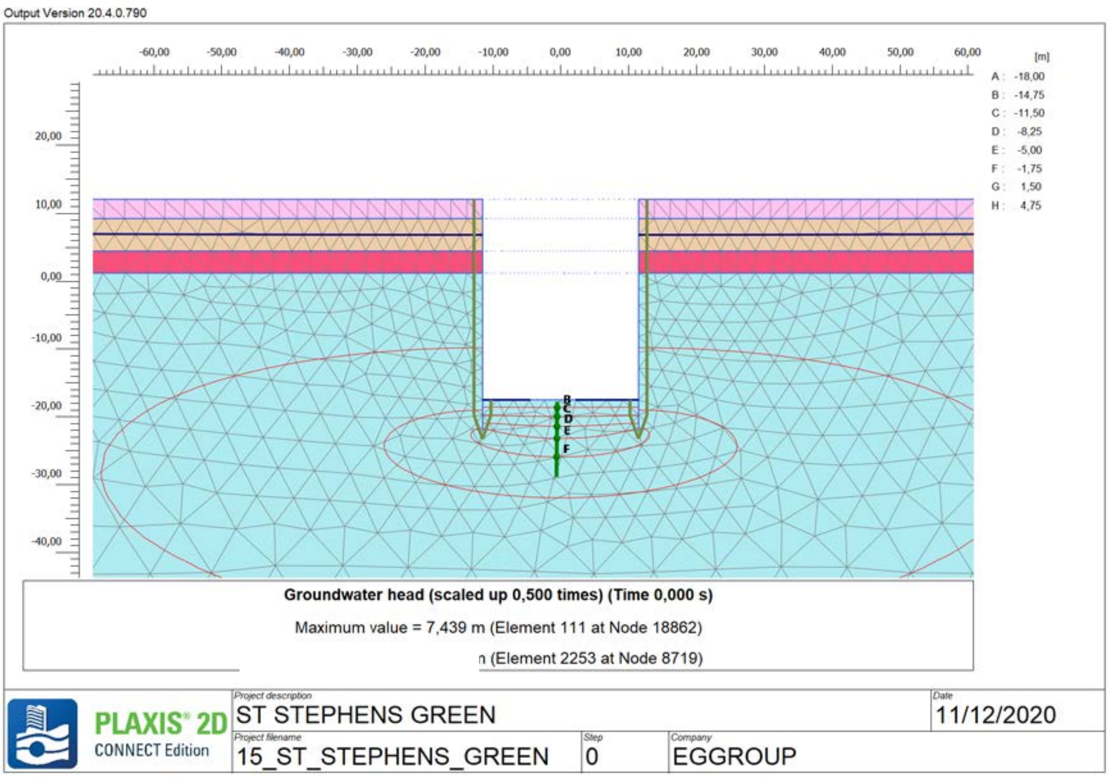


Figure 5-120. Illustration of groundwater head. ST Stephens Green Station.

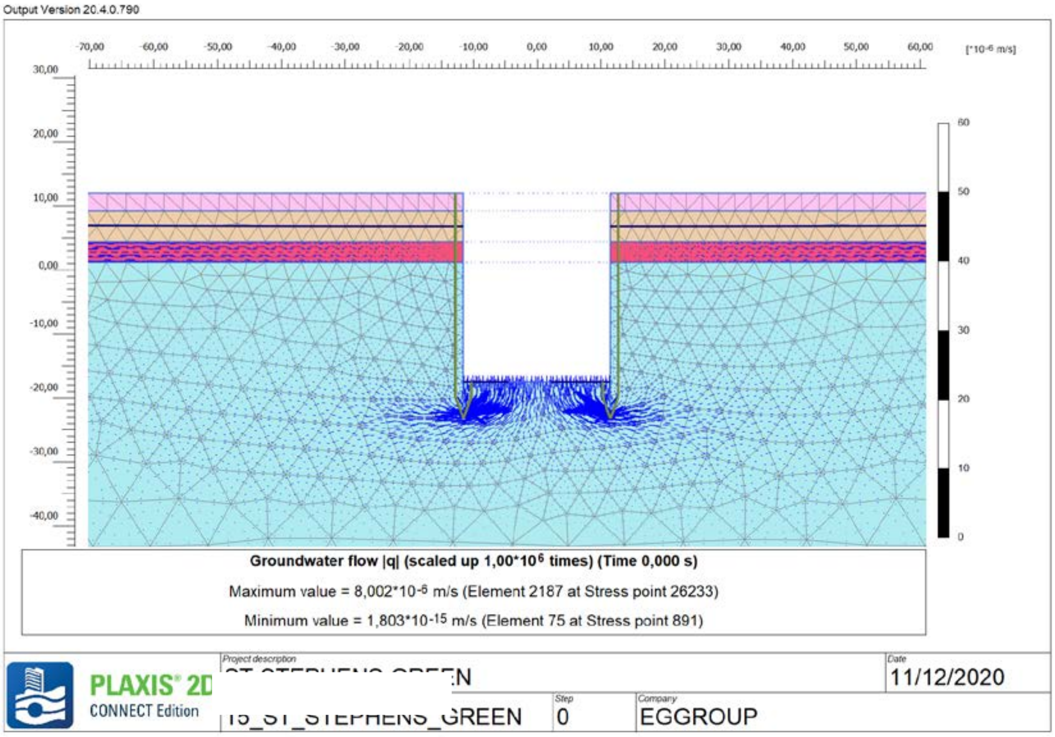


Figure 5-121. Illustration of groundwater flow. ST Stephens Green Station.

