Pre-print version of a paper published as:
Brassington, F C and Preene, M (2004). A horizontal wellpoint as a low-impact water source in a dune-sands aquifer. *Water and Environmental Management Journal* 18, No. 2, May, 102–106.

A HORIZONTAL WELLPOINT AS A LOW IMPACT WATER SOURCE IN A DUNE SANDS AQUIFER

F.C. Brassington, BSc, MSc, CGeol, FGS, CEng, MICE (Fellow)*
and
M. Preene, BEng, PhD, CGeol, FGS, CEng, FICE (Member)**

ABSTRACT

A horizontal wellpoint (HWP) groundwater source has been constructed to supply irrigation water to a golf course from a coastal dune sands aquifer in an area with vulnerable wetland habitats of European importance. The source was designed to abstract the required quantities with less drawdown compared to that expected from a conventional vertical wellpoint system, thereby reducing any potential threat to the nature conservation sites. Pump testing of the source showed the yield was more than adequate to meet the golf club's needs and to allow efficient operation of the computer controlled course irrigation system. Data from observation wells indicate that there will be no drawdown beyond the golf course boundaries and none of the nature conservation sites will be affected. The HWP method, which has not been widely applied in the UK, may have wide applications for irrigation water users wishing to abstract water from shallow aquifers

Key words: ***Abstraction; aquifer; environmental impact groundwater, Habitats Directive; sustainability; water source***

* Consultant Hydrogeologist, Warrington, UK
** Associate Director, Arup Water, Leeds, UK

INTRODUCTION

The Southport and Ainsdale Golf Club (S&A) has a traditional links golf course located on the sand dune belt that runs along the Sefton coast between the Mersey and Ribble Estuaries (Fig. 1). This coastal strip has a number of important nature conservation areas including vulnerable wetland habitats that have European importance and are protected by the EC Habitats Directive[1].

The Club has a Countryside Stewardship agreement with the Department of the Environment, Food and Rural Affairs for the management of the dune heath habitat that extends across the course and a strategy to conserve the dune environment and minimize environmental impacts that includes avoiding over-irrigation and the selection of appropriate native grass species. The sustainable management of the course involves irrigation to maintain the tees, greens and fairways to encourage grass growth in areas of high wear using a new computer-controlled irrigation system. This limits water application to the volumes required in each part of the course, thereby minimizing both the use of water and pumping costs.

The irrigation water had been abstracted from a pond excavated below the water table with problems of failing yield, safety and maintenance. The pond was located in the part of the course closest to the wetland conservation areas giving rise to concerns as it is widely recognized that sensitive water related habitats can be adversely impacted by abstraction from shallow aquifers[2,3]. It was decided therefore that the application to the Environment Agency (EA) for permission to abstract greater quantities of water should include the construction of a new source to provide an adequate yield and minimize the environmental impacts.

HABITAT CONSERVATION CONSIDERATIONS

In 1995, English Nature designated the Sefton coastal belt as a candidate Special Area of Conservation in terms of the EC Habitats Directive[1] and the UK habitat protection regulations[4,5] because it hosts species and habitats of European importance. These habitats include seasonal 'wet slacks' or valleys between the sand dunes where the winter level of the water table is high enough to form pools; and 'dry slacks' where the water table never rises above the ground level, although the shallow water table plays an important role in habitat support (Fig. 2). The wet slacks form suitable breeding conditions for Natterjack toads and various species of newts, and these areas may also provide suitable habitats for creeping willow and a number of rare pants such as Petalwort.

The Environment Agency's Catchment Abstraction Management Strategy[6] is based on the sustainable use of water resources that assesses the needs of abstractors against those of the natural environment. This policy provides the framework within which all applications for water abstraction licences are determined.

The habitat protection regulations[4,5] require all permissions that regulate activities including water abstractions, to be reviewed in terms of the potential impact on the protected habitats. The EA has a policy statement regarding such reviews[2] setting out how the EA will gather sufficient data for the review to be completed. The EA's North West Region carried out an investigation along the Sefton coast dunes aquifer involving the construction of a number of boreholes and the development of a numerical groundwater model as a consultancy project[7]. At the same time the S&A had a preliminary feasibility study[8] carried out in support of their application to vary their abstraction licence.

