MetroLink

Supplemental Note:

Dewatering Assessment in Station Boxes and SCL Tunnels (Version 2)

TBC | P02

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Contents

1. Supplemental Technical Note: Dewatering Assessment in Station Boxes and SCL Tunnels.

The following supplemental technical note has been issued in order to address queries raised by the Inspector's Experts related to the grouting strategy and the objective of preventing any dewatering (and associated settlement) outside of the Station Box and Intervention Shaft structures. This technical note supplements our earlier note entitled '*Dewatering - Permeabilities Targeted with Grout Bottom Plug*' (which provides informative details on the grouting design and ground investigation).

This technical note is structured such that each of the sub-sections 1.1 to 1.6 included below addresses the particular query posed by the Inspector's Experts during Module 1 of the Oral Hearing currently in progress (initial queries raised on the 22nd of February, day 4, and additional queries raised on the 29th of February, day 8 of the OH).

1.1 Can TII detail the dewatering strategy and the related settlement issues?

Lowering of the water table will not take place outside of the station boxes. This is because the station box design includes the following mitigation measures in order to prevent any lowering of the water table beyond the footprint of the station boxes:

1. D-Walls will be installed according to structural design, followed by installation of fissure grouting (i.e. toe grouting) to a further 5 metres depth. The D-Wall and toe fissure grouting will be installed and completed prior to any excavation works and will not involve any dewatering. Therefore, no lowering of the existing water table will take place.

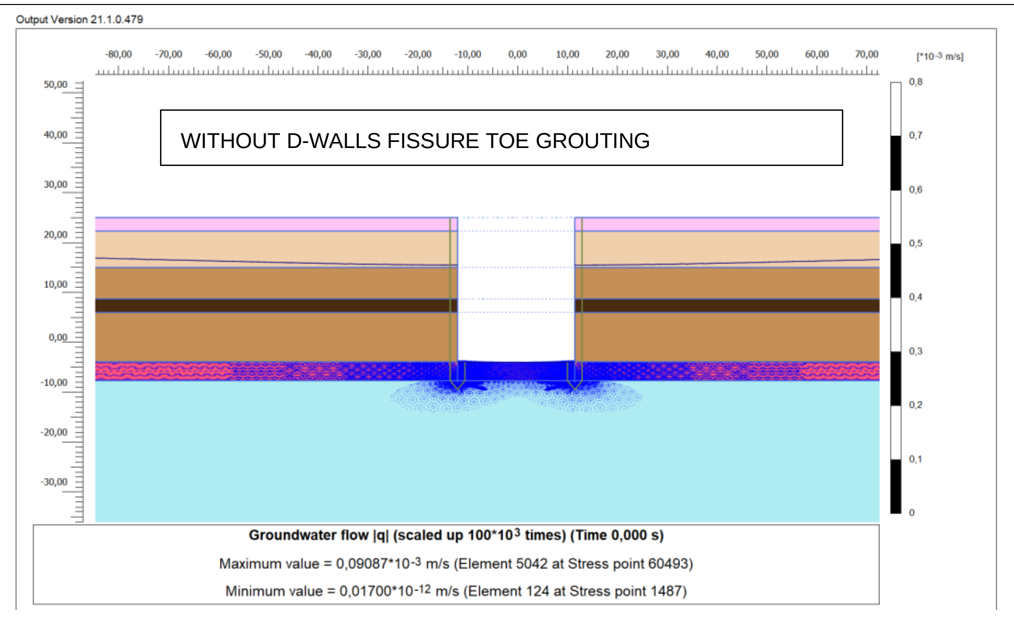
2. Mitigation design measures include installation of specifically designed and screened monitoring boreholes around the stations with the objective of monitoring of the local water table conditions for a period of one year prior to commencement of any excavation. Boreholes will be installed within each station excavation (i.e. after the installation and completion of the D-Walls and toe grouting) to conduct pumping test(s) which will confirm any seepage rates post installation of D-Walls and toe grouting. This mitigation is adequate to prevent lowering of the water table.

3. Where pumping test analyses within the station box identifies localised higher inflow, targeted fissure grouting at the bottom of the station box is available if required to reduce inflows. Fissure grouting at the bottom of the station box involves an improving methodology consisting of decreasing the rock mass permeability formed with assemblies of overlapped [borehole] columns, drilled from the existing ground surface and prior to commencing the excavation of the station box down to Finished Floor Level (FFL). See figure of below. Furthermore, the fissure grouting technic will consist only in reducing the permeability of the rock. Thus, no bottom plug is required and therefore there is no potential for an uplift risk.

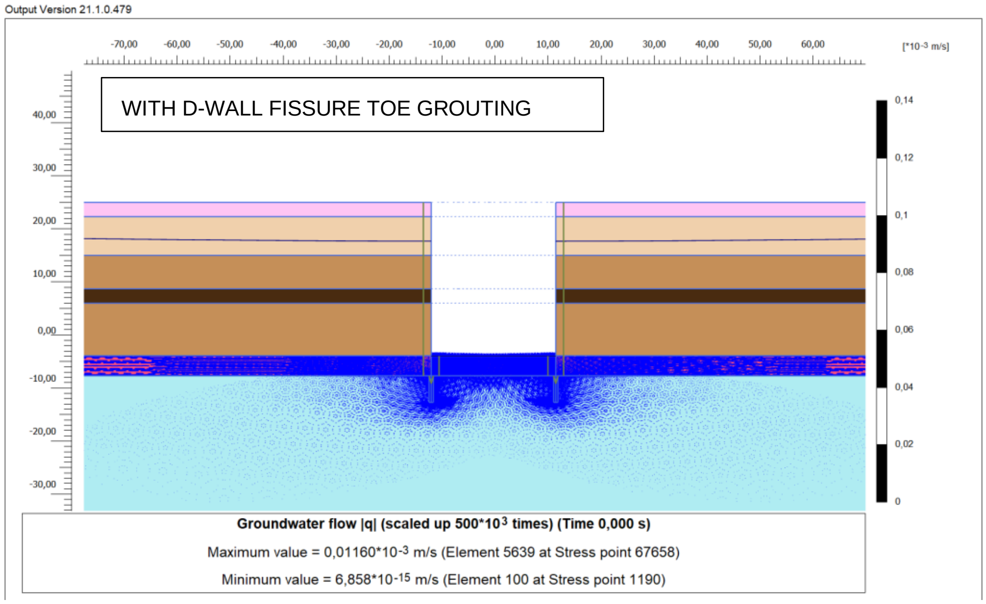
As a consequence, there is no potential for associated issues related to settlement. The Building Damage Assessment (presented in the EIAR as Appendix A.17) is consistent with a groundwater level which is not drawn down and is consistent with natural fluctuations.

To illustrate how effectively these design mitigation measures will work, a Plaxis-2D model has been updated with particular focus on the 'worst-case' ground model section and the flow rates applied from the modelling report included in the EIAR Appendix A19.8 (Plaxis-2D modelling). As observed, without application of the design mitigation measures, the groundwater level is shown to decrease slightly. A second scenario has been modelled with D-Wall toe fissure grouting mitigation measure, employed in the construction resulting in no depression of the groundwater levels outside of the structure.

