Groundwater Abstraction for Large Yields

This module is designed for users proposing to drill a water borehole for the abstraction of large volumes of groundwater, possibly with associated reinjection. It is intended for users proposing to abstract more than 20 m^3/d for a water supply or open loop ground source heat pump system (or aquifer thermal energy storage scheme).

It contains an evaluation of the geological formations beneath the site in terms of aquifer potential including groundwater yields, water levels, direction of groundwater flow and groundwater quality. It also contains information on aquifer properties of the formations under the site and recommendations on the design of the proposed water borehole and information on the legal requirements.

Proposed yield is 200m^3/d (metres cubed per day).
Proposed use is for a non potable (grey water) supply for a large office complex.

Groundwater Potential

The required yield of 200 m3/d is equivalent to 5.6 l/s (20 m3/hr) for a 10 hour/day pumping regime.

Till is present on the eastern edge of the site. This comprises stiff, grey clay, weathered to yellow-brown in the upper 2 m, with pebbles and cobbles of flint and rare limestone and chalk. Boreholes in the area show the Oadby Till to be locally underlain by a thin sand which is water bearing. This is unlikely to form a sustainable water resource. The groundwater is likely to be of the calcium-bicarbonate type with a total dissolved solids content of less than 500 mg/l; water derived from glacial deposits is often ferruginous.

The Mercia Mudstone Group is generally of low permeability and transmits groundwater mainly through fractures in the occasional thin, impersistent siltstones and sandstones that are present (referred to as skerries). These skerries commonly possess only a very small outcrop area and consequently recharge is often limited. They tend to vary in thickness and may not be laterally persistent, making it difficult to identify their presence and thickness without drilling. The success of a borehole will depend on the number and thickness of these beds penetrated, with failure to penetrate a skerry or intersecting one that is only poorly fractured, resulting in a dry or low-yielding borehole. Yields are generally less than 0.5 l/s and can decline significantly with time as pumping depletes groundwater storage within the water-bearing horizons. If no skerries are encountered, supplies are rarely obtained from below the weathered zone.

It is anticipated that the rest water level beneath the site is likely to be about 48 m above OD. However this could differ by as much as 5 m, as there are significant differences in water levels across the whole BGS site from 57 m above OD in the east to 43 m above OD in the west from boreholes penetrating to the Arden Sandstone. This equates to a steep hydraulic gradient of about 1 in 27 westwards, assuming that the same skerries contribute in both boreholes. In addition seasonal water level fluctuations may occur.

There are some records of boreholes abstracting from the Mercia Mudstone Group in the surrounding area. A 50.3 m deep borehole at Burton-on-the-Wolds (SK 5781 2022) into the Branscombe Mudstone Formation was tested at 0.9 l/s. A 26.2 m deep borehole in Plumtree (SK 6139 3309) only yielded 0.4 l/s. A 61.3 m deep borehole at Keyworth (SK 6132 3168) supplied up to 45 m3/d, but was unable to pump for more than 3 or 4 hours at a time, before having to stop and allow the water level to recover for an hour. A 24 m deep borehole at Ruddington (SK 5872 3316), drilled into marl with skerries (Arden Sandstone Member) yielded 0.44 l/s for a drawdown of 0.8 m after an 8 hour pumping test.

Water quality from the Mercia Mudstone Group is very hard with the total dissolved solids content likely to be in excess of 2000 mg/l, of which the predominant ions are calcium and sulphate, derived from gypsum in the rocks. A 42.6 m deep borehole sited near the top of the Mercia Mudstone Group at Bunny Lane, Keyworth (SK 6090 3085) recorded a small yield of water 'unsuitable for drinking and with a similar effect to Epsom Salts' from a 2.1 m thick bed which was described as limestone and is likely to have been dolomitic sandstone, encountered at a depth of 11 m below ground level. Borehole logging of existing boreholes on the site indicated that the Windmill Hill Sandstone within the Branscombe Mudstone Formation contained groundwater under pressure with a total dissolved solids content of between 2000 and 2300 mg/l. Beneath this the water becomes more mineralised with the water from the Arden Sandstone at the top of the Edwalton Formation probably having a total dissolved solids content of around 5000 mg/l. Water with this level of mineralisation can be corrosive.