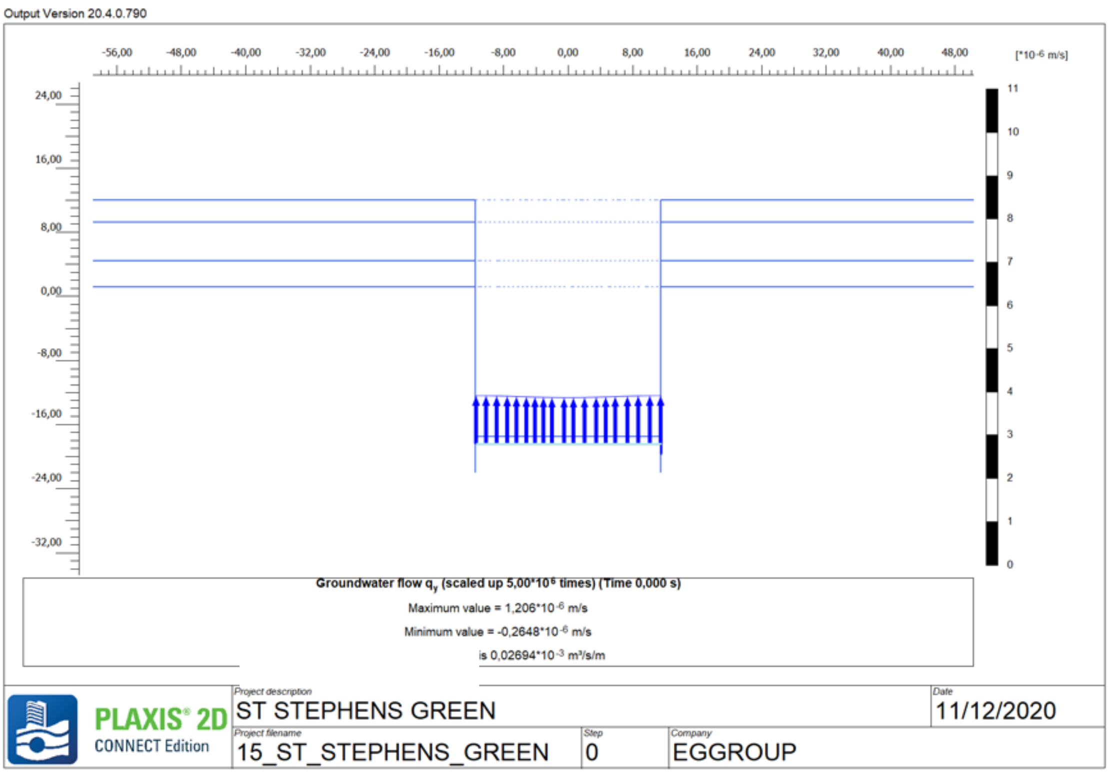


Figure 5-122. Water discharge ratio at the bottom of the excavation. Stephens Green Station.

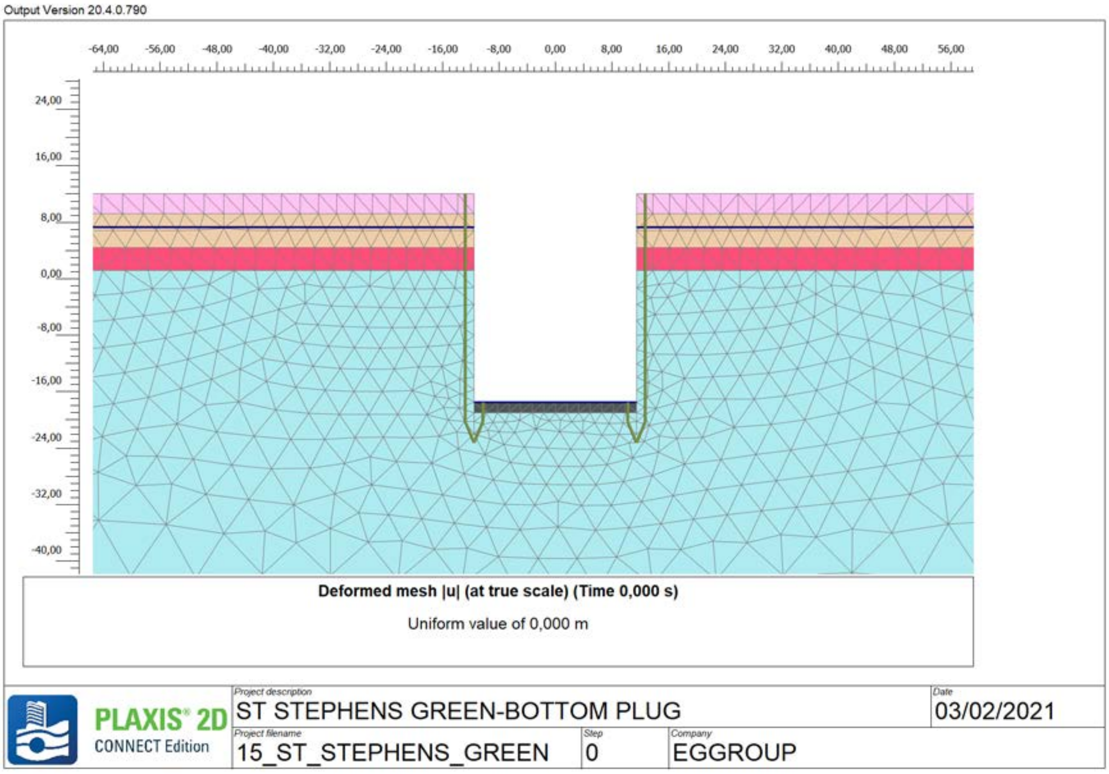


Figure 5-123. Bottom Plug geometry embedded in 2D model. ST Stephens Green Station.

