TECHNICAL NOTE

Project Title:	Penrhos 132 kV Cable Replacement Project		
Project No.	794-ENV-GDE-21696		
Issue Date:	09/06/2025		
Document Ref:	250612 TN 21696 ES Penrhos – Radius of Influence & Abstraction Volumes Tech. Note	**Rev:**	Version 1
Subject:	Methodologies used to deduce the radius of influence & abstracted groundwater volumes for the Penrhos proposed cable corridor.		

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1. RADIUS OF INFLUENCE CALCULATIONS & ABSTRACTED GROUNDWATER QUANTITIES – REQUEST FOR FURTHER INFORMATION

This statement has been composed in response to the request from NRW on the 3rd of June 2025 for further information in support of the abstraction license applications (PAN-029212/3/4):

- 'Please provide an explanation of the values used in the Radius of Influence Calculations'
- 'Please explain how the requested maximum abstraction quantities relate to the dewatering calculations.'

As stated in the 'Abstraction Licence Application – Technical Note' the proposed abstractions will be solely composed of groundwater infiltrating into open trenches during construction and potential rainfall runoff across the three catchments traversed by the proposed cable corridor. These three catchments include Holy Island, Anglesey Island and Stanley Embankment.

As stated in '250609 TN 21696 ES Penrhos - Evidence of discharged water quality', results of recent investigations on Stanley Embankment have shown water to be absent within the concrete troughs which contain the current transmission cables that are due to be replaced. Subsequently, the necessity for groundwater abstraction along the embankment is now deemed unlikely.

Estimated maximum abstracted groundwater volumes and radius of influence on Holy Island and Anglesey Island were calculated using the same quantitative model presented in the 'Dewatering Calculations.xlsx' which was submitted with the original application. The model uses a steady state analytical solution for groundwater inflows to an open linear excavation (Powrie, et al., 1992) and has the following 3 stages:

1. Definition of a ground model, using site specific data (where available)
2. Calculation of the radius of influence using the proposed excavation depth.
3. Calculation of groundwater inflows to the proposed excavation, equivalent to the quantities requiring abstraction.

1.1 Definition of the Ground Model

The simplified ground model developed for the site can be seen in Figure 1. The model utilises average depths of geological units, as recorded within historical ground investigation at the old rectifier yard, the site of the proposed substation at Penrhos. These geotechnical logs have been provided in Appendix A.

Literature values for hydraulic conductivity (K) and the associated reference is provided in Table 1. These values, along with the average unit thickness were used to calculate the equivalent hydraulic conductivity and equivalent transmissivity using the formulae present in Equation 1.

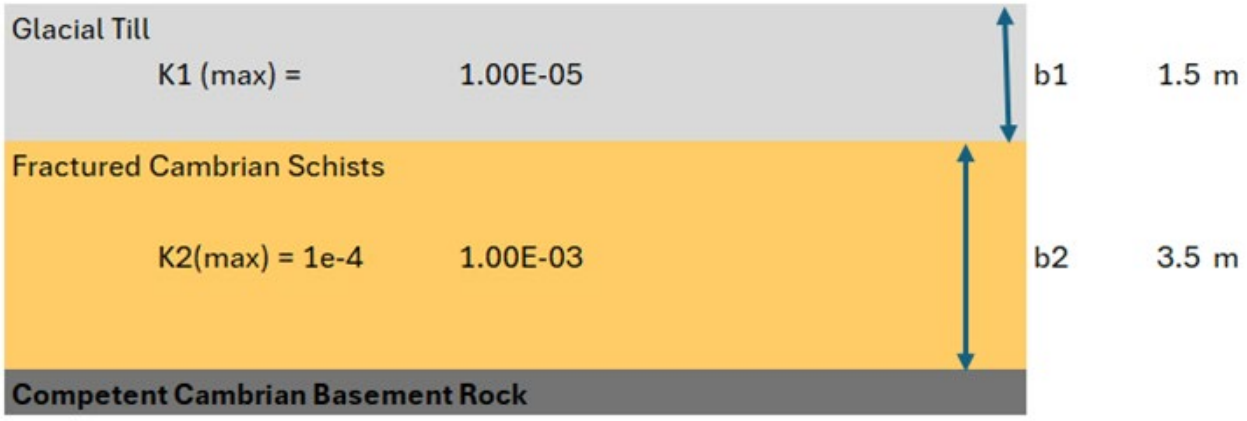


Figure 1 - Simplified ground model constructed using BGS records and results of site investigation

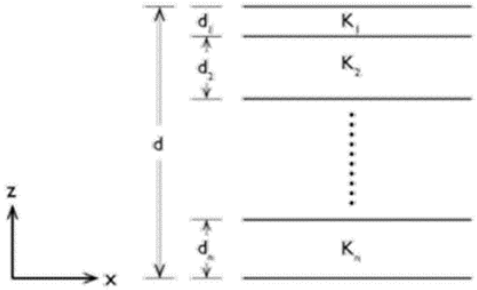
Table 1- Parameter Values used in construction of the ground model with associated references