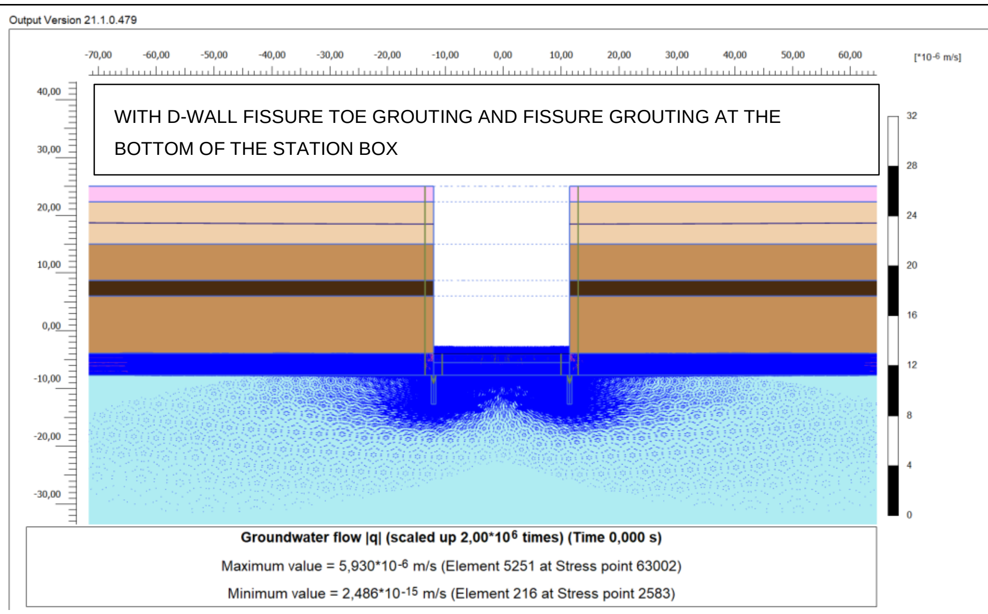
However, in other to reduce the water inflow through the bottom of the station, an additional third scenario has been shown applying fissure grouting at the bottom of the station box. This methodology would only be undertaken where it was necessary to reduce the volume of inflow. This model has been included as Appendix A to the present supplemental note. The scenarios are presented below.



1) <u>Without</u> any mitigation measure, the flow rates are 0.071×10^{-3} $m^3/s/m$ (6.13 $m^3/d/m$) and the modelling indicates the potential for some lowering of the water table.



2) With the application of the toe grouting methodology, the flow rates are 0.034 x10^{-3} m^3/s/m (2.93 m^3/d/m) and the modelling indicates no measurable lowering of the water table beyond the structure and consequently no settlement issues. Consequently, settlement does not occur. This application of the bottom grout alongside the toe grouting negates the need for any significant sump pumping within the open excavation.



3) Finally, applying the fissure grout at the bottom of the station box, together with toe fissure grouting at the D-Walls, the flow rates are further reduced to 0.018 x10^{-3} m^3/s/m (1.55 m^3/d/m) and again, the modelling indicates no lowering of the water table beyond the structure.

1.2 If dewatering occurs beyond the 30m/ 50m distance allowed by POPS, how will impacts on affected parties be addressed?

No dewatering will take place as outlined in Section 1.1 above.

D-wall toe fissure grouting is the main mitigation measure applied in order to prevent any decline in groundwater levels occurring. The effectiveness of this approach has been confirmed by modelling within the 'worst-case' ground model (see Appendix A) i.e. for Glasnevin Station, where the highest inflow rates were observed during modelling for the construction of the station box and when mitigation measures are not applied.

1.3 How will the 0.5l/ sec of dewatering be achieved at the station boxes?

The fissure grouting mitigation, described above, has been designed to ensure no lowering of the water table will occur. For clarity, the 0.5l/sec is not the criteria for achievement of mitigation. This figure was referenced in the EIAR (Appendix A19.11) only as part of collation of hydrogeology data within the Dublin area. The discharge volume will vary for each station depending on the local geology and has been determined by site investigations.

As was stated in the previous technical note '*Metrolink Permeabilities Targeted with Grout Bottom Plug to Avoid Upwelling in Station Boxes'* a permeability value of 10^{-8} m/s for grouting is targeted.

Given the difficulties in achieving the specified permeability value by subcontractor operations during construction (10^{-8} m/s), particularly in attaining 90% of the Required Sealing Efficiency, and in order to quantify the consequences of the 10% failure rate, an additional Plaxis-2D ground model was undertaken for Glasnevin Station (considered the worst ground conditions) to confirm the effects of fissure grouting at 10^{-7}m/s would not result in lowering the groundwater table.

For this worst-case scenario (Glasnevin station ground model and not achieving 10^{-8}m/s), after applying the aforementioned design mitigation measure (fissure grouting in toe D-Walls), and implementing a fissure grout at the base of the station box, it has been confirmed that no lowering of the water table will occur.

An increase in flow rate from 0.33 l/s (with a fissure grout permeability of 10^{-8} m/s) at the station to 1.7 l/s (with a grout permeability of 10^{-7} m/s) was observed. This discharge rate is within the agreed (Uisce Éireann) discharge limit in terms of drainage for the station during construction.

1.4 What is your strategy for dewatering control before the permanent membrane is installed in the construction of the Charlemont Intervention Tunnel?

Rock mass fissure grouting will be conducted ahead of the face of the tunnel excavation within rock for two main targets, firstly reduce water ingress and in consequence prevent dewatering. This approach will prevent any requirement for dewatering and hence the potential for water table lowering outside of any of the planned intervention tunnels.

The geological strength index (GSI) system is widely used for the design and practice of mining/tunnelling processes. It is a unique rock mass classification system related to the rock mass strength and deformation parameters. For the Intervention Tunnels forward probing will be undertaken in order to anticipate and define the geotechnical quality of the rock mass and assess the need for grouting ahead when terrain classified with GSI values below 45 points is excavated for the pedestrian or ventilation galleries.

Each probe will be 3m in length, overlapping with progress so that there is always 6m of probing in front of the excavation face. The minimum overlap shall be of 3m. The excavation strategy will include these constraints.

This probe drilling will be conducted only within the side limited by the MetroLink LOD/ property acquisition) with an inner diameter of 50mm (ID). The flows will be measured for a minimum of 1 hour immediately after the completion of the drilling of the last probe at the face of the tunnel excavation to:

- Formulate the grout strategy, and
- Ascertain the ground conditions at the same time.

The probe holes will be drilled while ensuring the following:

- ✓ The appropriate machinery to drill these holes must be available and on site.
- ✓ The probe hole drilling will be attended by the Geologist or Engineer and the following details will be duly recorded:
  - Time to drill each rod,
  - Computerised drilling pressure vs actual hole length,
  - Rock discontinuity depths,
  - Rock shipping observations, and
  - Groundwater flows (q).