OPTIONS FOR IMPROVED WATER SUPPLY

A shallow dune sands aquifer extends along the Sefton Coast and consists of sand originally deposited by wind, blown from the west. As a result, both the sand grain size becomes finer and the aquifer thins inland, towards the east. The aquifer boundary is located about 500 m east of the S&A course and sample analysis shows it to be both well sorted and fine-grained.

Experience of the existing source shows that a lagoon tends to silt up easily, reducing the yield and has significant safety issues associated with deep water. It was decided that a new source was required and if this were to be located close to the water storage tank that supplies the irrigation system there would be operational advantages. Additionally, as this position is more remote from the areas of wet and dry slacks the potential environmental impacts are significantly reduced.

The anticipated limited thickness and moderate hydraulic conductivity (permeability) of the dune sand aquifer militated against the use of a conventional borehole water source as the relatively shallow borehole depth is unlikely to yield sufficient to meet the S&A's needs. An alternative water source sometimes used in shallow sand aquifers is the wellpoint system, consisting of lines or groups of small diameter (c. 50 mm) shallow wells (known as wellpoints), which are pumped by a suction pump via a common header pipe[9]. It was initially proposed to replace the pond with a wellpoint system similar to other local golf clubs. However, this was later changed to a horizontal wellpoint (HWP) for the reasons discussed here.

HORIZONTAL WELLPOINT SYSTEM

A HWP consists of a perforated drainage pipe installed horizontally below the water table and connected to a suction pump at the surface (Fig. 3). These systems are used in dewatering schemes for civil engineering construction as an alternative to vertical wellpoint installations[9]. The term *horizontal wellpoint* is widely used in the dewatering industry for horizontal drains used to lower groundwater levels in broadly the same manner that wellpoints are employed[9].

The use of a HWP as a permanent water source is unusual. The drainage contractor used on the project is the only one in the UK with equipment capable of installing a wellpoint to the depths used here, and claims that there no other UK examples. Pyne[10] reports that horizontal well technology for water supply is relatively new with some examples in the USA having been in successful operation since the early 1990s.

A HWP is hydraulically efficient because it has a very large screen area that remains below the water table during operation. Conventional wellpoints often inadvertently cause sufficient drawdown to expose the upper part of the screen, thereby reducing the open area available for inflows and compromising efficiency. For a HWP the groundwater flow will be planar to the sides of the perforated pipe in contrast with flow local to a vertical wellpoint system, where flow lines converge radially to each wellpoint, resulting in greater drawdowns. The reduced drawdown with HWPs will result in minimal environmental impacts to groundwater dependent habitats as well as lower pumping costs because of the reduced lift. An advantage of a small drawdown is that groundwater flow velocities are kept to a minimum. The potential for flowing water to carry particles is directly proportional to the velocity hence the fine particles in an aquifer are less likely to be mobilized and drawn to the screen, thereby reducing the risk of clogging and significantly extending the life of the system.

A further advantage is the limited visual impact of the source works. In a conventional wellpoint system, the top of each wellpoint extends above ground level and is attached to a header main that runs along the ground surface. In contrast, a HWP has no aboveground works other than the pump and therefore can be located below landscape features.

DESIGN OF THE HORIZONTAL WELLPOINT SYSTEM

Fine-grained and well-sorted aquifers pose practical difficulties in conventional well design as there is a very limited range of available grain sizes in the filter media needed to form a gravel pack around the borehole. This requires careful specification of both the gravel pack grain size and the slot size for the screen perforations to avoid sand pumping or the screen becoming clogged. Typically, the particle size distribution curve for the aquifer material is used to construct an envelope defined by four- and six-times the aquifer grain size to delineate an ideal gravel pack[11]. This practical approach provides latitude in the pack specification, and allows some flexibility in the choice of a suitable commercially available sand at an economic cost.

Particle size distribution curves were obtained for three sand samples obtained from the EA borehole close to the S&A course. These showed a similar well-sorted fine-grained sand that would require an artificial gravel pack round the screen in conventional well design. The extremely well sorted nature of the aquifer sand imposed severe difficulty in locating similarly well-sorted filter sand. It was necessary to compromise and use the closest available sand that was slightly finer than the design envelope for the coarsest 50 per cent of the material. It was judged that these differences are small and would not cause disadvantages to either the effectiveness of the pack material or the hydraulic performance of the water source.