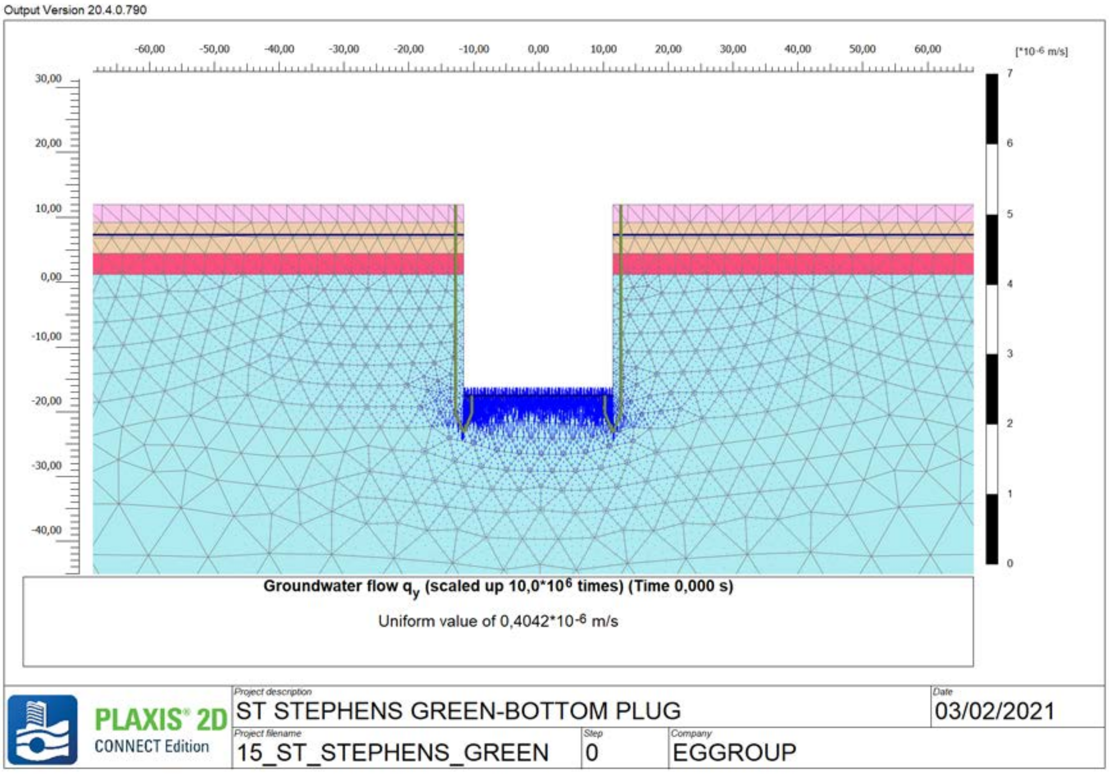


Figure 5-124. Groundwater flow (qy) with Bottom Plug. ST Stephens Green Station.