All the information recorded will be retained. Probe and core holes outside the tunnel profile will be sealed with cementitious and quick setting grout.

Afterwards, pre-excavation grouting, will be required when the inflows from a single probe hole or multiple holes measured over 6m length and a minimum of 1 hour after termination of drilling exceed the limits below:

- Criteria for Pre-Excavation Grouting -
  - When GSI <30
  - When q >3l/s

Injection within the excavation face for pedestrian or ventilation galleries will be required when any one of the criteria given above takes place. Pre-excavation fissure grouting will be required as described below:

- 6-metre-long holes will be drilled in the excavation face.
- The holes will be drilled forming a 0 volume of grout.
- The deviation of holes will be of the order ± 5º to achieve this shape.
- One hole per metre of perimeter will be drilled.
- The water: cement ratio of the grout will be 1:1.
- The grouting pressure at injection stage shall be the hydrostatic + 1 bar.
- These applications could be adapted in order to increase their effectiveness in soils.

As grouting into low permeability fissured rock or soils with high-water pressure is rather difficult, the grouting strategy will therefore involve using environmentally friendly, low viscosity cementitious grout based on the use of micro-fine cement [with super plasticiser and deflocculant] injected under carefully controlled pressures.

1.5 Have you completed any assessment of this?

Yes, Plaxis-2D models have been undertaken and the modelled outputs confirm that the surrounding groundwater levels beyond the structure are not lowered due to effective grouting techniques.

1.6 What is the target for fissure grouting?

The fissure grouting is presented as a design mitigation measure for decreasing the permeability of the local rock mass and consequently avoiding dewatering and limiting upwelling effect through the bottom of the excavation box.

This D-wall fissure toe grouting will be applied to prevent any decline in groundwater levels occurring.

Appendix A. Glasnevin Station. Worst-Case Ground Model Section

Plaxis 2D Modelling for calculating the inflow rates through the bottom of the excavation.

Cases analysed:

1. Station box inflow rates without D-Walls toe fissure grouting into the rock mass.
2. Station box inflow rates considering D-walls toe fissure grouting 5m into the rock mass.
3. Station box inflow rates considering D-walls toe fissure grouting 5m into the rock mass and considering fissure grouting at the bottom of the station box.

- Fissure grouted rock mass permeability: k=1x10^{-7} m/s (~1 Lugeon)
- Fissure rock mass grouting at the D-Walls Toe: thickness of 5m beneath the D-Walls Toe.
- Fissure rock mass at the bottom of the station box: thickness of 4.5m beneath the bottom of the station box.
- Table below shows the geometric features for Glasnevin Station box.

STATION	L (m)	width (a) (m)	length (b) (m)
GLASNEVIN	4,00	23,00	96,00

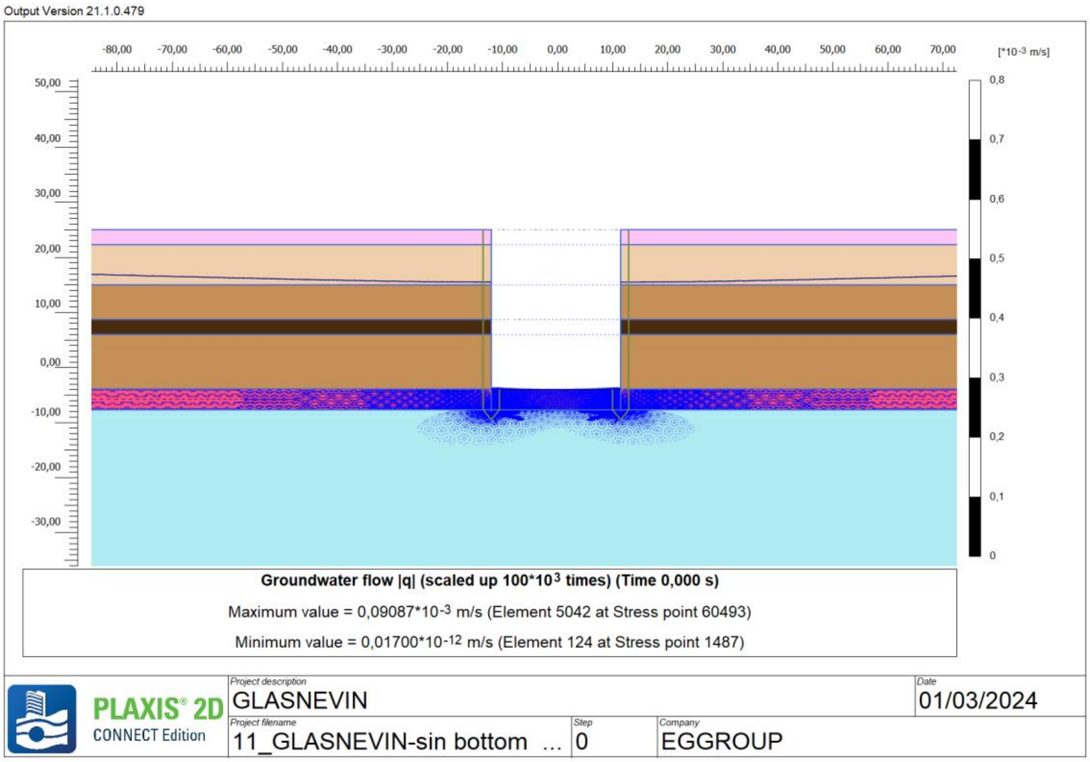
- Table below shows the Ground Model for Glasnevin Station Box.

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

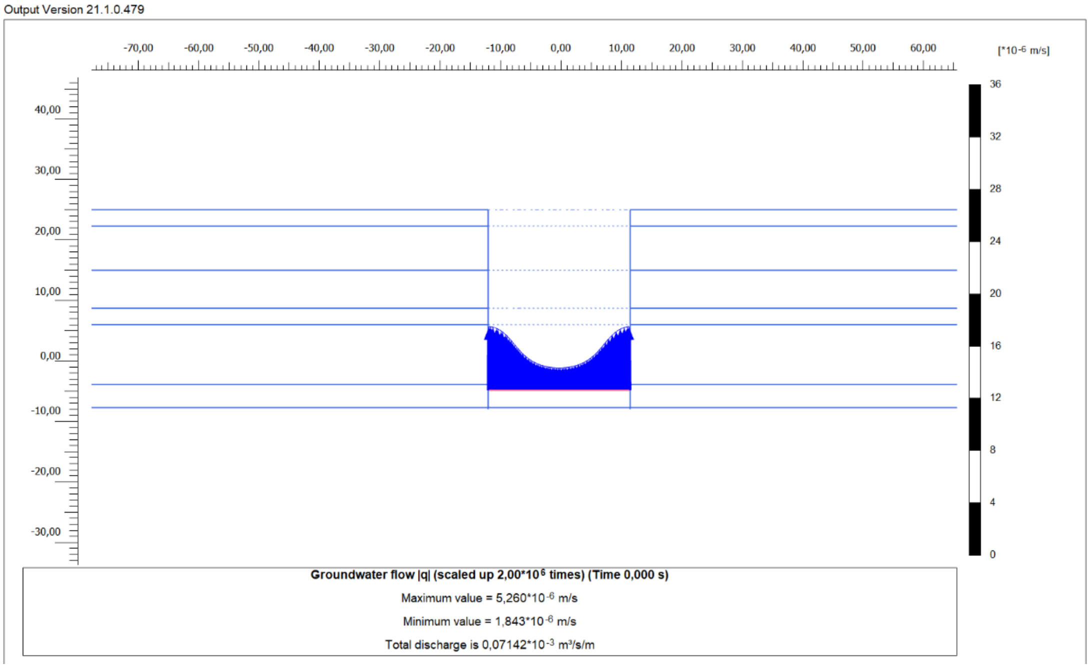
1.- STATION BOX INFLOW RATES WITHOUT D-WALLS TOE FISSURE GROUTING INTO THE ROCK MASS.

