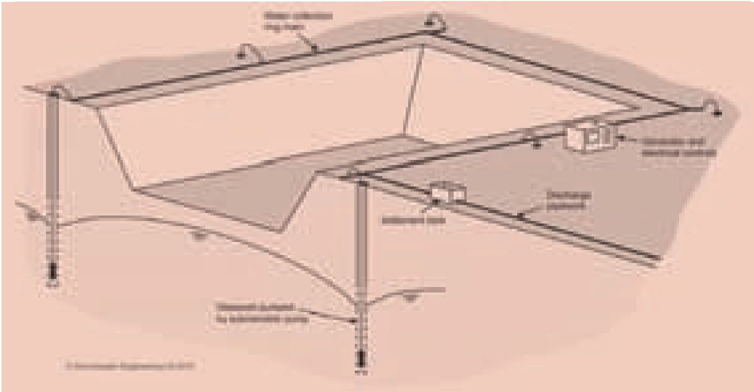
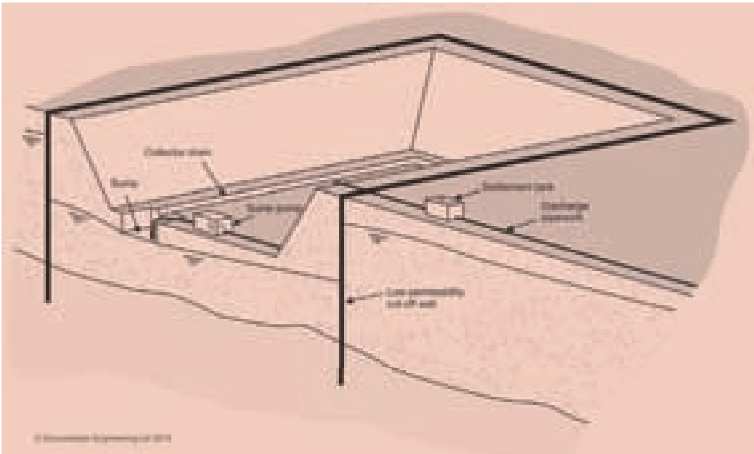
Keeping it under control

Martin Preene of Preene Groundwater Consulting and Groundwater Engineering's Seb Fisher discuss the potential impacts of groundwater control in urban areas

Martin Preene (top) and Seb Fisher



Above left: Fig 1 – groundwater control by pumping



Left: Fig 2 – groundwater control by exclusion

Many construction and mining projects rely on groundwater-control techniques to allow excavation below groundwater level in dry and stable conditions.

Examples include deep basements, transport infrastructure (e.g. road underpasses or metro rail systems), utility infrastructure (water and power tunnels) and open-pit mines.

In the past, it was not routine to consider the potential environmental impacts of dewatering and groundwater control. However, in recent decades, discussion and guidance has emerged on potential environmental impacts, with dewatering guidance documents being produced in the UK and in the Middle East, and these issues are now routinely considered.

This article describes the issues and potential environmental impacts associated with groundwater control in urban areas, where the restricted working space and the presence of neighbouring structures will influence the choice of methods, and discusses the requirements for monitoring and mitigation.

METHODS OF CONTROL

Groundwater control can be achieved via two principal types of methods: pumping and exclusion. A range of methods can be used to control groundwater as shown in Table 1.

The techniques most commonly associated with groundwater control are the pumping methods. These involve pumping groundwater from an array of wells or sumps (see Fig. 1) with the aim of temporarily lowering water levels to allow excavation to be carried out in stable conditions.

Pumping methods are also known as groundwater lowering, construction dewatering or simply dewatering. The amount of lowering of the groundwater level is known as drawdown.

In contrast, exclusion methods rely on low-permeability cut-off walls around the excavation to exclude groundwater (Fig. 2). Exclusion methods can significantly reduce, or even eliminate, the requirement to pump groundwater.