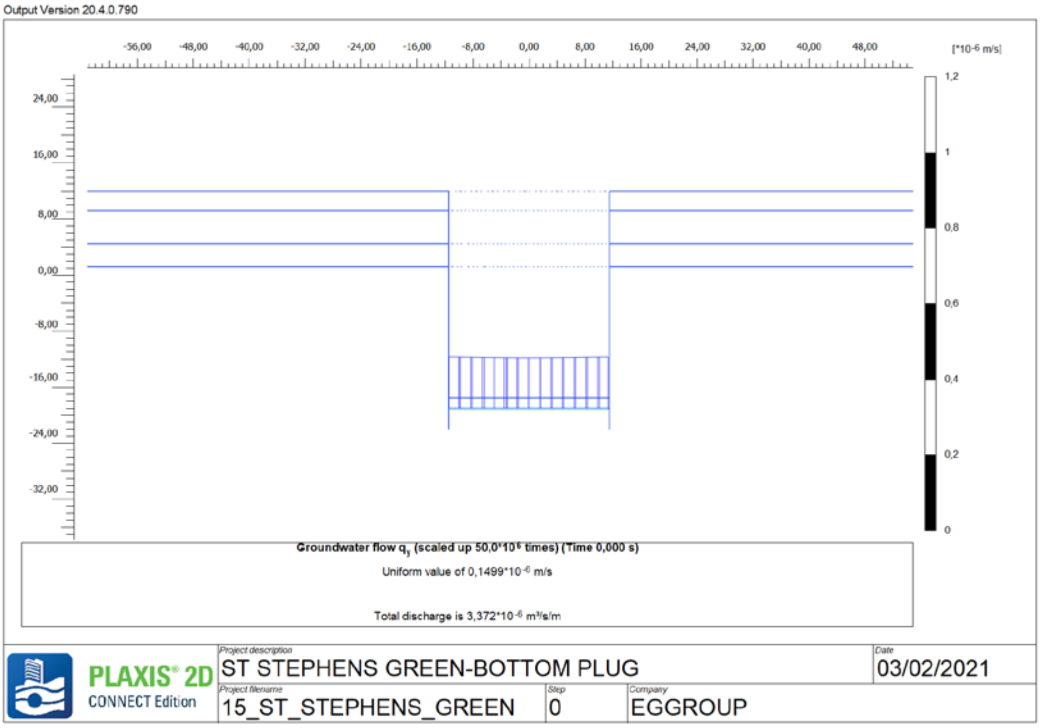


Figure 5-125. Water discharge ratio at the bottom of the excavation with Bottom Plug. ST Stephens Green Station.

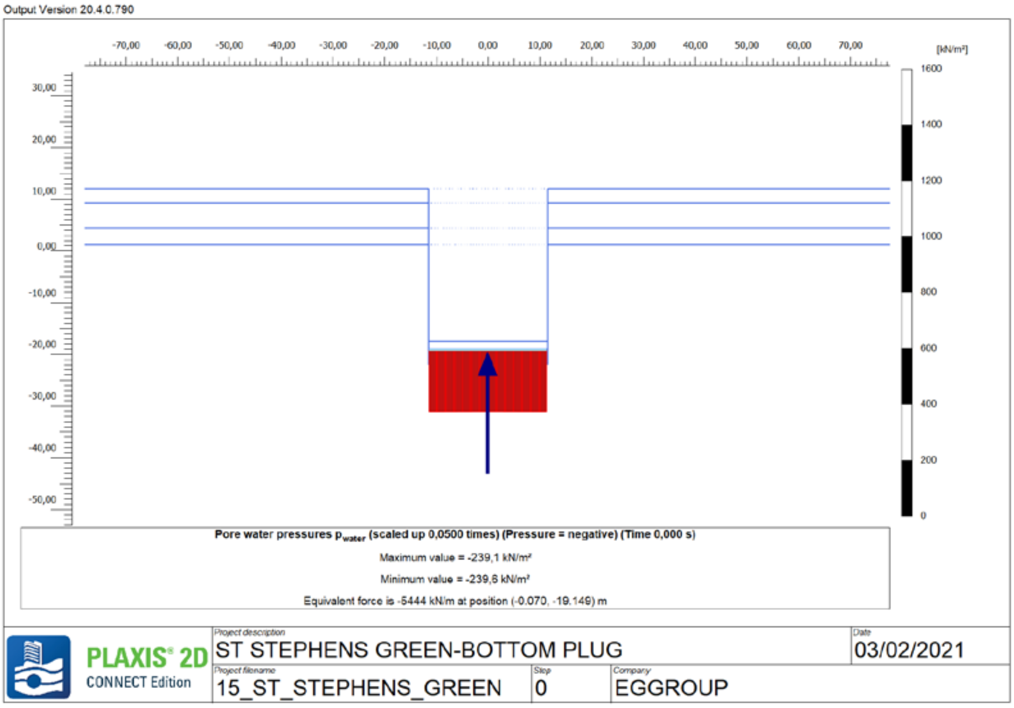


Figure 5-126. Pore water pressure under Bottom Plug. ST Stephens Green Station.

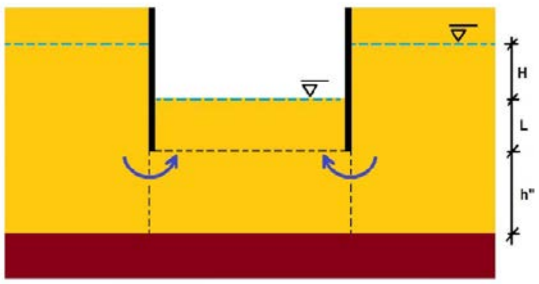
5.15 Charlemont

N	STATION NAME	TOP	Qx	QBR<10 m	BoD	CLU
		(m)	(m)	(m)	(m)	(m)
16	CHARLEMONT	16	14	8,5	6,1	-28,61

thickness			
Qx	QBR<10 m	BoD	CLU
(m)	(m)	(m)	(m)
0	2,25	2,4	34,71071

	K(Permeability)			
	Qx	QBR<10 m	BoD	CLU
	(m/s)	(m/s)	(m/s)	(m/s)
Kx	7,65E-07	7,62E-07	2,90E-04	4,70E-06
Kv	7,65E-07	7,62E-07	2,90E-04	4,70E-07

Exc.	W.L.
(m)	(m)
-13	11



$$k_{II} = \frac{H}{\sum_{1}^{m} \frac{H_a}{k_a}}$$

$$h'_{min} = \frac{ab}{2(a+b)}$$

$$k_I = \frac{\sum_{i=1}^{n} k_i \cdot H_i}{H}$$

Kh	Kv	H	L	a	b	h´	Vol	ro	φ1	φ2	R	Rf	Qv	Q Plaxis	Q Plaxis	Qt
(m/s)	(m/s)	(m)	(m)	(m)	(m)	(m)	(m3)	(m)	(m)	(m)	(m)	(m)	(m3/s/m)	(m3/s/m)	(m3/d/m)	(m3/d)
2,19E-05	5,12E-07	24,00	6,00	23,00	117,00	9,61	6,46E+04	29,27	71,00	47,00	131,74	134,95	1,08E-05	2,00E-05	1,73	202,18

Q Plaxis	Q Plaxis	Qt	Water pressure under grout slab
(m3/s/m)	(m3/d/m)	(m3/d)	(kN/m2)
2,74E-06	0,24	27,70	230,00

Figure 5-127. Summary of results. Charlemont Station.