Flow rates = **$0{,}071 \times 10^{-3}$ $m^3/s/m$ (6.13 $m^3/d/m$ or 6.81 l/s along the whole station)**

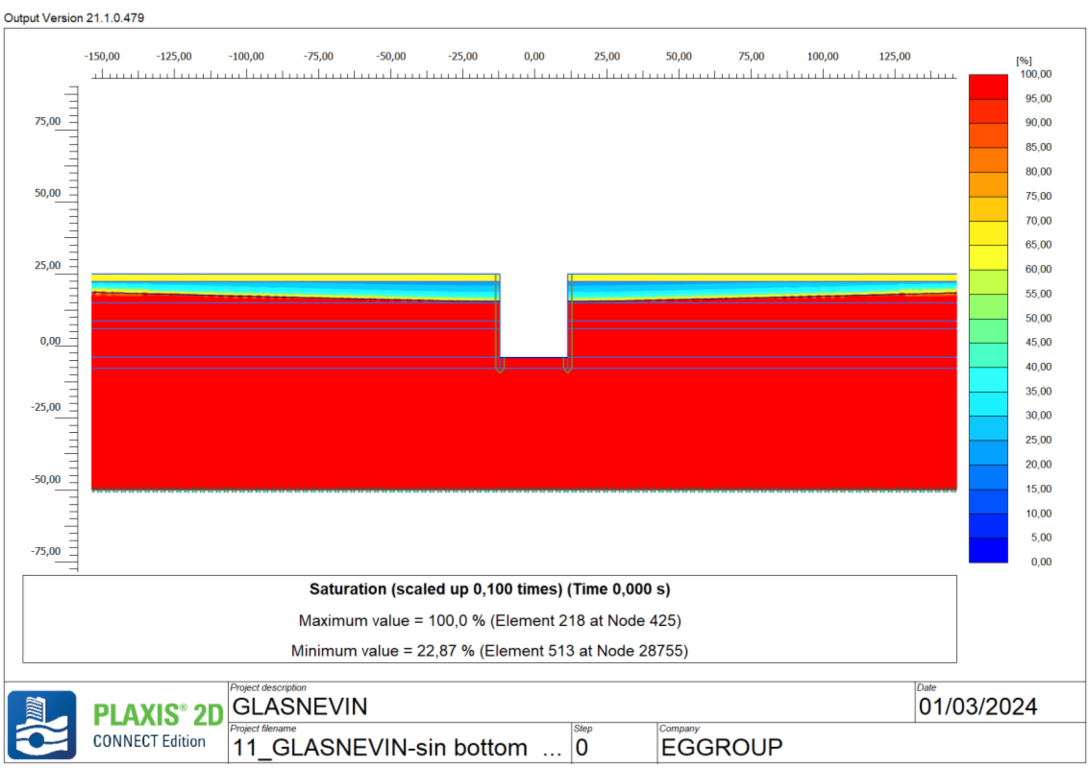
Water inflow through the bottom of Glasnevin station box without D-walls toe grouting



Flow rates to the bottom of Glasnevin station box



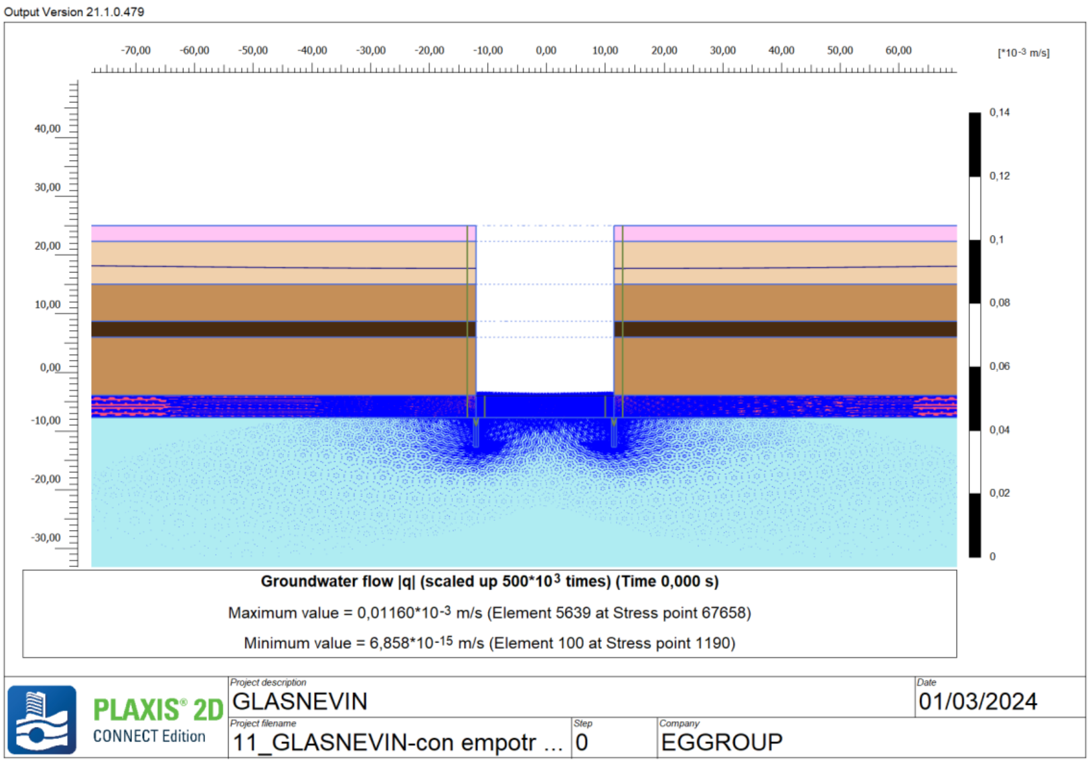
Lowering of the groundwater level. Decrease of approximately four (4) meters.



