Groundwater control – a distress purchase that is worth getting right

Dr Martin Preene, Preene Groundwater Consulting, discusses the importance of groundwater control and dewatering for underground works, and gives guidance on good practice

Groundwater control – a geotechnical distress purchase

It is simple fact that encountering groundwater in an excavation will make life harder for all concerned. When groundwater problems are anticipated in water-bearing permeable soils and rocks (or indeed when groundwater problems are encountered unexpectedly) geotechnical designers have to deal with the risk of inundation due to groundwater inflows, and potential instability of excavation sides and bases caused by high pore water pressures. Contractors have to deal with potentially wet working conditions, spoil that is less easy to handle and re-use, and other factors that can affect the safety and reduce the efficiency of below-ground works. Other things being equal, most designers and contractors would prefer a 'dry' job to a 'wet' one.

When an excavation is faced with the challenges of groundwater inflows or groundwater pressures there are a range of groundwater control techniques that can be deployed. One of the principal types of groundwater control is the use of construction dewatering methods (also known as pumped groundwater control), where water is pumped from arrays of wells or sumps in order to lower groundwater levels to below the base of the excavation. Available construction dewatering techniques are described by Preene *et al* (2016). Table 1 summarises the principal techniques.

However, there is sometimes a perception that construction dewatering is a distress purchase – in others words "a good or service purchased only because there are no alternatives, or the alternatives are all far inferior, rather than having any desire to actually purchase this good or service". Also, if it cannot be avoided altogether, there is a temptation to focus purely on minimising the cost of dewatering.

It is interesting to consider why pumped groundwater control methods might be sometimes viewed in this way, and why designers may on occasion not give dewatering the consideration it deserves. Some characteristics of pumped groundwater control systems include:

They are unusual in that there is no physical end product (while there is when deploying a groundwater cut-off method, eg a sheet-pile wall or a block of grouted soil). The actual outcome of lowering groundwater levels is to change the behaviour of soils (turning wet, unstable, material into dry workable ground) on a temporary basis. When pumping is stopped, as water levels recover, the soil will return to its former state.

Construction dewatering systems are almost always part of the temporary works (permanent works applications are not unknown, but are very rare, for example the Stratford station on the HS1 railway line in east London, Whitaker, 2004) because of this temporary almost ephemeral effect. Such temporary works may not be fully considered at design stage, and be left 'to be sorted out on site'.

Under the framework of BS EN 1997-1:2004 (Eurocode 7) there is no document covering groundwater control by pumping under the suite of British Standards documents that provide guidance on the execution of special geotechnical works This contrasts with the likes of grouting, jet grouting and concrete diaphragm walls etc where such execution codes exist (BS EN 12715:2010, BS EN 12716:2001, BS EN 1538:2010). This lack of formal standards may devalue groundwater control for some people.

Table 1 Summary of principal pumped well groundwater control methods (after Preene et al, 2016)

Method	Typical applications
Drainage pipes or ditches (eg French drains)	Control of surface water and shallow groundwater (including overbleed)
Sump pumping	Shallow excavations in clean coarse soils
Wellpoints	Generally shallow, open excavations in sandy gravels down to fine sands and possibly silty sands. Deeper excavations (requiring >5 m to 6 m drawdown) will require multiple stages of wellpoints to be installed
Deepwells with electric submersible pumps	Deep excavations in sandy gravels to fine sands and water-bearing fissured rocks
Shallow bored wells with suction pumps	Shallow excavations in sandy gravels to silty fine sands and water-bearing fissured rocks
Passive relief wells and sand drains	Relief of pore water pressure in confined aquifers or sand lenses below the floor of the excavation
Ejector system	Excavations in silty fine sands, silts or laminated clays in which pore water pressure control is required
Deepwells with electric submersible pumps and vacuum	Deep excavations in silty fine sands, where drainage from the soil into the well may be slow
Electro-osmosis	Very low permeability soils, eg clays

Table 2 Categories of impacts from groundwater control (after Preene and Fisher, 2015)

Impact category	Types of impact
Geotechnical impacts	Ground settlement – effective stress Ground settlement – loss of ground
Contamination impacts	Mobilisation by pumping Creation of vertical flow pathways
Water feature impacts	Reduction in flow Change in water quality Change in water level
Water resource impacts	Change in water availability Change in water quality
Water discharge impacts	Change in water quality Downstream scour and flooding

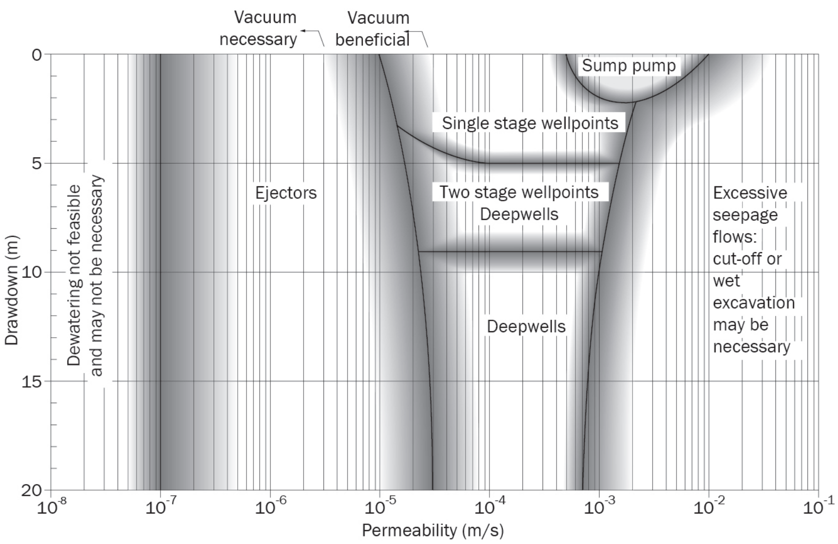

Figure 1 Range of application of pumped well groundwater control techniques (from Preene et al, 2016)

The importance of getting groundwater control right

Despite these factors, there are compelling reasons to make sure that groundwater control is adequately planned and executed.