Parameter	Value	Units	Justification / Note	Reference
Average thickness of glacial till at Penrhos site	1.5	m	Average value taken from historical site investigation	Appendix A
Average thickness of fractured schist bedrock at Penrhos site	3.5	m	Average value taken from historical site investigation	Appendix A
Hydraulic Conductivity (K) of Glacial Till	1.00E-05	m/s	Conservatively high estimate taken from literature	(Freeze, et al., 1979)
Hydraulic Conductivity (K) of Fractured Metamorphic Rock	1.00E-03	m/s	Conservatively high estimate taken from literature	(Freeze, et al., 1979)
Equivalent hydraulic conductivity (K^{equiv})	6.95E-04	m/s	Calculated from literature K values for glacial till and fractured metamorphic rock, using the equation cited in Equation 1.	
Equivalent transmissivity (T^{equiv})	3.47E-03	m^2/s	Calculated from literature K values for glacial till and fractured metamorphic rock, using the equation cited in Equation 1.	

Equation 1 - Equations for equivalent hydraulic conductivity (K) and Transmissivity (T) of a complex block of porous medium (Sun, 2025)

$$K_{\square}^{equiv} = \frac{K_1 b_1 + K_2 b_2 + \cdots + K_N b_N}{b_1 + b_2 \ldots + b_N}$$

$$T_{\square}^{equiv} = \sum_{i=1}^{N} T_i$$



1.2 Calculation of the radius of influence using the proposed excavation depth

The radius of influence for the proposed excavation (cable trench) was calculated using the following formula:

$$R = 1.5\left(\frac{Tt}{S}\right)^{\frac{1}{2}}$$

Equation 2 - Radius of Influence - Where R is radius of influence [L], T is transmissivity [L2/T], t is time [T], and S is storage coefficient [dimensionless]. (Duffield, 2014)

To calculate the radius of influence, the values listed in Table 2 were used in conjunction with Equation 2 as well as transmissivity values, as listed in Table 1. It should be noted that Equation 2 calculated the radius of influence for a pumping well in an infinite, confined aquifer. The ground model for the site has been developed on the assumption that the aquifer in question is unconfined. Using an analytical model for a confined scenario results in smaller results for the radius of influence. As the relationship between groundwater inflow to a trench (see Section 1.3) and the distance to the constant head boundary (radius of influence) is inversely proportional, this results in larger abstraction volumes.

The aim of the preliminary quantitative model was to determine the maximum potential abstracted volume of groundwater; hence this deliberately risk-averse method has been applied.

Table 2 - Parameters used in defining the radius of influence for dewatering the proposed excavation.

Parameter	Value	Units	Justification / Note	Reference
Storage Coefficient (S)	0.02 – 0.16	dimensionless	For an unconfined aquifer, specific yield is equal to the storage coefficient. See values below.	(Duffield, 2019)
Upper bound of specific yield for glacial till	0.16	dimensionless	Literature value for Specific yield for glacial till (predominantly sand) used to be conservatively high.	(Duffield, 2019)

Lower bound of specific yield for fractured igneous and metamorphic rock	0.02	dimensionless	Literature value for lower bound of Specific yield for fractured igneous and metamorphic rock used to capture potential range.	(Woessner, et al., 2020)
Time (t)	86400	s	One calendar day in seconds (to calculate total daily abstraction quantities)	

The following maximum and minimum values for the potential radius of influence were obtained:

$$R_{max} = 183.72\ m$$

$$R_{min} = 64.96\ m$$

Equation 3 - Results for maximum and minimum radius of influence of the dewatered excavation, calculated using Equation 2.

1.3 Calculation of groundwater inflows to the proposed excavation, equivalent to the quantities requiring abstraction

Projected maximum volume of groundwater inflow, equivalent to the quantities requiring abstraction, were calculated using the model presented in Figure 2 and Equation 3.