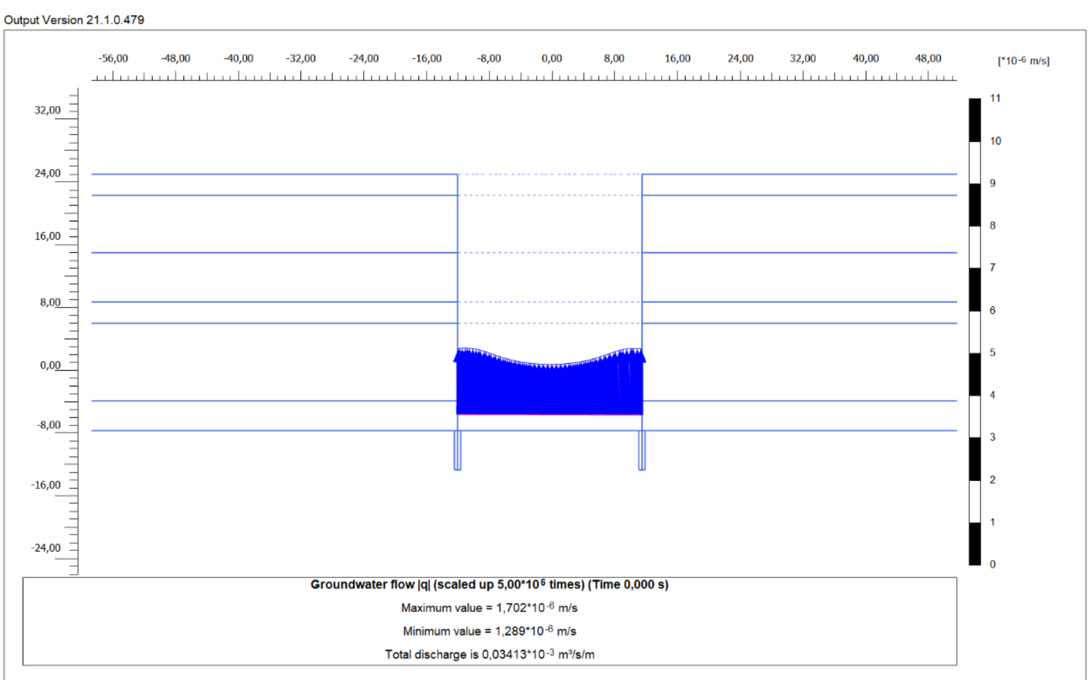
2.- STATION BOX INFLOW RATES CONSIDERING D-WALLS TOE FISSURE GROUTING 5M INTO THE ROCK MASS.

Flow rates = **0,034 x10^{-3} m³/s/m (2.9 m³/d/m or 3,2 l/s along the whole station)**

Groundwater level remains unchanged.



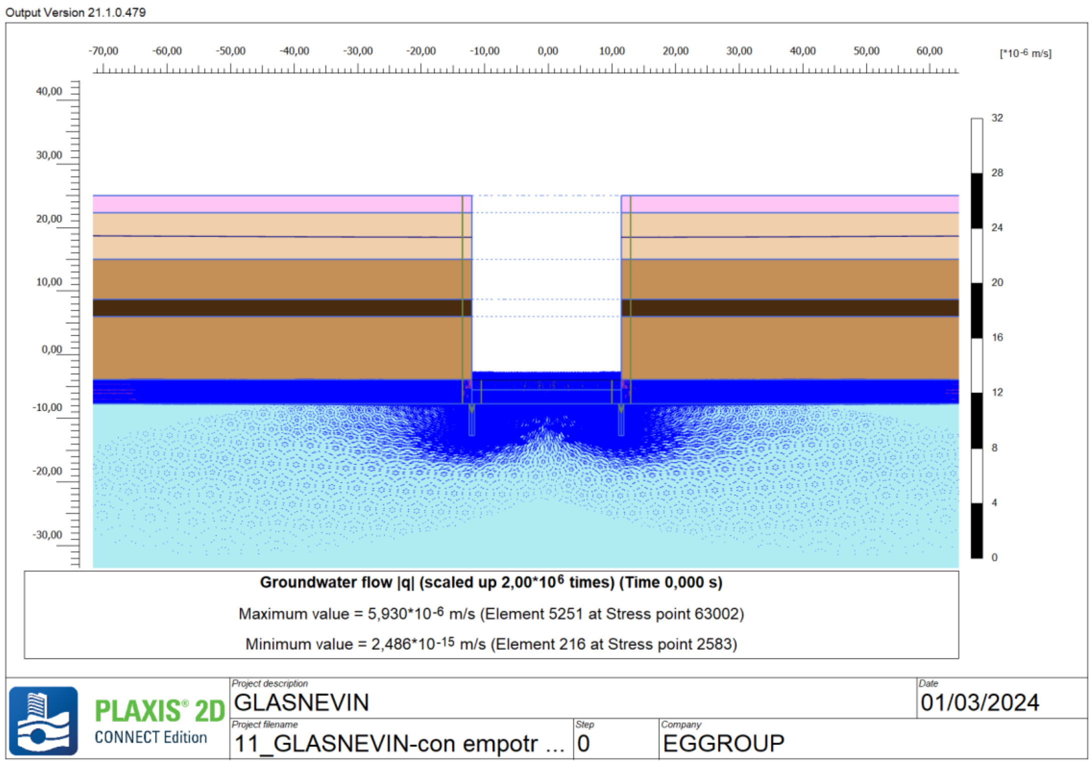
Flow rates to the bottom of Glasnevin station box



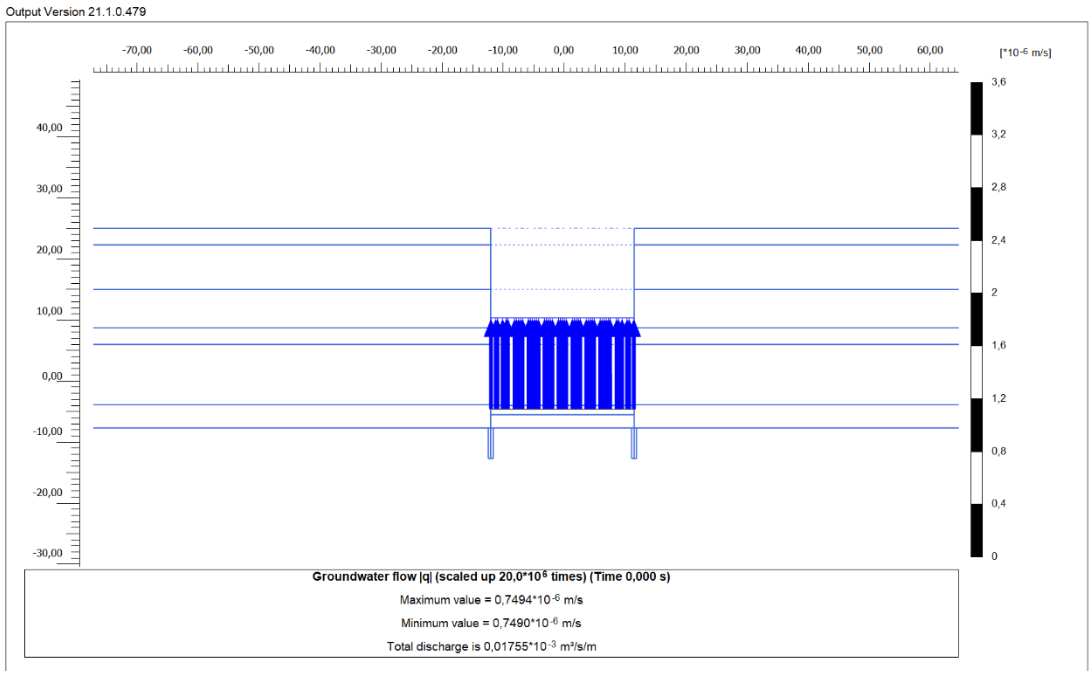
3.- STATION BOX INFLOW RATES CONSIDERING D-WALLS TOE FISSURE GROUTING 5M INTO THE ROCK MASS AND FISSURE GROUTING AT THE BOTTOM OF THE STATION BOX.