For practical and cost reasons it was decided to construct the HWP using easily available standard materials. A corrugated plastic land drainage pipe was used for the HWP that has a diameter of a 160 mm, a slot size of 2 mm and was factory-wrapped in Terram 1000 geotextile with a pore size of 150 µm (Fig. 4). This pore size is smaller than the recommended slot size for the gravel pack but it was decided to adopt a cautious design in view of the difficulty in placing a layer of filter sand completely around the pipe.

INSTALLATION OF HORIZONTAL WELLPOINT SYSTEM

HWPs are commonly installed using crawler-mounted trenching machines equipped with a continuous digging chain (Fig. 3). As the machine tracks forward, a vertical sided trench about 225 mm wide is cut to depths between 2 and 6 m. A reel of flexible perforated drainage pipe feeds through the boom supporting the digging chain and is laid in the base of the trench. One end of the pipe is unperforated and is brought to the surface to be connected to a suction pump. For basic installations the spoil from the trench is allowed to fall back into the excavation and cover the drainage pipe. However, in many cases the hydraulic performance of the HWP can be improved by placing a more permeable filter material as a 'gravel pack' around the pipe. This is achieved by deflecting the spoil away from the trench, and placing the filter media into the excavation from a special hopper mounted on the trenching machine.

Fig. 5 shows the contractor's deep trenching machine as the cutting head is being positioned near the water tank to commence the installation of the HWP with the digging boom extended to allow an initial trench depth of 6.5 m. The continuous chain of buckets runs along the bottom of the boom with the square-section pipe feed-tube immediately above the buckets. Operators can be seen feeding the drainpipe into the funnel on the top of this feed-tube. A second, larger feed-tube has been fitted on top of the assembly to allow filter sand to be placed on top of the pipe as it is guided into the bottom of the trench. The filter sand is stored in the large hopper at the top of this feed-tube. The first length of HWP pipe is not slotted and extends from the bottom of the digging boom. The end has been secured (out of shot) so that it remains at the surface at the pump end of the HWP and the pipe will form a curved connection from ground level to the perforated HWP.

Fig. 6 shows the cutting head and continuous chain of buckets in more detail. The HWP pipe is seen extending out of the bottom of the digging boom assembly with the bottom of the filter sand feed tube seen above it.

At the suction end of the HWP the pipe was installed to a depth of 6.5 m with the curved part between the surface and the horizontal section comprising unperforated pipe. The HWP runs sub-horizontally for some 150 m to the south-southeast where it turns through some 65^{o} to the north and runs in a northeasterly direction for a further 130 m. The depth of burial gradually decreases along the length of the horizontal well point and is some 4.5 m at the change point and some 4 m depth at the furthest end. The HWP installation was completed in less than two hours.

Water is abstracted from the HWP by means of a centrifugal self-priming suction pump driven by an electric motor installed in a chamber constructed at one end of the HWP with the control panel and switches housed in the nearby Greenkeeper's shed along with the control gear for the irrigation system. During operation water is delivered to an adjacent 152 m^3 capacity storage tank by the pump controlled on float-switches. The computer controlled irrigation system then delivers water at a higher instantaneous rate where it is required on the course.

PUMPING TEST

The HWP was test pumped to establish its yield, to provide data to support the abstraction licence application, and to assess the impacts on the nearby habitats. The test and the data analysis are described in detail in the report[12] to the EA supporting the licence application. The effect on groundwater levels was monitored in the observation well network across the course and a series of additional observation wells constructed close to the HWP. Three rows of observation wells were installed at right angles to the HWP, one at each end and the third near the centre in line with the EA's observation borehole.

The average pumping rate over the 72-hour pumping test was 46.25 m^3/hour, equivalent to 1.11 Ml/d compared to the required daily rate of 0.425 Ml/d. The water initially contained small amounts of silt/clay and cleared after a few minutes. Subsequent operational experience shows that the water is frequently coloured for a short period immediately after pumping recommences following a long period of rest. The colouration is due to small quantities of ochre precipitated from the groundwater in the HWP and derived from iron oxides in the dune sands. The recovery in water levels was measured for some 18 days following the cessation of pumping. The operational experience has also shown that the yield has been maintained supporting the view that low groundwater velocities minimize clogging problems.

The data collected during the test are principally the water level measurements from the observation well network and the EA's observation borehole. They have been scrutinized to evaluate the aquifer behaviour and assess the hydraulic conductivity and storativity[12]. An innovative feature of the analysis is the use of a highly specialised analytical solution[13] to model drawdown under planar flow conditions to long, pumped drainage features such as the HWP. This was necessary because the implicit assumption of radial flow, present in almost all classical hydrogeological analyses is not valid.