Groundwater control is one of the first geotechnical processes on site, and enables many subsequent excavation and foundation activities. These in turn enable the wider construction project, for example the superstructure and fit-out of a building. If construction dewatering is not carried out effectively and in a timely manner, there is a real risk that subsequent work phases will not be able to start on programme, and that knock-on delays may affect the rest of the project.

A study by Roberts and Deed (1994) showed that the direct cost of construction dewatering systems is very small (typically less than one per cent of total costs for large projects). If there are project delays as a result of inadequate or ineffective dewatering, the delay costs will dwarf the costs of doing it right in the first place. There have been examples where, in construction disputes arising from the alleged poor performance of construction dewatering systems, delay costs of more than £10m have been claimed on sites where the direct cost of effective groundwater control would have been significantly less than £100 000 (assuming the dewatering was done to high standards).

Good practice in groundwater control

The best approaches to the design and implementation of groundwater control systems use a 'conceptual model' to shape the way a groundwater control system is developed.

A conceptual model is a way of summarising, ideally in simple terms that can be understood by non-technical specialists, the nature of the groundwater problem, the proposed technological solution, any significant practical or physical constraints, and the key risks or uncertainties (which are often, but not always, associated with the ground conditions and the quality and quantity of site investigation information available).

A conceptual model should attempt to summarise:

- The principal objectives of the dewatering system. For example, is the priority to prevent flooding of the excavation from high permeability water-bearing strata, or is the objective to lower pore water pressures to ensure slope stability or avoid base heave in soils of low to moderate permeability?
- A conceptualisation of the ground conditions, specifically relevant to groundwater control. This might include the principal permeable layers (sometimes termed aquifers), any significant low permeability layers (aquitards), groundwater levels and piezometric pressures, and any significant aquifer boundaries (such as bodies of surface water in hydraulic connection with the aquifer, which might act as close sources of recharge).
- Any identified shortcomings or inconsistencies in the ground investigation information (ie in the quantity, quality and relevance of the information). The impact on dewatering design of uncertainties in the ground investigation should be considered, and if necessary the design modified, or further monitoring and investigation carried out.

- An initial assessment of the most appropriate construction dewatering technique. Ideally, this should be assessed early in the design process, as it will help shape and direct subsequent design stages. Figure 1 outlines the range of application of pumped well groundwater control systems can be useful in this regard.
- Any potentially significant environmental impacts that may influence the groundwater control design (Table 2).
- Any non-geotechnical constraints on the design, such as limited access or regulatory constraints.

Experience suggests that successful groundwater control projects involve the following stages, whether carried out by one or several organisations, depending on the contractual framework for the project:

1. Assessment of potential groundwater problems during the design of permanent and temporary works, including potential environmental impacts, where possible selecting appropriate groundwater control techniques at an early stage.
2. Execution of a ground investigation (including desk study) designed to provide the information needed for groundwater control systems.
3. Consultation with the appropriate environmental regulator or authority to obtain the necessary consents for both groundwater abstraction (pumping) and discharge.
4. Use of design methods that concentrate on getting the conceptual model right and selecting appropriate permeability values.
5. Methods of analysis and calculations that use sensitivity or parametric analyses to assess the effect of variations in permeability or boundary conditions. It is not realistic to expect a set of unique answers from calculations, and it is better to predict a range of values of, say, flow rate.
6. Design and specification of a robust and flexible system that can be easily modified to meet the credible range of analytical results (eg flow rate, time to achieve drawdown).
7. Supervision of the installation of the system to make sure it is carried out correctly.
8. Monitoring and analysis of the performance of the system at start up and during the initial drawdown period, in order to facilitate a prompt response if modifications are necessary.
9. Maintenance and monitoring during the operational period.
10. Review of the groundwater control aspects on completion of the project and dissemination of data.

Figure 2 ***Deepwell dewatering for groundwater control for a large excavation within retaining walls (courtesy WJ Groundwater Limited)***

Figure 3 ***Well head and discharge pipe for a deepwell dewatering system for an open cut excavation (courtesy WJ Groundwater Limited)***

This is the good practice approach proposed in CIRIA C515 (Preene *et al*, 2000), which was updated in 2016 (Preene *et al*, 2016). Both guides play a key role in promoting high standards of pumped groundwater control in the UK construction industry.

About the author

Dr Preene is a geotechnical consultant with 30 years' experience in dewatering and groundwater control. He is the co-author of CIRIA C750 published in 2016.

For more information about the updated guide, go to: **www.ciria.org**

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Statutes

BS EN 1997-1:2004 *Eurocode 7: Geotechnical design. General rules*

BS EN 12715:2010 *Execution of special geotechnical works. Grouting*

BS EN 12716:2001 *Execution of special geotechnical works. Jet grouting*

BS EN 1538:2010+A1:2015 *Execution of special geotechnical works. Diaphragm walls*