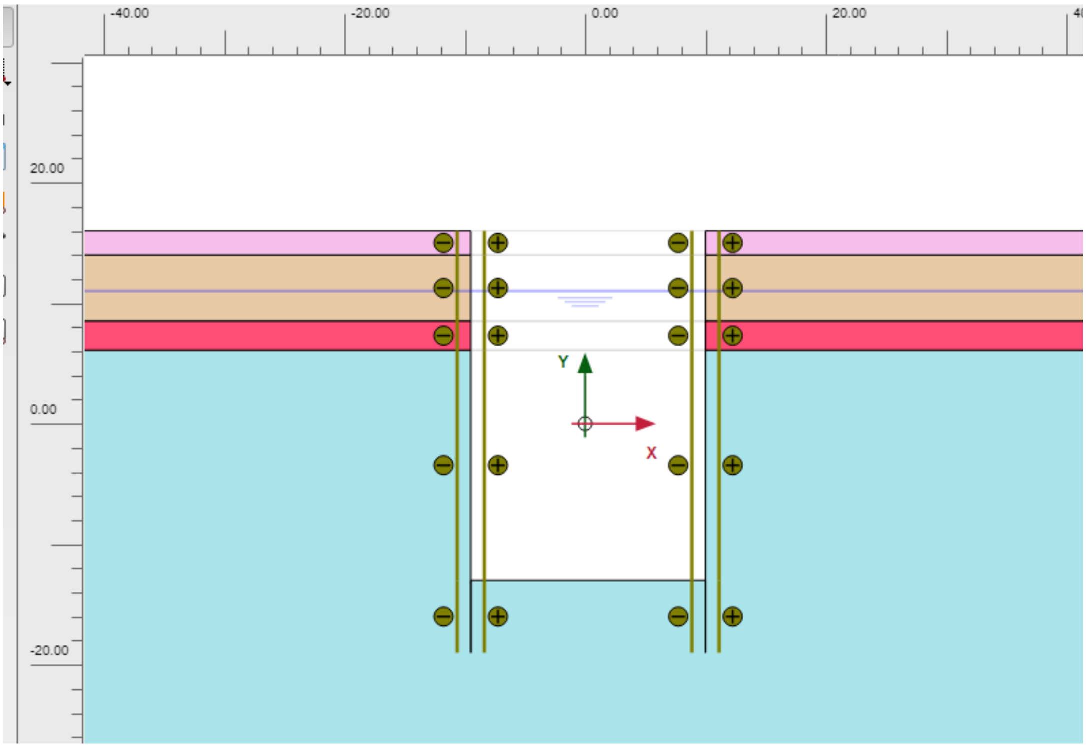


Figure 5-128. Illustration of Plaxis 2D Model. Charlemont Station.