Each group of methods (pumping and exclusion) has the potential to cause different types of environmental impact. ►

Table 1: Groundwater-control methods

Pumping methods	Exclusion methods
Sump pumping	Steel sheet-piling
Vertical wellpoints	Vibrated beam walls
Horizontal wellpoints	Cement-bentonite or soil-bentonite slurry walls
Deep wells with submersible pumps	Concrete diaphragm walls
Ejector wells	Bored pile walls
Passive relief wells	Grout curtains (permeation grouting; rock grouting; jet grouting; mix in place)
Electro-osmosis	Artificial ground freezing

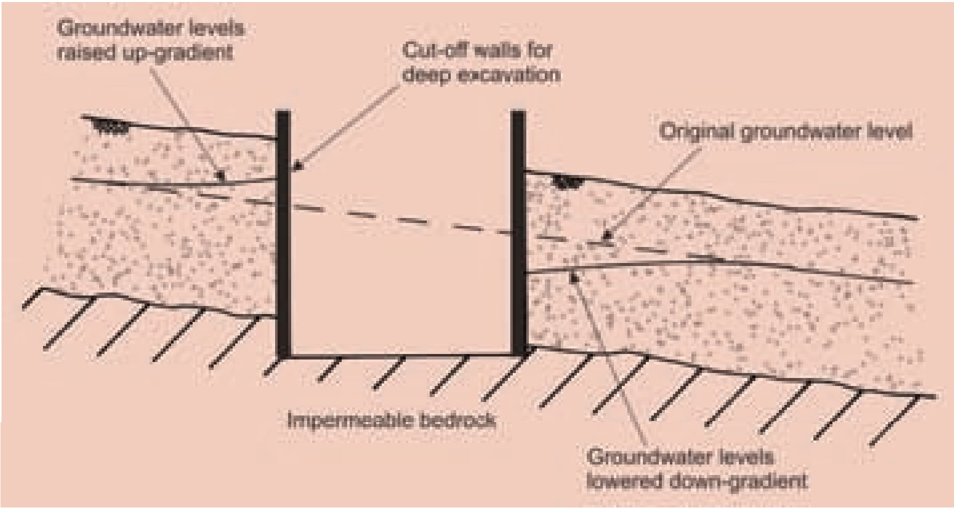


Fig 3 – low-permeability cut-off walls acting to block natural groundwater flow

INDICATIVE FACTORS

It is difficult to provide generic indicators of the risk of impacts. This is partly because the potential impacts depend on hydrogeological conditions, which are unique to each site. Additionally, the type of groundwater control methods used can have a key influence on the potential impacts.

One of the challenges of working in dense urban areas is that the project site is likely to be surrounded by neighbouring sites, which may have different sensitivities and vulnerabilities to impacts from groundwater control.

The potential for impacts has to be assessed on a site-by-site basis. Ideally, such assessments need some structure or framework, and the categories of impacts in Table 2 are suggested as an aid to planning and structuring the assessments.

The impacts listed in Table 2 are the direct impacts from interference with groundwater. There will also be indirect impacts (such as noise, emissions from plant, etc.) associated with physical construction, such as well drilling or pumping. These are not discussed here.

TYPES OF IMPACT

Geotechnical impacts: where the geotechnical properties or state of the ground are changed by groundwater-control activities.

The most common impact in this category is ground settlement, with the risk of distortion and damage to structures, services and other sensitive infrastructure. Ground settlement can be caused by two principal mechanisms:

- Increases in effective stress as a result of lowering groundwater levels, resulting in compression and consolidation of the ground.
- Removal of fine particles from the ground (loss of fines), which can occur when poorly controlled sump pumping draws out soil particles with the pumped water. With good design and implementation, loss of fines (and the associated settlement risk) can be avoided.

Contamination impacts: where pre-existing ground or groundwater contamination is mobilised and/or where transmission pathways are created.