At the end of the test the drawdown in the EA observation borehole was some 0.45 m (Fig. 7). The greatest drawdown was seen in the observation wells closest to the pump (Row C) with the well over the HWP being drawn down by some 1.11 m (Figure8). An estimate of the furthest extent of the drawdown caused by the proposed abstraction suggests that there will be no drawdown beyond the golf course boundaries and none of the nature conservation areas will be affected.

CONCLUSIONS

1. The yield is more than adequate to meet the S&A needs and proved to be greater than would be expected from an aquifer with the hydraulic properties assessed from the pumping test. This is attributed to the horizontal wellpoint running sub-parallel to the water table contours and the enhanced aquifer charateristics along the horizontal wellpoint caused by the ground disturbance during construction.
2. The instantaneous source yield is sufficient to allow the efficient operation of a sophisticated irrigation system that places water in the right quantities at the right time, thereby minimizing water use.
3. The small flow velocities associated with a horizontal wellpoint system reduce the risk of clogging by fine particles from the aquifer, thereby extending the life of the system.
4. The water source uses an innovative technology transfer from dewatering techniques to water supply engineering. This is unusual as such transfers are often in the other direction, with dewatering specialists using water abstraction experience and equipment.
5. The source design makes use of planar rather than radial groundwater flow that requires significantly less drawdown to drive the groundwater flow through the aquifer. Consequently drawdown is minimized, thereby reducing both the impact on the local groundwater levels and any alteration of the natural groundwater system. In combination with the source location remote from the wetland areas, the environmental impact has minimized and any potential threat to the important nature conservation sites has been removed.
6. The improvements to the course irrigation ensure the long-term future of the Club and its ability to continue to conserve the habitats on the course as part of the on-going Countryside Stewardship Agreement while maintaining a high-quality golf course.
7. The HWP method, which has not been widely applied in the UK, may have wide applications for irrigation water users wishing to abstract water from shallow aquifers.

ACKNOWLEDGEMENTS

We are grateful to the Southport & Ainsdale Golf Club for permission to publish this paper. Thanks are due to the Course Manager, Mike Mercer and his staff for collecting the majority of the groundwater level readings. We are especially grateful to Mr Bob Hutt, latterly Chairman of the Greens Committee for his encouragement and support throughout the completion of the project.

This paper is based on a submission by the authors for the 2003 CIWEM Chris Binnie Award for Sustainable Water Management.

REFERENCES

(1) COUNCIL OF EUROPEAN COMMUNITIES. Directive on the Conservation of Natural Habitats and of Wild Flora and Fauna. (92/43/EEC). *Official Journal* L 206–7. 1992.

(2) ENVIRONMENT AGENCY. *Policy for Implementing the Habitats Directive*. Policy Number 181–01. Environment Agency, Bristol. 2001.

(3) HISCOCK, K.M., RIVETT, M.O. & DAVISON, R.M. Sustainable groundwater development. Chapter 1 in *Sustainable Groundwater Development*. Geological Society Special Publication 193. Geological Society, London, pp1–14. 2002.

(4) UK GOVERNMENT. *The Conservation (Natural Habitats &c) Regulations 1994* (Statutory Instrument Number 2716), HMSO, London. 1994.

(5) UK GOVERNMENT. *Conservation (Natural Habitats &c) (Amendment) (England) Regulations 2000* (Statutory Instrument Number 192), HMSO, London. 2000.
(6) ENVIRONMENT AGENCY. *Managing Water Abstraction – The Catchment Abstraction Management process*. Updated 2002. Environment Agency, Bristol. 2002.
(7) ENTEC. *Southport and Sefton Water Resources Evaluation Study.* Consultancy report for the Environment Agency North West Region. 1999.
(8) LONGSTAFF, S.L. & BRASSINGTON, F.C. *Environmental Impact of Proposed Groundwater Abstraction at Southport & Ainsdale Golf Club, Southport, Lancashire*. Consultancy report, for S&A by Stanger Science & Environment. 1998.
(9) PREENE, M., ROBERTS, T.O.L, POWRIE, W. & DYER, M. R. *Groundwater Control –Design and Practice.* CIRIA Report C515. Construction Industry Research and Information Association, London. 2000.
(10) PYNE, R.D.G. *Groundwater Recharge and Wells – A Guide to Aquifer Storage Recovery.* Lewis Publishers, Boca Raton. 1994.
(11) CLARK, L. *The Field Guide to Water Wells and Boreholes*. John Wiley & Sons, Chichester. 1988.
(12) BRASSINGTON, F.C. *Environmental Impact Assessment of a Water Abstraction from a New Horizontal Well Point System at the Southport & Ainsdale Golf Course.* Consultancy report, for S&A by Rick Brassington Consultant Hydrogeologist, Warrington. 2000.
(13) POWRIE, W. & PREENE, M. Time-drawdown behaviour of construction dewatering systems in fine soils. *Géotechnique*, 44, No.1, pp83–100. 1993.