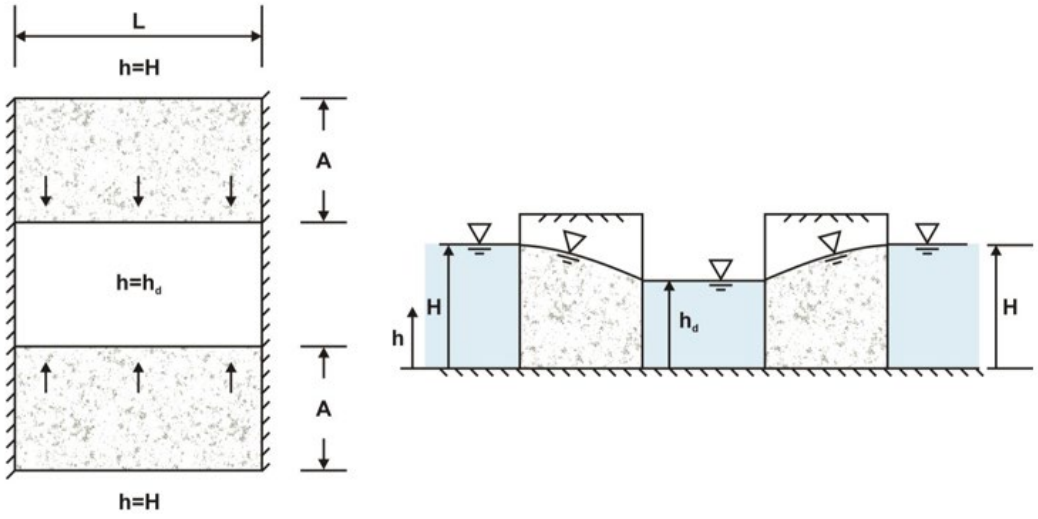


Figure 2 - Model for linear, unconfined flow into a trench (Powrie, et al., 1992)

$$Q = -K\frac{(H^2 - h_d^2)}{A}L$$

Equation 4 - Formula for linear unconfined flow into a trench. Where Q is volumetric flow [L^3], K is hydraulic conductivity [L/T], H is hydraulic head at the constant head boundary [L], A is distance to constant head boundary [L] and h_d is head in the excavation [L]. (Powrie, et al., 1992)

To calculate the volume of groundwater inflow, the values listed in Table 3 were used.

Table 3 - Parameters used in defining the groundwater inflow to the proposed excavation.

Parameter	Value	Units	Justification / Note
Hydraulic Conductivity (K)	6.95E-04	m/s	Equivalent hydraulic conductivity, as defined in Table 1.
Hydraulic head at the constant head boundary (H)	5	m	Assumes water table to be at the surface. Value for hydraulic head is the sum of the unit thicknesses using in the ground model, see Figure 1.
Maximum distance to the constant head boundary (A)	183.72	m	This is equivalent to the Radius of influence, as calculated in Equation 3
Minimum distance to the constant head boundary (A)	64.96	m	This is equivalent to the Radius of influence, as calculated in Equation 3
Hydraulic head in the excavation (h_d)	3.5	m	Maximum trench depth will be 1.5m. h_d = total thickness of ground model (5m) – maximum trench depth (1.5m)

The maximum and minimum values calculated for groundwater inflow per 1m of trench are as follows:

$$Q_{max} = 1.36 \times 10^{-4}\ m^3/s$$

$$Q_{min} = 4.82 \times 10^{-5}\ m^3/s$$

The maximum length for an open section of trench at any given time shall be 20m. Using this value the following maximum values for daily abstraction rates and annual abstraction rates for a 20m section of open trench has been deduced in Table 4.

Table 4 - Predicted maximum groundwater volumes requiring abstraction

Parameter	Value		Units
	Max (Calculated with R_{min})	Min (Calculated with R_{max})	
Maximum daily abstraction rate for a 20m section of open trench	235.6	83.3	m^3/day
Maximum annual abstraction rate for a 20m section of open trench	8.6E04	3.04E04	m^3/annum

2. SUMMARY

The calculations and model discussed within this technical note represent a provisional estimate of maximum groundwater abstractions and potential effects that is deliberately conservative in nature in order to be risk averse. This model is due to be updated within the full Hydrogeological Impact Assessment that shall be produced following the completion of the Phase 1 Intrusive Ground Investigation for the project and the factual reporting, as discussed in the Penrhos Desk Top Study Report and Preliminary Hydrogeological Risk Assessment (Document Reference 250519 Penrhos DTS & PHRA V2). At that point, the model will be refined and consolidated using the site-specific data to provide a more reliable estimate of the forecasted groundwater abstraction quantities.