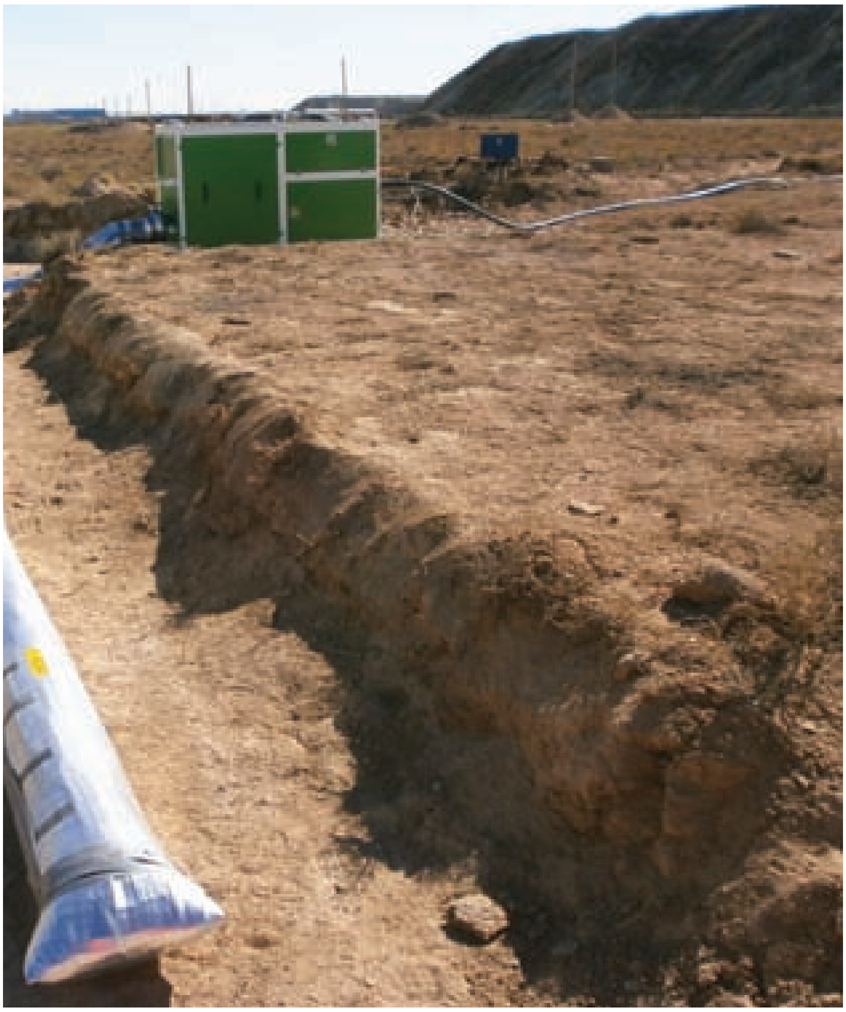
Many urban sites have a legacy of former industrial uses, which may have left behind contamination in soil or groundwater. Groundwater contamination can be mobile under the effect of hydraulic gradients and can migrate away from the source.

Dewatering pumping will generate hydraulic gradients that are much larger than natural gradients, and any nearby groundwater contamination will tend to be drawn toward the pumping system. The mobility of groundwater contamination is complex to assess, primarily being controlled by the nature and hydraulic conductivity of the ground, and the type and properties of contaminant.

In some cases groundwater contamination from a neighbouring site may reach the pumping system (and emerge in the discharge water) within a few hours of pumping, while in other circumstances it may be weeks or months before the contamination emerges in the system.

Water-feature impacts: where groundwater flows, levels and/or quality are affected in water-dependent features (both natural and artificial features).

This primarily relates to the consequences of lowering of



Groundwater control in action

groundwater levels or changes in flow pattern as a result of groundwater-control works. An obvious example is pumped groundwater control near natural water-dependent features such as wetlands (where water levels may fall due to increased seepage losses) or springs (where flow rates may be reduced).

Artificial features, such as archaeological remains, might also be detrimentally affected by lowered groundwater level, and this may need to be considered.

Even if groundwater pumping is not planned to be significant, low-permeability cut-off walls used for groundwater exclusion can also have impacts. Groundwater levels may rise on the upgradient side and fall on the downgradient side (Fig. 3).

Water-resource impacts: where water availability or water quality are affected either at defined abstraction points (wells or springs) or in known water-resource units (aquifers).

While groundwater is often viewed as a 'problem' for a construction project, that same water may be a resource used by others for purposes such as drinking, irrigation, agriculture or in industrial processes.

For large dewatering projects it is important that a review of nearby groundwater uses is carried out so that the potential impact on water-resource use can be assessed if necessary.

Possible impacts on water resources from groundwater control include a reduction in the quantity of water, due to lowering of groundwater levels or reduction in the yield of wells and springs.

Other impacts may affect water quality (the chemical makeup of the water), for example, by drawing in saline water from coastal waters or drawing in poorer-quality water from abandoned mine workings.

Discharge impacts: where the discharge of water from pumping systems impacts the receiving environment (surface water or groundwater, where recharge wells are used).

Where water is pumped, it must be disposed of, potentially creating a range of impacts. The most common impact is where discharge water has a significant sediment load. When discharged to surface watercourses, the sediment will be harmful to aquatic life and can build up in ponds and channels, affecting hydraulic capacity.