The Sherwood Sandstone Group forms an excellent aquifer in the East Midlands, however in this area it occurs at a depth in excess of 200 m, although it is anticipated that the rest water level will rise to within 30 to 40 m of the ground surface. At this depth, it is likely that the water quality would be poor. A 251 m deep and 200 mm diameter borehole at East Leake (SK 5530 2775) yielded 17.7 l/s during a 15 day test for a drawdown of 16.4 m from 58.8 m of saturated Sherwood Sandstone. The rest water level was 167 m above the top of the sandstone (27 m above OD). A nearby 152 mm borehole of similar depth (SK 5534 2774) yielded only 4.2 l/s for a drawdown of 14.6 m. The water was of the calcium sulphate type and brackish with a total dissolved solids content of 1690 mg/l and a sulphate ion concentration of 865 mg/l. Another borehole at Edwalton Nurseries, West Bridgford (SK 5872 3437) was 228.6 m deep and yielded 15 l/s for a 26.5 m drawdown from the Sherwood Sandstone during a 3 day pumping test; the main yielding horizons being in the Nottingham Castle Sandstone Formation between a depth of 213.4 m and the bottom of the borehole. The water contained high concentrations of sodium (890 mg/l), calcium (268 mg/l), chloride (1410 mg/l) and sulphate (680 mg/l). A borehole at Ruddington (SK 5650 3243) which penetrated Sherwood Sandstone between depths of 142.3 and 209.5 m, encountered water 'so hard as to be unusable' and a depth sample from the Sherwood Sandstone in the Plungar borehole (SK 7720 3347) showed it to have a total dissolved solids content of over 4000 mg/l, of which 2646 mg/l were sulphate.

Aquifer Properties Data

Mercia Mudstone Group

The values held in the BGS aquifer properties database are from cores for 34 samples from 6 locations across England. The porosity values obtained from outcrop samples range from 12 to 31%, with a mean value of 25%. Permeability values for outcrop samples range from between 0.0096 and 2.35 m/d (average 0.56 m/d). The values closest to the site were obtained at Edingley Hill (SK 6679 5561) with a porosity of 30% and a permeability of 0.328 m/d. The majority of the samples are likely to have been taken from weathered sandstones (skerries). The lowest values were obtained from a railway cutting at Runcorn (SJ 5101 8238) with an average porosity of 20% and permeability of 0.017 m/d. This may be more representative of the formation as a whole, as it was from a less weathered recent manmade exposure. There are no core values in this area from boreholes. The mudstones are regarded as effectively impermeable, with a hydraulic conductivity of the order of 0.01 m/d (Black JH and Barker JA, 1981, Hydrogeological reconnaissance study: Worcester Basin, British Geological Survey internal report ENPU81/3).

There are 39 transmissivity values quoted for the Midlands in Jones et al (2000, The physical properties of minor aquifers of England and Wales, British Geological Survey report WD/00/04). These range from 0.75 to 402 m^2/d, with a geometric mean of 12.3 m^2/d. The closest value is 1.5 m^2/d from a site at Asmer Seeds Ltd (SK 6351 1243). There are no storage coefficient values quoted for the East Midlands.

Sherwood Sandstone Group

The porosity of core samples in the East Midlands range from 21.0 to 37.2%, with a mean value of 29.7%. The permeability is slightly anisotropic with values from horizontal samples (range 3.9 x 10-6 to 20.5 m/d with a median value of 2.7 m/d) about twice that of vertical ones (range 2.4 x 10-6 to 22.5 m/d with a median value of 1.2 m/d). The porosity and permeability values obtained from core samples from the borehole closest to the site at Loughborough (SK 5437 2083) are 23.3% and 0.203 m/d, respectively.

The limited marl bands in this area mean that the formation generally acts as a single aquifer with high intergranular and fracture permeabilities. The effective aquifer thickness is generally the thickness of saturated aquifer penetrated by the borehole. Transmissivity values for the Sherwood Sandstone in the East Midlands range from to 100 to 1000 m2/d at outcrop. Models in the area have used values of 10 to 40 m2/d for the confined aquifer, but this will generally be for areas with a lesser thickness of overburden than at the site. The closest transmissivity value is 11 m2/d at Kegworth (SK 481 272), obtained from a borehole penetrating 57 m of Sherwood Sandstone below 132 m of Mercia Mudstone. Values in the deep confined aquifer throughout the East Midlands range up to 420 m2/d. There are no storage coefficient values in the confined aquifer within 30 km, the nearest values to the north being around 4 x 10-4.

Groundwater Vulnerability

The mudstones of the Mercia Mudstone Group may provide some protection from contamination occurring at the ground surface to groundwater in the skerry horizons. However, the predominance of fracture flow can lead to the rapid transport of contaminants both to, and through, the saturated horizons.