Flow rates = **0,018 x10^{-3} m^3/s/m (1.5 m^3/d/m or 1.7 l/s along the whole station)**

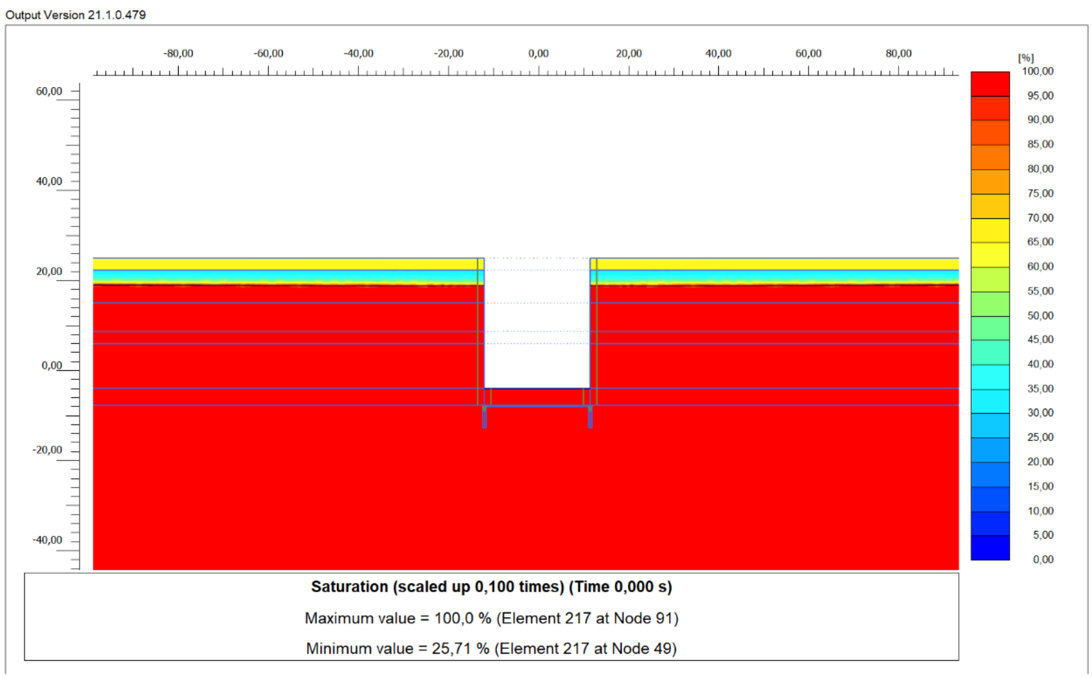
Groundwater level remains unchanged.



Flow rates to the bottom of Glasnevin station box



Groundwater level remains unchanged.



Appendix B. Dewatering Assessment for Charlemont Intervention Tunnel

DEWATERING ASSESSMENT FOR CHARLEMONT INTERVENTION TUNNEL

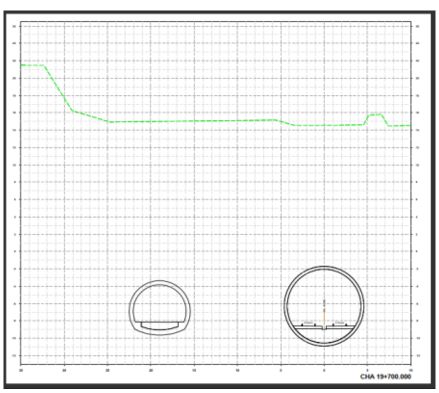
Ground Model for Charlemont Station and Intervention tunnel

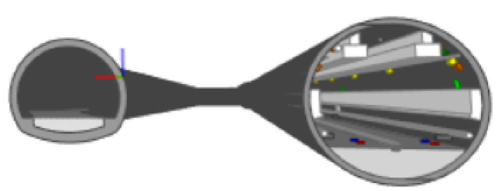
STRATIGRAPHY	THICKNESS (m)	DEPTHS (m)
Made Ground (**QX**)	2,00	2,00
Brown Boulder Clay (**QBR<10m**)	5,50	7,50
Base of Drift Deposit (**BoD**) and Top of Weathered Rock	2,40	9,90
Lucan Formation (CLU)	-	>9,90
N.F	-	5,00

Material permeabilities

IDENTIFICATION	U	Qx	QBR < 10 m	BoD	CLU	Fissure Grouted rock mass
e_0	-	0,68	0,26	0,22	-	
Kx	m/s	7,65E-07	7,62E-07	2,90E-04	4,70E-06	1E-07/1E-08
Ky	m/s	7,65E-07	7,62E-07	2,90E-04	4,70E-07	1E-07/1E-08

Intervention Tunnel Geometry. Section: A≈ 33 m^2 & Length of the tunnel face 5.5m



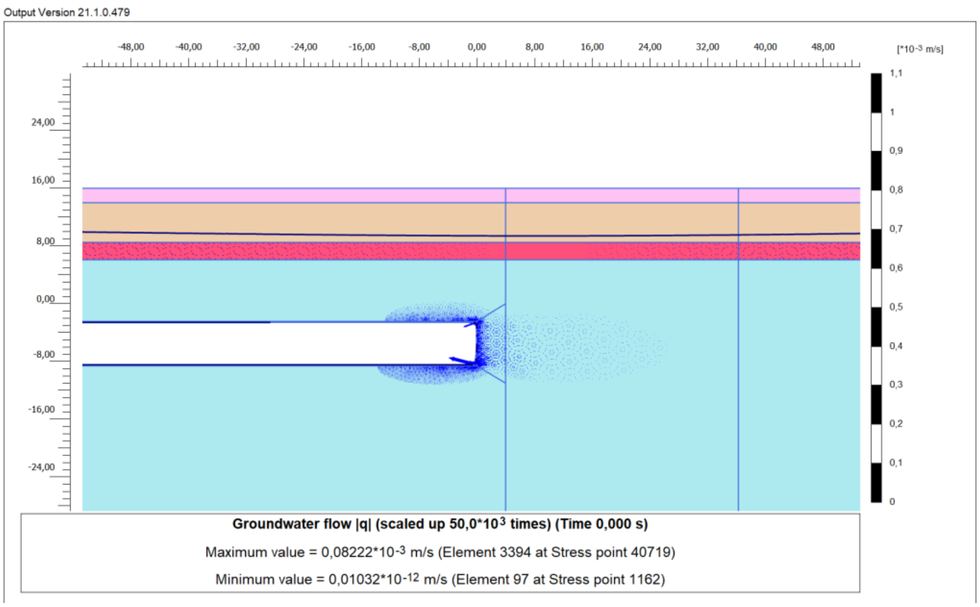


Plaxis 2D Modelling for calculating the inflow rates during the excavation of Charlemont Intervention Tunnel