If suspended solids in the pumped water cannot be avoided through the use of well filters, then the water should be passed through a sedimentation system ►

"The potential for impacts has to be assessed on a site-by-site basis"

Table 2: Categories of groundwater-control impacts

Impact category	Types of impact
Geotechnical	Ground settlement – effective stress & loss of ground
Contamination	Mobilisation by pumping; creation of vertical flow pathways
Water feature	Reduction in flow; change in water quality; change in water level
Water resource	Change in water availability & quality
Water discharge	Change in water quality; downstream scour & flooding

Table 3: Principal monitoring parameters related to impacts from groundwater-control works

Monitoring	Comments
Pumped flow rate from groundwater-control system	Both instantaneous flow rates and cumulative volumes pumped are relevant to impact assessment.
Groundwater levels	Should be monitored close to the groundwater-control system, as well as closer to vulnerable receptors. Piezometers with defined response zones in specific strata are preferred over wells with long screened sections.
Surface water levels	Can be monitored in rivers, ponds and wetlands that may be affected by groundwater control.
Surface water flow rates	Can be monitored in rivers, ponds and wetlands that may be affected by groundwater control.
Discharge water chemistry	Temperature, suspended solids and water chemistry should be monitored.
Groundwater and surface water chemistry	Can be monitored in wells, springs, rivers, ponds and wetlands.
Ground levels	Monitoring of ground levels will allow the magnitude of ground settlement to be assessed.
Condition of structures	Visual inspection and structural monitoring will aid the identification of any structural distortion and damage.
Climate	Monitoring of rainfall and barometric pressure useful to identify any natural variations in groundwater conditions to separate such variations from artificial impacts.

before discharge. Even if the pumped water has a low sediment load, the aquatic habitats in the receiving watercourse may be affected by differences in chemistry and temperature between the pumped water and the receiving waters.

If groundwater is pumped from or near a contaminated site, the discharge water may be contaminated and require specialist treatment before discharge.

MONITORING

Monitoring and mitigation should be used to identify and measure (through monitoring), and then minimise and control (through mitigation) the potential impacts from groundwater-control works.

- Baseline (pre-construction) monitoring. It is prudent to have pre-construction monitoring of groundwater levels, spring flows, ground levels, etc. to determine baseline conditions against which any impacts can be assessed. This will require early access to site, or sourcing of third-party data.
- Operational monitoring. Monitoring of groundwater levels and pumped flow rates is a routine and necessary part of the operation of any groundwater-control scheme.

However, where environmental impacts are assessed to be of concern, then operational monitoring assumes even greater importance. Potential monitoring parameters for monitoring are given in Table 3.

MITIGATION

Mitigation measures must be developed on a site-specific basis, but can include:

- Artificial recharge: Groundwater from the pumped discharge can be re-injected (via wells) or re-infiltrated (via shallow wells or trenches) back into the ground, either to prevent lowering of groundwater levels and corresponding ground settlement, or to prevent depletion of groundwater.
- Targeted groundwater cut-off walls: Where there is a specific receptor to be protected, such as a wetland or sensitive structure, it may be possible to install a targeted section of cut-off wall or grout curtain between the dewatering system and the receptor, to reduce drawdown at the receptor.
- Temporary cut-off walls: If there is a concern that permanent cut-off walls will act as a barrier and affect the long-term groundwater flow regime, then it may be possible to use temporary cut-off methods, such as steel sheet-piles that are withdrawn at the end of the project, or artificial ground freezing, which will eventually thaw and allow groundwater flow to pass.
- Protection of individual receptors: If there are only a small number of isolated receptors, it may be more cost-effective to prevent the problem at the receptor itself, for example, by underpinning the foundations of a sensitive structure, or by replacing a residential water-supply well with a piped supply where lowering of groundwater levels has reduced the yield.

CONCLUSION

A range of environmental impacts can result from groundwater control, even if pumping is not involved. Categories presented in this article can be useful to classify potential impacts to help identify sites and projects that may be significantly impacted.

Monitoring and mitigation measures can be used and should be based on a sound hydrogeological conceptual model developed from the available site investigation data, ideally including a desk study.

This article is based on a paper presented at the XVI European Conference on Soil Mechanics and Foundation Engineering in Edinburgh, Scotland, in September 2015