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 200 m^3/d (cubic metres per day)
Proposed use is for a large (non-potable) water supply for agricultural use

Groundwater Potential

A yield of 200 m^3/d is equivalent to 5.6 l/s (20 m^3/hr) pumping for 10 hours/day. This size of abstraction would require an Environment Agency licence.

The Northmoor Sand and Gravel Member is likely to be partially saturated, with a rest water level about 2 m below ground surface (about 46 m above OD), indicating that a saturated thickness of between 2 to 4 m is present below the site. The superficial deposits should be capable of supplying a reasonable yield as the base of the deposit is likely to lie below river level and hence it will probably be in hydraulic continuity with the River Thames. A borehole adjacent to the river at Howbery Park [SU69SW284; SU 6135 9007] was 5.2 m deep and assumed to abstract from the superficial deposits, it yielded up to 18.9 l/s (68 m^3/hr) for 2.1 m of drawdown after an unknown period of pumping in the 1960s. Water in these permeable deposits will be vulnerable to pollution from the ground surface.

The West Melbury Marly Chalk Formation and underlying Glauconitic Marl Member are both thin at this site and unlikely to provide any significant supply of water. Several of the boreholes in the area obtain their supplies from a mixture of the superficial sand and gravel deposits and underlying Upper Greensand Formation. The record for the production borehole at Hydraulics Research at Howbery Park [SU69SW297; SU 614 900] appears to indicate that the borehole had plain casing installed to 6 m, there was no casing between 6 m and 9 m through 2 m of clay and 1 m of gravels and sands (superficial deposits) which is unlikely, and then below 9 m, a further metre of gravels and sands and the Upper Greensand both had slotted casing installed against them. Another recent borehole [SU68NW328; SU 6166 8986] at Howbery Park had slotted casing installed between depths of 5 and 23 m, against the basal 4 m of the superficial sands and gravels and the whole of the Upper Greensand. The borehole was drilled at 500 mm diameter and fitted with 330 mm diameter slotted casing and a sand pack. The blowout yield was 12.6 l/s.

The Glauconitic Marl may be of low permeability and this could hydraulically separate groundwater in the Northmoor Sand and Gravel Member from that in the Upper Greensand. One of the existing boreholes on the site [SU68NW302; SU 6154 8964] struck water in the superficial deposits at a depth of 2.8 m and also in the Upper Greensand at a depth of 6 m. It was plain cased to a depth of 11 m and is currently generally artesian, implying that at this site, the superficial deposits are not in hydraulic continuity with the Upper Greensand, the borehole recorded a 1.8 m thick clayey, sandy and glauconitic silt between 4.4 m and 6.2 m below ground level (presumably Glauconitic Marl Member).

Boreholes at Howbery Park have produced yields from the Upper Greensand of up to 15 l/s (54 m^3/hr) for an unknown drawdown, and 11.8 l/s (42.5 m^3/hr) for 12.5 m of drawdown during a 24 hour test from 20.3 m of saturated aquifer [SU69SW31; SU 6165 9023], and 13.6 l/s (49 m^3/hr) for 14.2 m of drawdown after 7 days pumping from 16 m of saturated aquifer [SU69SW286; SU 6167 9015].

Water from two 15-16 m deep boreholes into the Upper Greensand at Wallingford Pumping Station [SU68NW25; SU 6023 8951 and SU68NW259; SU 6028 8947] had a total hardness of 370 mg/l and 513 mg/l (as $CaCO_3$), respectively. Water from a 14 m deep borehole into Upper Greensand at Benson [SU69SW32; SU 635 921] had a pH of 6.9, a total dissolved solids content of 363 mg/l, total hardness of 274 mg/l (as $CaCO_3$), permanent (non-carbonate) hardness of 52 mg/l (as $CaCO_3$), chloride ion concentration of 21 mg/l, nitrate of 4.4 mg/l (as NO_3), and total iron 500 µg/l, of which none was in solution. However, three analyses from boreholes at Fairmile Hospital, Wallingford [SU58NE24; SU 5980 8604 and SU58NE26; SU 5975 8607], undertaken between 1948 and 1952, reported no iron.

Water in the Lower Greensand is confined by the overlying Gault and likely to be brackish. The water level rose to 50 m above OD (pre 1910) in a borehole at Warborough [SU59SE24; SU 5975 9415] and overflowed (water level more than 48 m above OD) in 1882 at Shillingford [SU59SE21; SU 5956 9293].

The borehole at Warborough produced brackish groundwater with a total dissolved solids content of 7780 mg/l and that at Shillingford had a total dissolved solids content of 1396 mg/l, in both cases over half of this was attributable to sodium chloride with concentrations in excess of the recommended drinking water limits of 200 mg/l and 250 mg/l, for sodium and chloride, respectively; so unsuitable for potable use without treatment. Wells at Newington [SU62NW23; SU 6101 9640 and SU62NW28; SU 6100 9684] also encountered poor quality water in the Lower Greensand (or Portland Formation).