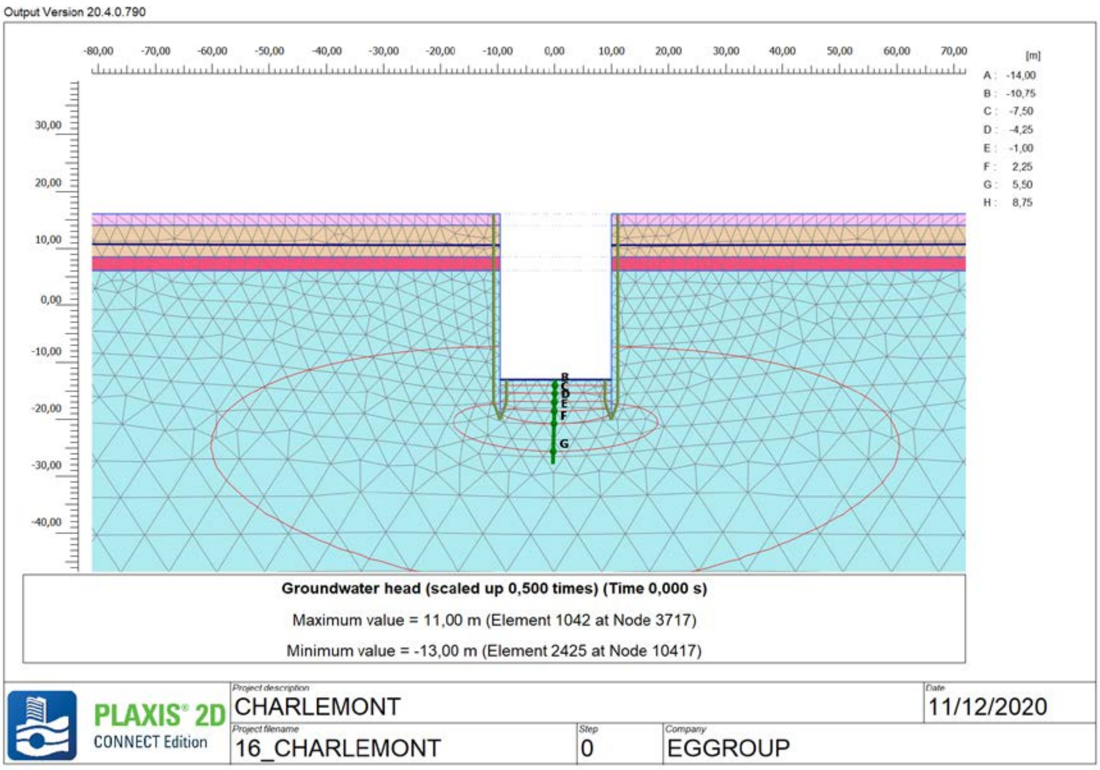


Figure 5-129. Illustration of groundwater head. Charlemont Station.

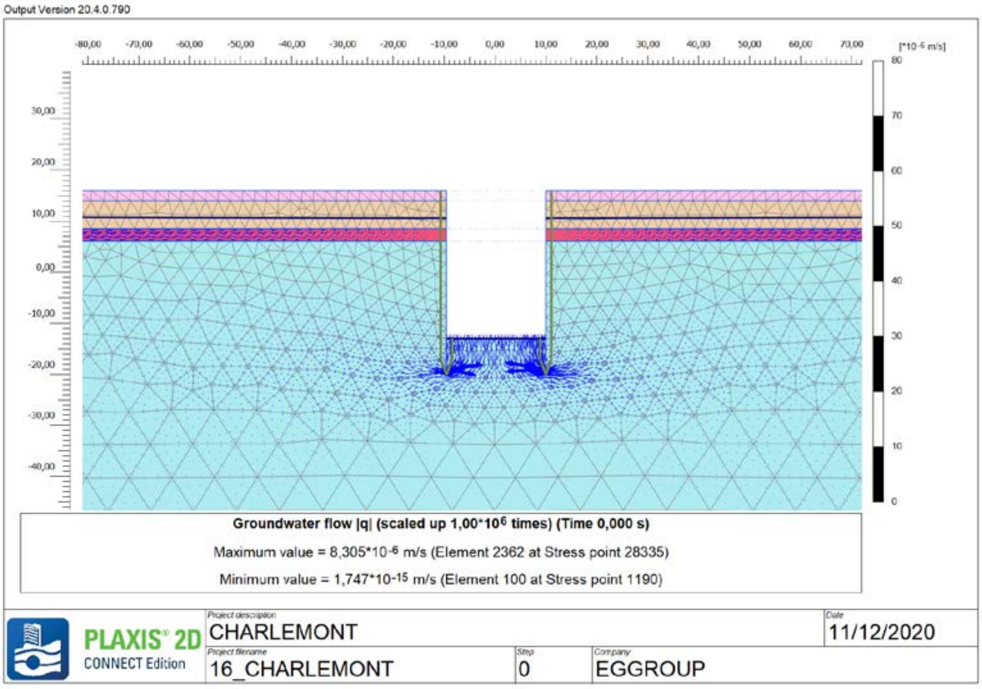


Figure 5-130. Illustration of groundwater flow. Charlemont Station.

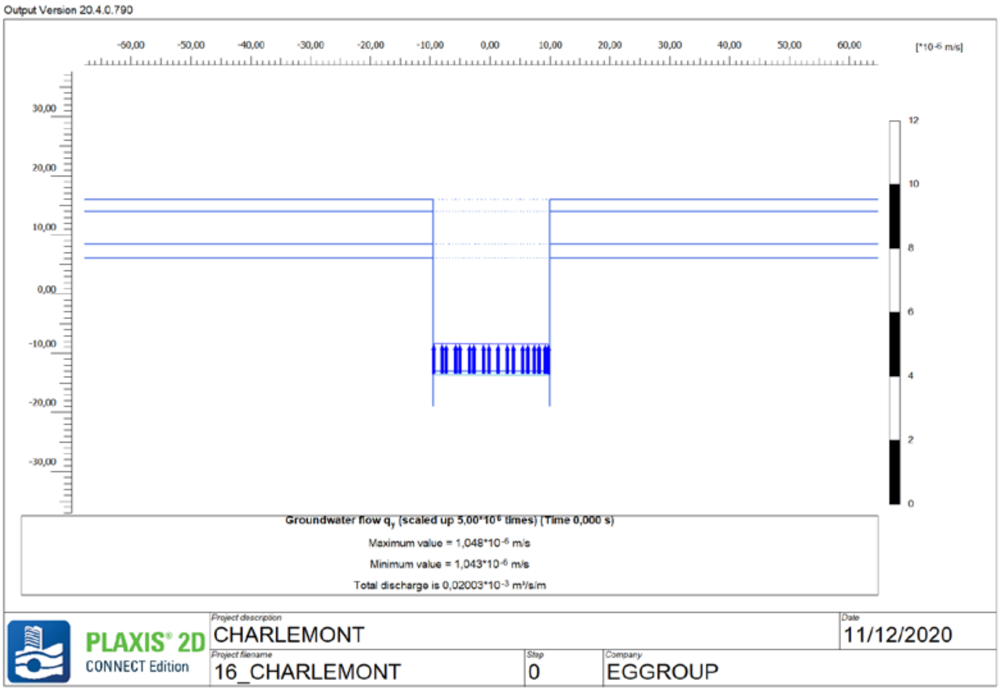


Figure 5-131. Water discharge ratio at the bottom of the excavation. Charlemont Station.