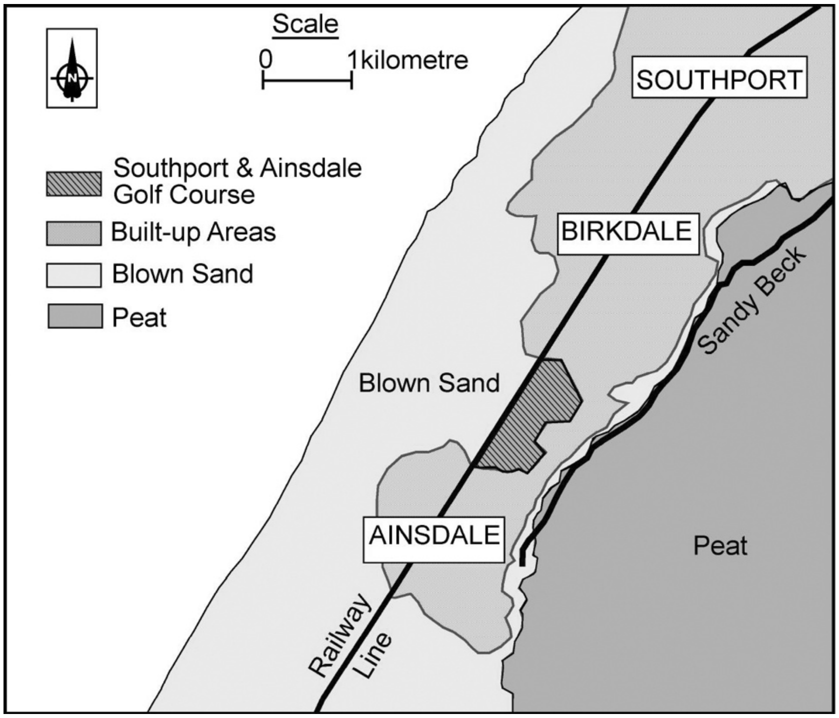

Fig.1 Location map with outline geology

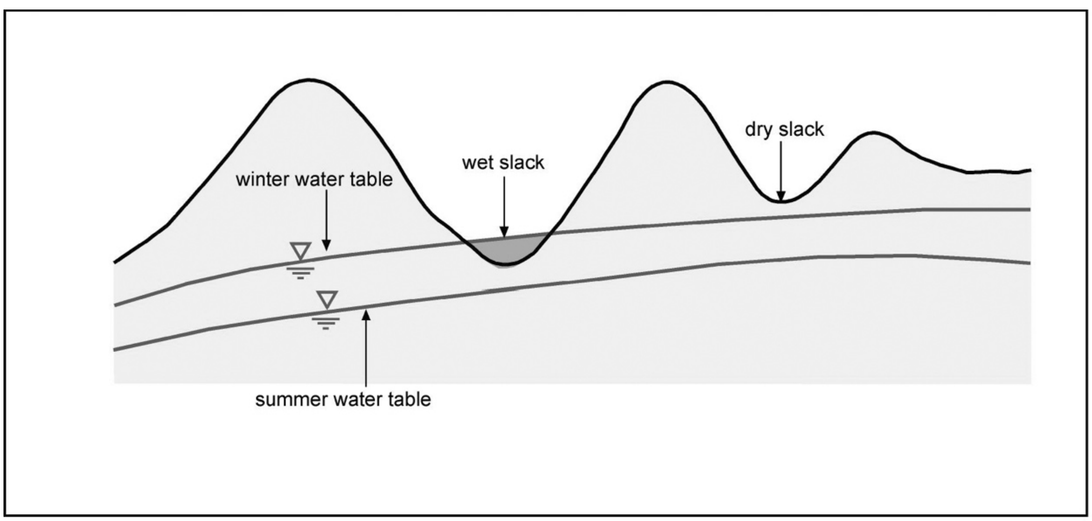

Fig 2 Wet and dry slacks

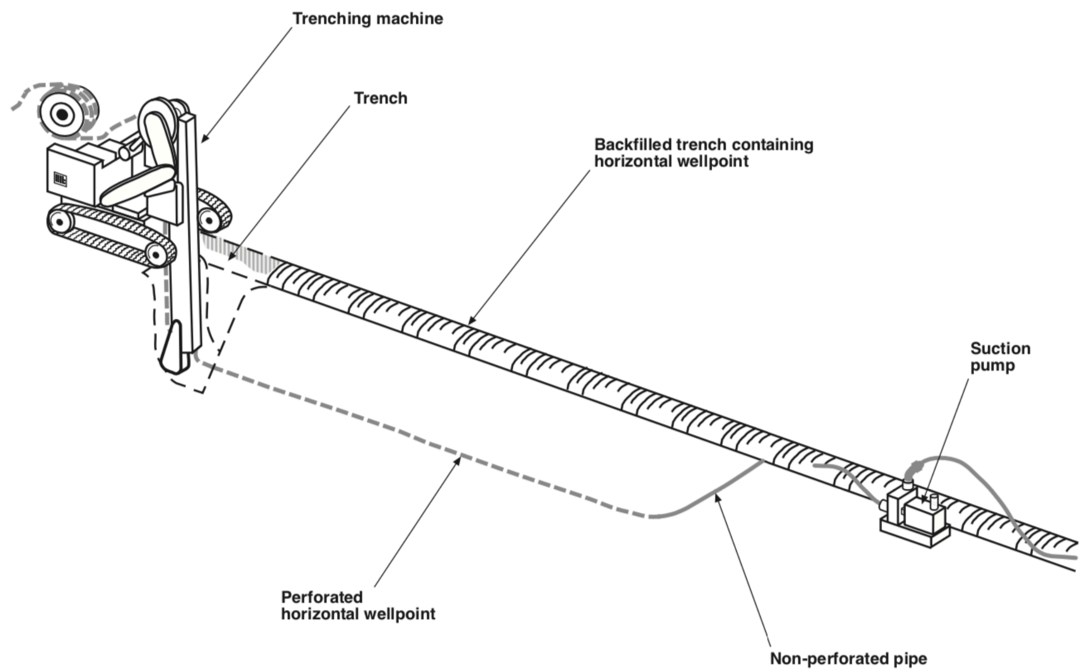