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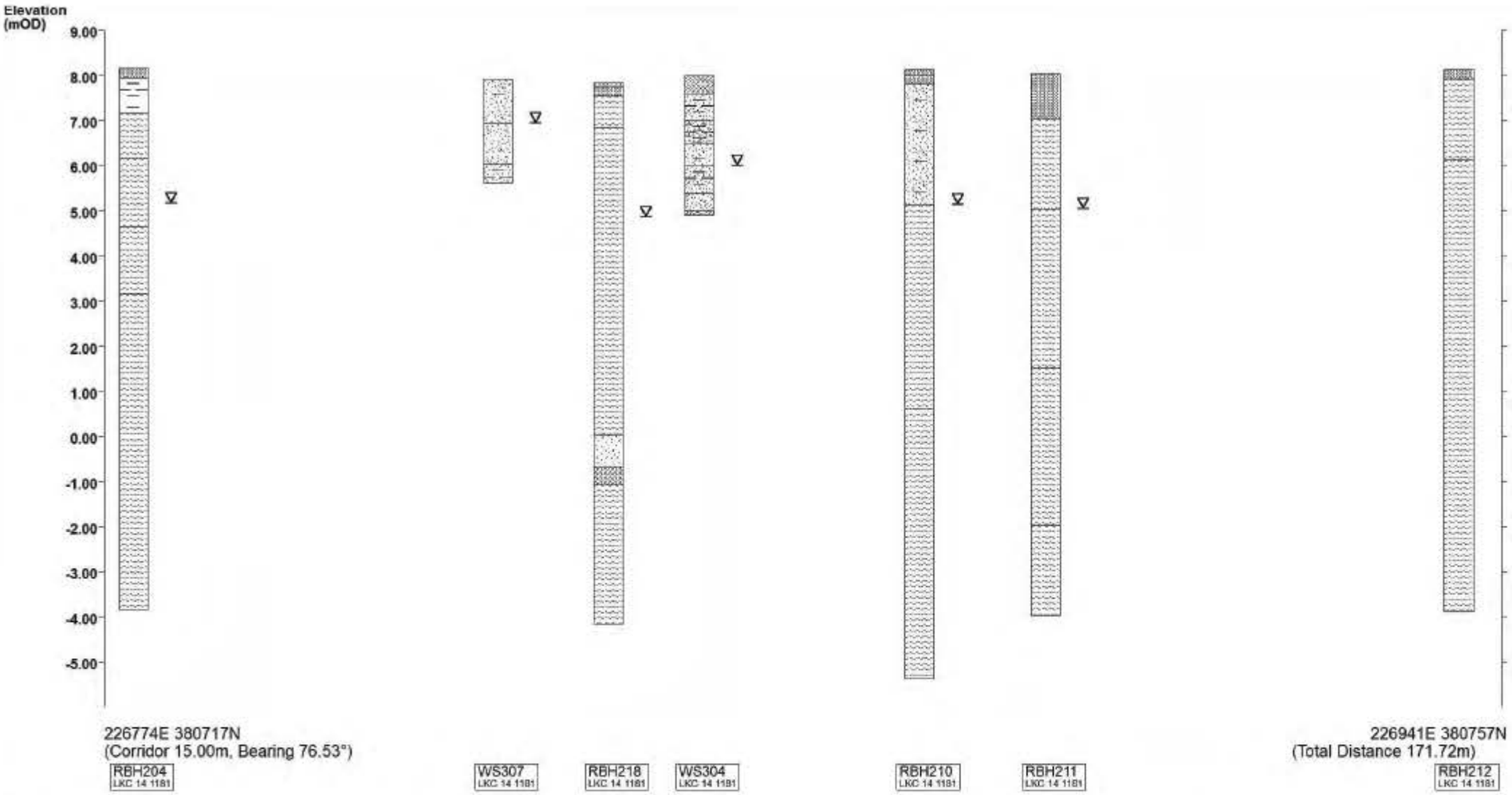
Appendix A

Historical Ground Investigation Records for the Penrhos Substation Site

Document Control

Document Ref.	Rev.	Date	Authored by	Checked by	Approved by



Key

- Water Strike
- Water Rise
- Highest Recorded Piezo Level
- Piezo Tip
- Schist
- MADE GROUND
- MADE GROUND
- CLAY
- Sandy gravelly CLAY
- Sandy gravelly organic CLAY
- Gravelly SAND
- GRAVEL
- Clayey sandy GRAVEL
- Silty sandy GRAVEL
- BRECCIA
- Medium grained METAMORPHIC

Additional Parameter: No Additonal Parameters

Horizontal Scale: 0 6 12 18 21

Extract from: GEOtechnical DAtabase SYstem (GEODASY)
Drawing Ref: (00/00/2000)

KEY

Sampling Locations and features annotated by LK Consult Ltd are approximate and are based upon observed measurements unless otherwise stated. Do not scale from this drawing and work from marked dimensions only. All dimensions and features should be confirmed on site by the Contractor. Where this drawing includes information provided to LK Consult Ltd by others, LK Consult Ltd gives no warranty, representation or assurance as to the accuracy of such information.

LK CONSULT LIMITED

Client: Orthios

Site: Anglesey Aluminium, Holyhead

Title: Geological Cross Section (Rectifier Yard)

Job No.:	Scale (See Scale Bar):	Figure:	Revision:
LKC 14 1181	See Scale Bar	6	

Drawn By:	Checked By:	Drawn:
AC	CH	Jun 2017