Cases analysed:

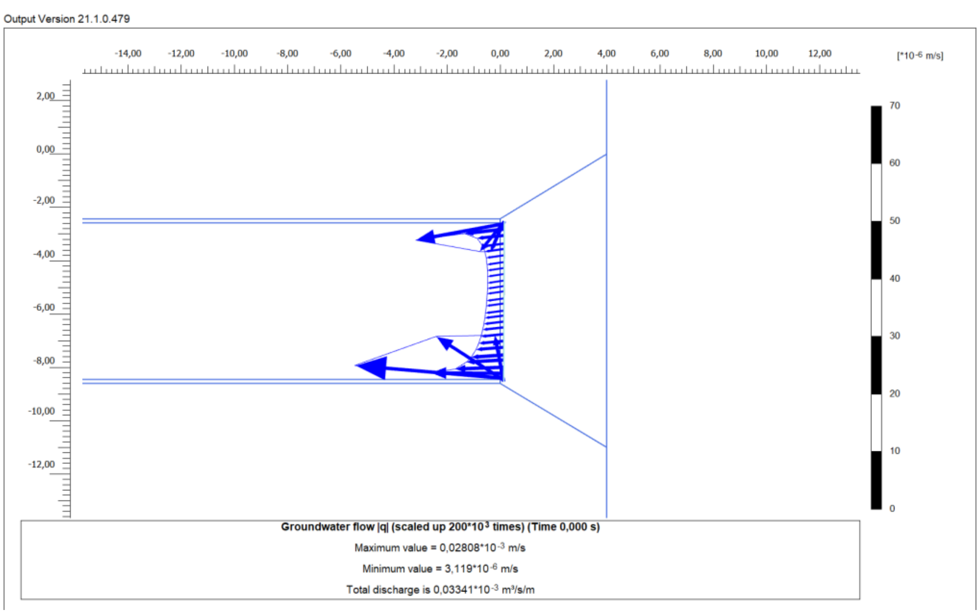
4. Excavation without grouting at the tunnel face.
5. Fissure grouting around the tunnel excavation section and at the section face. 6m length.

Flow network towards the tunnel face excavation

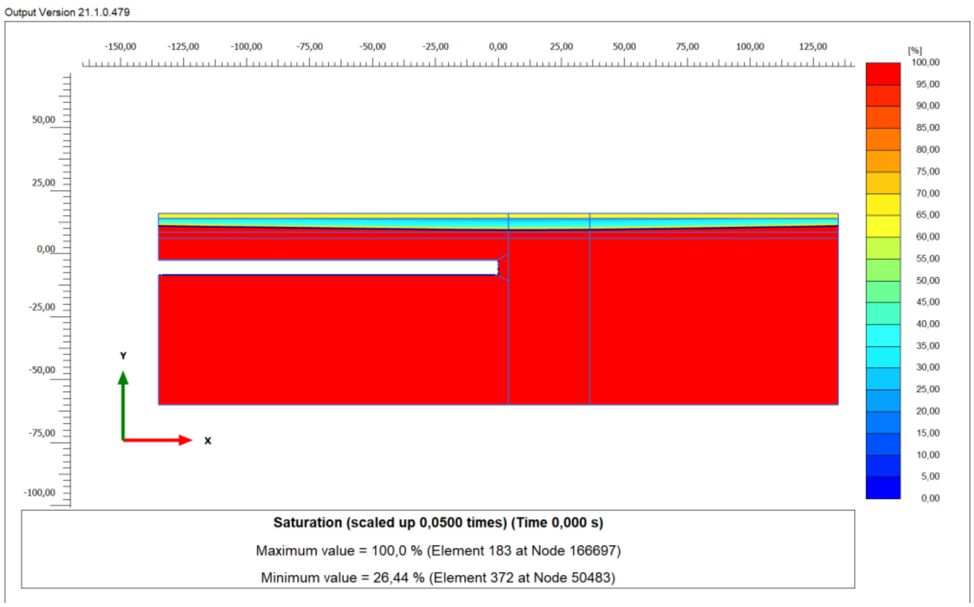


1.- EXCAVATION WITHOUT GROUTING AT THE TUNNEL FACE

Flow rates of 33 l/s/m (≈Section A=33m²). Q_{total} =33x5.5=181l/s



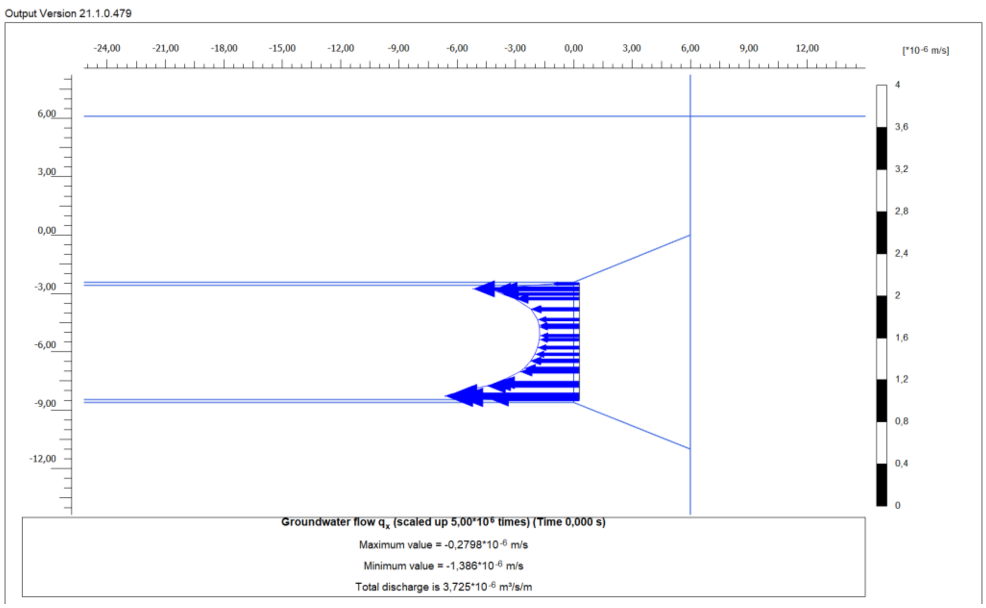
In this case lowering of the groundwater level. Decrease of 1.6m.