Fig 3 The main features of a horizontal wellpoint

Fig 4 Coil of 150 mm diameter drainage pipe used for the HWP

Fig 5 The deep trenching machine ready to start installation

Fig 6 Detail of the cutting head

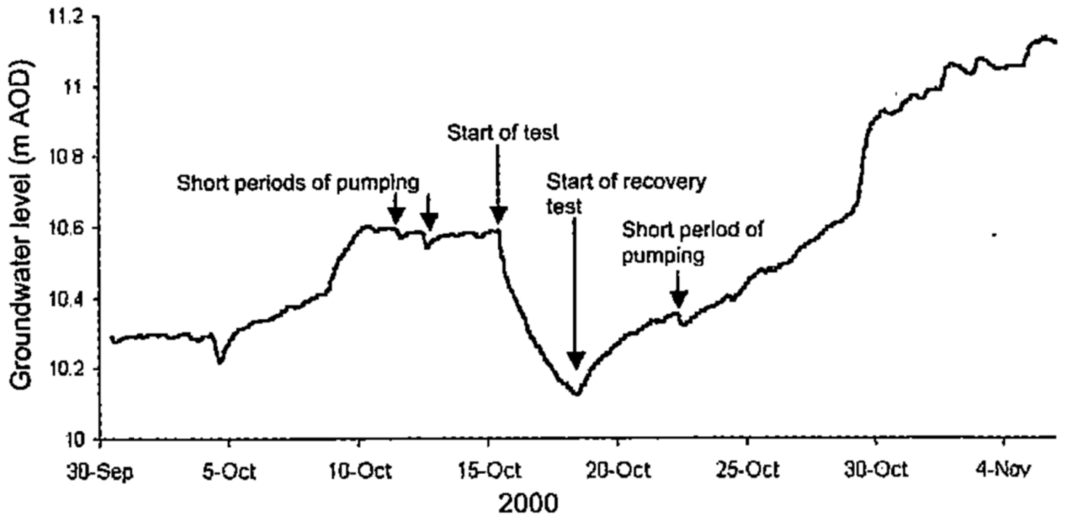

Fig 7 Groundwater hydrograph in the Environment Agency observation borehole

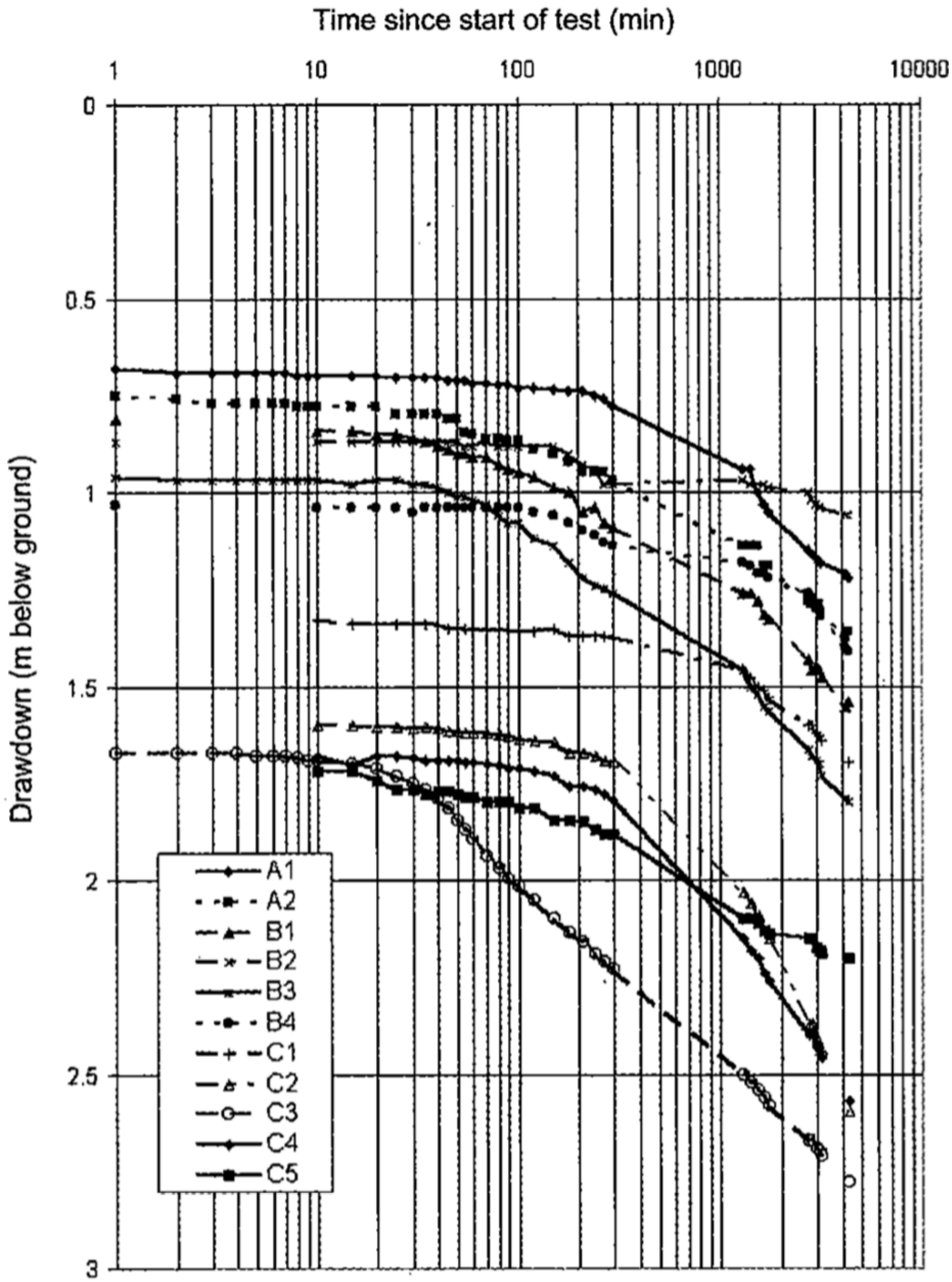

Fig 8 Groundwater level changes in Row C observation wells