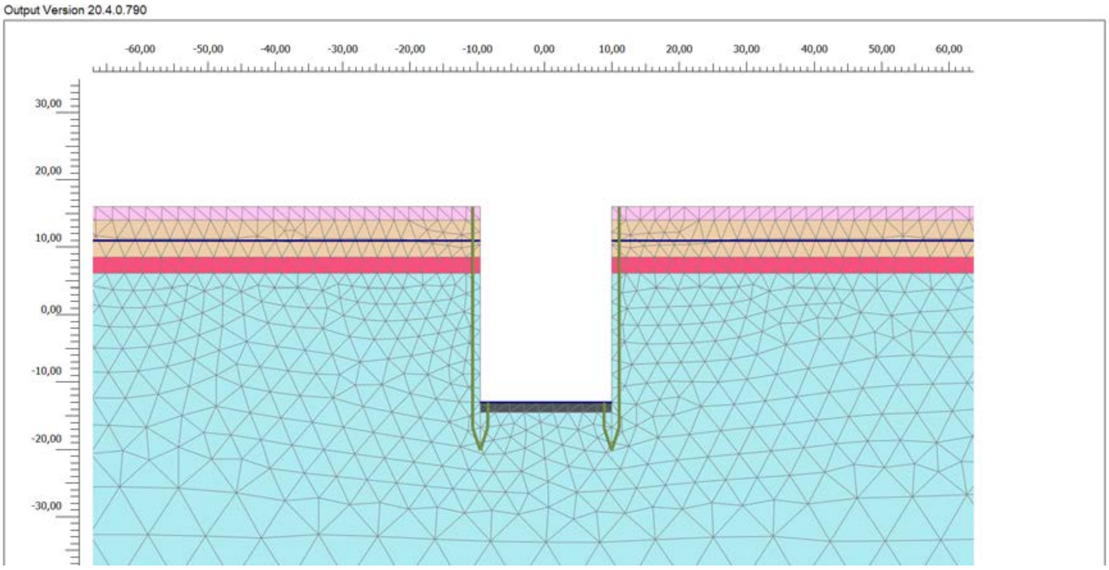


Figure 5-132. Bottom Plug geometry embedded in 2D model. Charlemont Station.

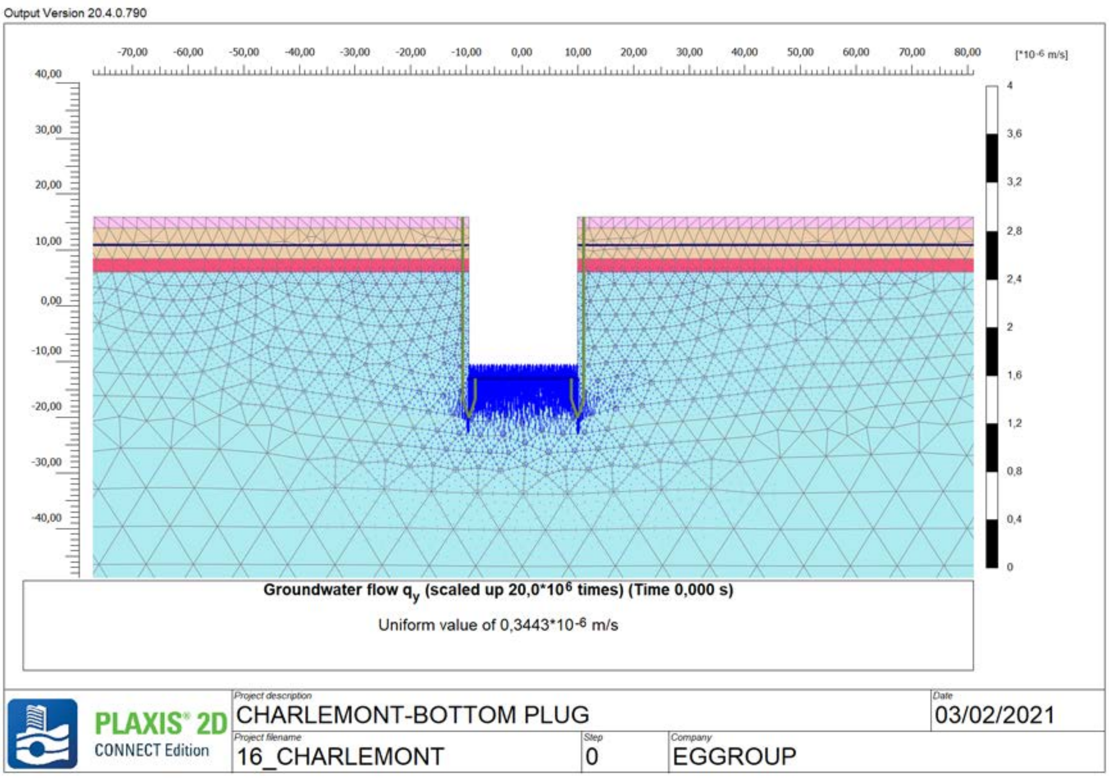


Figure 5-133. Groundwater flow (qy) with Bottom Plug. Charlemont Station.