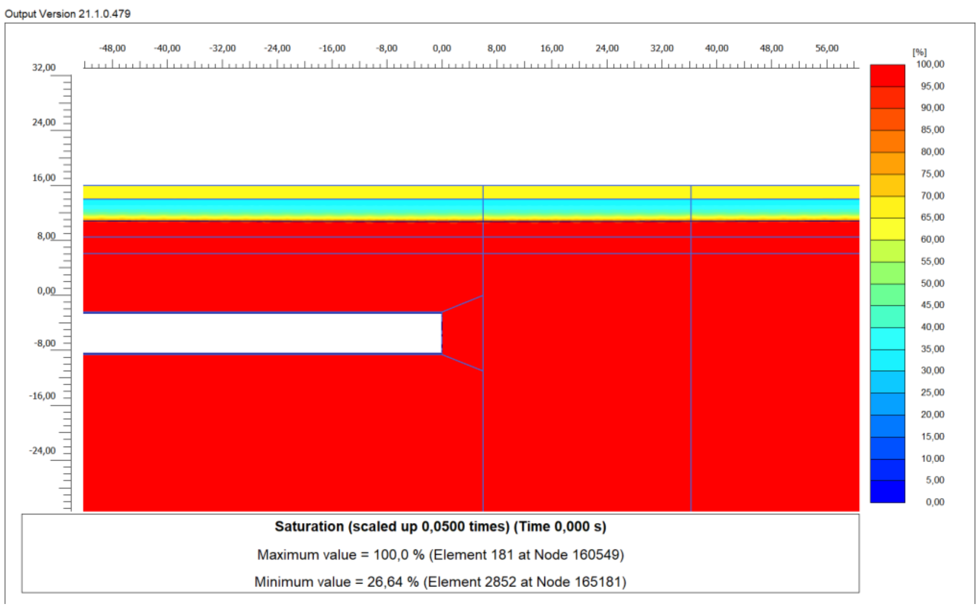
2.- FISSURE GROUTING 6m LENGTH. TUNNEL EXCAVATION SECTION AND AT THE SECTION FACE

Fissure Grouting with permeability of $K=10^{-7}$ m/s.

Flow rates of $3.7x10^{-3}$ l/s/m (≈Section A=33m²). $Q_{total} = 3{,}7x10^{-3}$ x5.5=20,3 $x10^{-3}$ l/s (0,02 l/s)

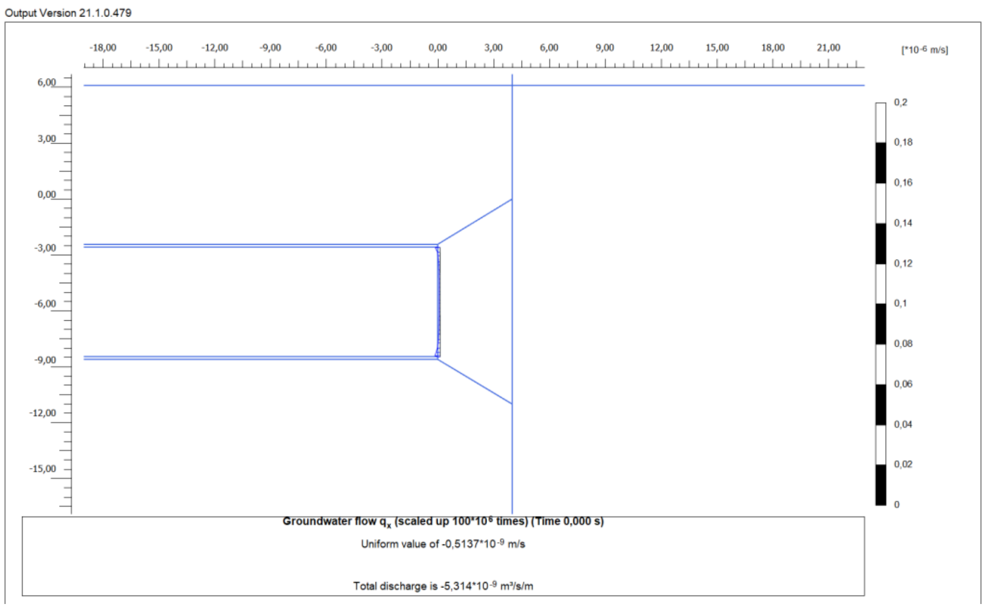


Lowering of the groundwater level of 0.23m.

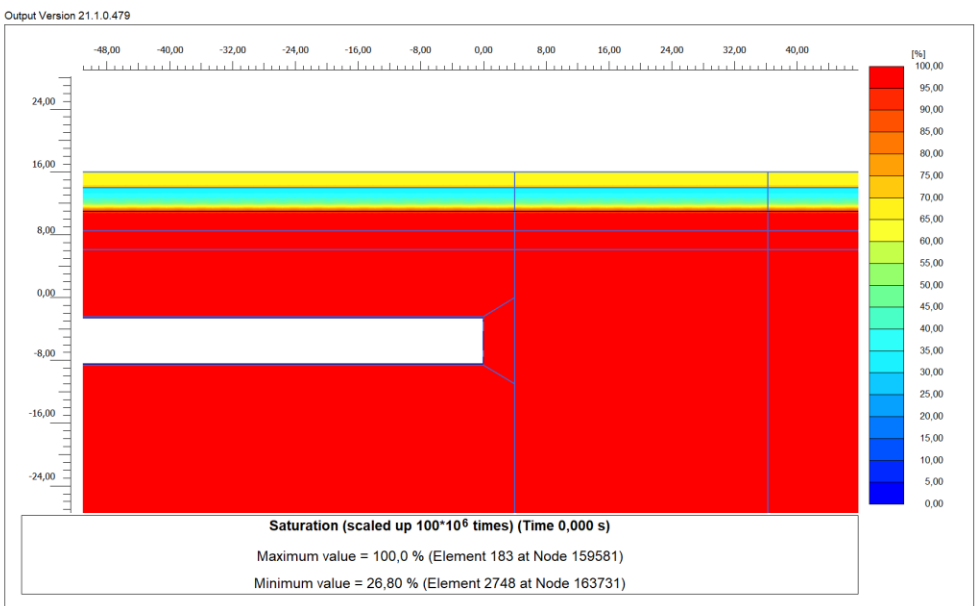


<u>Fissure Grouting with permeability of $K=10^{-8}$ m/s.</u>

Flow rates of $5.3x10^{-6}$ l/s/m (≈Section A=33m²). $Q_{total} = 5,3x10^{-6}$ x5.5=30 $x10^{-6}$ l/s



Groundwater level remains unchanged.



In the case that permeability of 10^{-8}m/s is not achieved and groundwater lowering of 0.23m occurs during the construction of the intervention tunnel (case with permeability 10^{-7}m/s), it must be pointed out that this decrease is clearly lower than the seasonal variation. As an example, Borehole monitoring NBH30, carried out between 4th of December of 2019 and 3rd of February of 2020, arises a variation between 0.69m.

- Shallower groundwater level: 4.262mbgl on the 18/12/2019 at 17:30h
- Deepest groundwater level: 4.954mbgl on the 03/02/2020 at 15:00h