Conclusion

In conclusion, the site is not a good one for developing a large groundwater supply. The Mercia Mudstone Group is unlikely to be capable of providing the required yield, even if several boreholes were constructed. A borehole to obtain a supply from the Sherwood Sandstone would need to fully penetrate this aquifer, a depth of about 240 to 260 m. It is possible that this would not supply the whole of the required yield. If several boreholes were constructed to obtain a larger yield, it is possible that interference effects (between the zones of drawdown) could be significant as high rates of abstraction, accompanied by large water level drawdowns in each borehole, will be likely to induce depression of the piezometric surface over a broad zone, possibly extending for hundreds of metres. This interference will increase the total amount of drawdown in the boreholes and may consequently restrict the yield that can be obtained from each borehole. Interference effects can be minimised by the careful siting of additional boreholes but this requires a detailed knowledge of aquifer properties beneath the site. Such information can only be obtained from data collected during a carefully conducted aquifer test that includes the monitoring of water levels in observation boreholes. There could also be thermal interference effects between the boreholes.

The groundwater is likely to be slightly brackish, and may require some treatment prior to use. If this aquifer is developed, the whole of the Mercia Mudstone should be lined out and if friable horizons are encountered in the Sherwood Sandstone these will require perforated casing, possibly with a sand screen and filter pack.

Borehole Location, Construction, Testing and Legal Obligations

Location:

It is good practice to site a borehole as far away as possible, and preferably upslope, from any potential sources of pollution, including septic or fuel tanks, soakaways, slurry pits and areas of intensive grazing. A minimum distance of 50 m between a water borehole and any potentially polluting activity is recommended.

Construction:

For boreholes abstracting from the superficial deposits, the top few metres should be cased out (the depth of plain casing depending on the aquifer thickness at the specific site). A borehole abstracting water from a bedrock aquifer should be sealed off through the superficial deposits by installing a length of plain casing to at least 5 m below the upper surface of the bedrock. The casing should be grouted effectively in order to minimise the risk of poor quality surface or shallow groundwater entering the borehole.

Testing:

Any new borehole should be subject to a pumping test to determine the yield and drawdown of the water level. For a borehole designed for a single domestic property, it is recommended that a pumping test of at least 3 hours duration, or at least as long as the anticipated daily pumping period, is carried out, during which both the pumping rate and water level are monitored. For domestic supplies for more than one property, a longer pumping test of at least 6 to 12 hours is more appropriate. For larger supplies the Environment Agency are likely to require a test of several days duration, as well as the monitoring of nearby water sources before, during and after test pumping.

Water quality:

It is recommended that a water sample, taken during the final stages of the pumping test, is sent for full analysis to a reputable laboratory. They, or if a potable private supply is envisaged the Environmental Health Officer of the local council, should be able to advise on the range of analyses to be undertaken, which would normally include pathogenic indicator bacteria, iron, manganese and nitrate. An adequate and well-maintained disinfection treatment would be considered advisable for any supply intended for potable use.

Legal requirements:

While BGS may assess the groundwater potential at this site, the prerogative of granting a licence rests with the Environment Agency, <add relevant> Region. Currently all sources abstracting 20 m^3/d or more require an abstraction licence which should be obtained prior to drilling. If a borehole to more than 15 m depth is drilled, there is a statutory requirement (Water Resources Act, 1991) for the driller to supply full information to the Wallingford office of the BGS for inclusion in the National Well Record Archive. A form for supplying the required information is enclosed.

Maximum admissible concentrations and values for selected parameters in drinking water*

Parameter	Concentration or value
Physical characteristics	
pH	≥6.5 and ≤9.5
Electrical conductivity (SEC) @ 20°C (µS/cm)	2500
Inorganic parameters	
Aluminium (µg/l)	200
Ammonium (mg/l)	0.5
Chloride (mg/l)	250
Fluoride (mg/l)	1.5
Iron (µg/l)	200
Manganese (µg/l)	50
Nitrate (as mg/l NO_3)	50
Sodium (mg/l)	200
Sulphate (mg/l)	250
Arsenic (µg/l)	10
Bromate (µg/l)	10
Organic parameters	
Benzene (µg/l)	10
Pesticides-individual (µg/l)**	0.1
Pesticides-total (µg/l)	0.5
Polycyclic aromatic hydrocarbons (µg/l)	0.1
Tetrachloromethane (carbon tetrachloride) (µg/l)	3
Trichloroethene and tetrachloroethene (perchloroethylene) (µg/l)	10
Microbiological parameters	
Coliform bacteria (number/100 ml)	0
Enterococci (number/100 ml)	0
Escherichia coli (E. coli) (number/100 ml)	0
Clostridium perfringens (including spores) (number/100 ml)	0

*under the Water Supply (Water Quality) Regulations, England & Wales 2000 and Scotland 2001

**except aldrin, dieldrin, heptachlor and heptachlor epoxide where the limit is 0.03 µg/l