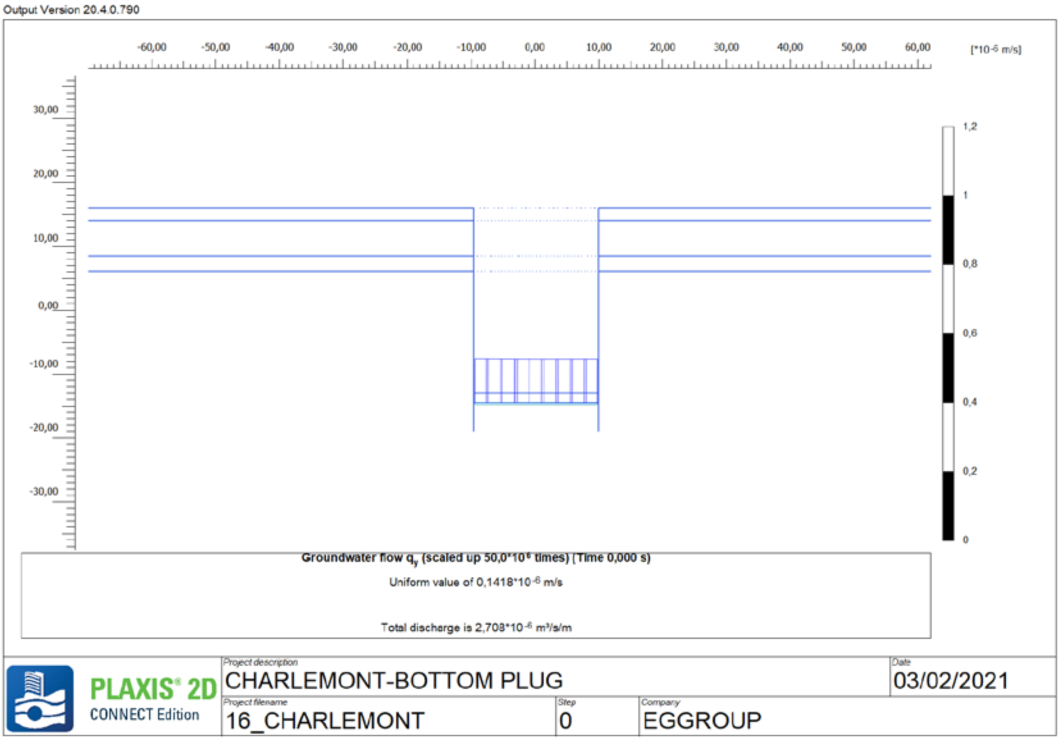


Figure 5-134. Water discharge ratio at the bottom of the excavation with Bottom Plug. Charlemont Station.

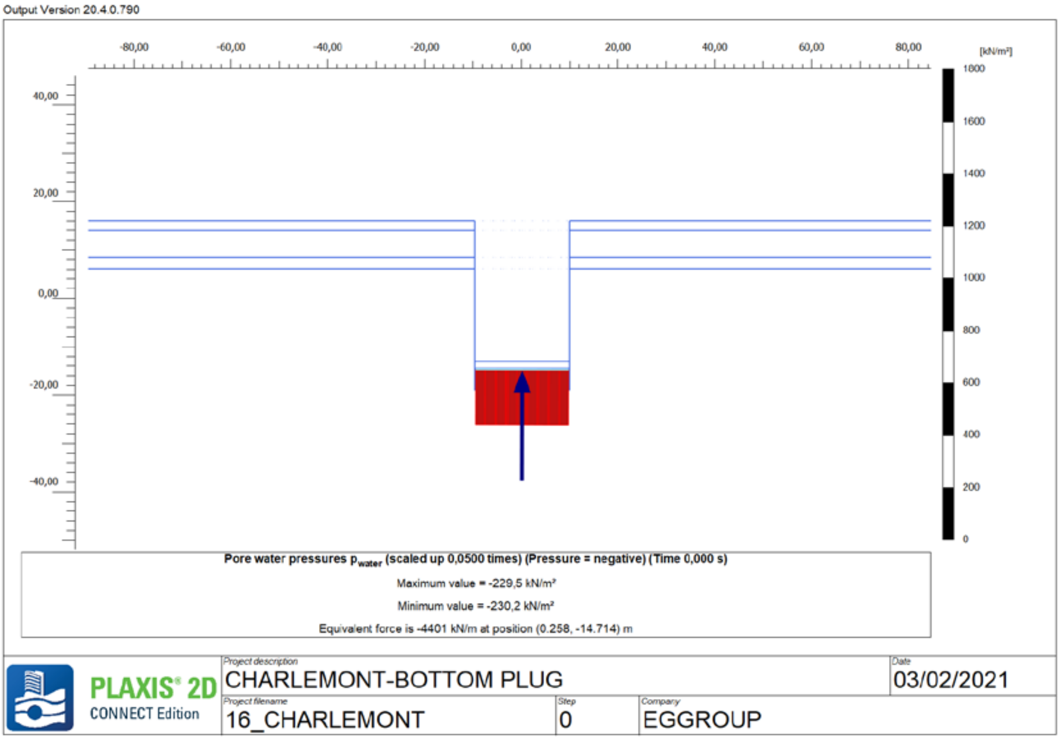


Figure 5-135. Pore water pressure under Bottom Plug. Charlemont Station.