The water at the base of the Corallian aquifer at a depth of 114 m at Shillingford [SU59SE21; SU 5956 9293] was reported to be 'palatable' when drilled in 1885, but there is no analysis to ascertain whether it would be considered suitable for potable use nowadays; the yield was described as 'not sufficient'. However, a borehole at Stadhampton [SU69NW30; SU 6019 9854] overflowed with brackish water from the Corallian, yielding 1.4 l/s (5 m^3/hr) for a drawdown to 23 m below the surface after 2 days pumping. Another borehole nearby [SU69NW29; SU 6024 9853] overflowed at 0.2 l/s (0.7 m^3/hr) but again was not used due to the high salinity; this water had a total hardness of 143 mg/l (as $CaCO_3$), all temporary (carbonate).

Aquifer Properties Data

A search of our databases has produced the following relevant aquifer properties data from within a distance of about 20 km.

Small core samples of Upper Greensand at North Farm, Bockhampton [SU37NW8; SU 3321 7970] had a porosity of 27.8% and a hydraulic conductivity of 0.017 m/d.

The nearest transmissivity values for the Upper Greensand are for a site at Manor Road Pumping Station, Wantage [SU38NE19-21; SU 397 869] with a value of 30 m^2/d and Upton [SU58NW57-58; SU 510 874] with a value of 20 m^2/d. A borehole at Chinnor [SU79NW94; SU 745 982] penetrating 30 m of Upper Greensand had a transmissivity of 690 m^2/d and a storage coefficient of 8.1×10^{-4}.

Core samples from the Corallian beneath 187 m of overburden at Harwell [SU48NE92; SU 4680 8644] had a mean porosity of 23.7%.

Groundwater Vulnerability

The superficial Northmoor Sand and Gravel Member deposits are highly permeable and will be vulnerable to contamination occurring at the ground surface. The shallow water table means that any contaminants are likely to be transported rapidly through the unsaturated zone of the aquifer to the water table.

Groundwater in the Upper Greensand could be protected from surface pollution by the presence of the overlying, less permeable, Glauconitic Marl, however this is thin and has been breached locally by boreholes. Where the water level is artesian, surface pollution is unlikely to enter this aquifer.

Conclusion

Based on the evidence of other boreholes in the area, it is considered possible that a large diameter borehole, drilled at a minimum of 400 mm diameter and completed at a minimum of 300 mm diameter, to just below the base of the Upper Greensand (about 30 m deep) could supply the required yield of 200 m^3/d over a 10 hour pumping period. The water should be of reasonable quality although iron may be present; this can be removed by aeration. A correctly designed and emplaced sand screen and filter pack will be required against the contributing horizons. The best chances of success will probably be a borehole that obtains water from both the superficial deposits (Northmoor Sand and Gravel Member) and the Upper Greensand; these two aquifers will require different screen sizes and sand packs. If a potable supply was to be required in the future, due to the shallow water table and high permeability and hence vulnerability to pollution from the ground surface, of the superficial deposits, it may be preferable to case these deposits out and obtain the water solely from the underlying Upper Greensand.

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 water level 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.

According to the geological maps, the geology, and therefore the borehole potential, does not vary significantly across the site. The chances of drilling a successful borehole are therefore similar across the site.

This borehole prognosis is primarily based on information held in the National Well Record Archive; this contains records of boreholes submitted at the time of drilling. Therefore, the information held is often historical in nature; the Environment Agency may hold more up-to-date information. Often the water quality data held is also historical in nature and will not have been analysed for trace elements that, if present, could be in concentrations greater than the current maximum admissible amounts for a potable supply.

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 to form a sanitary seal 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 system 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, West Thames area. Currently all sources abstracting 20 m^3/d or more require an abstraction licence. A 'Consent to Investigate Groundwater' must be obtained from the Environment Agency prior to a licensable borehole being drilled; this consent permits drilling and pump testing. If a borehole is drilled to more than 15 m depth, 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 under the Private Water Supply (England) Regulations 2016 and Private Water Supply (Wales) Regulations 2017

Microbiological parameters	**Concentration or value**
Enterococci (number/100 ml)	0
Escherichia coli (E. coli) (number/100 ml)	0
Pseudomonas aeruginosa[(i)]	0
Colony count @ 22°C[(ii)]	100
Chemical parameters	**Concentration or value**
Arsenic (µg/l)	10
Benzene (µg/l)	1
Boron (µg/l)	1
Bromate (µg/l)	10
Chromium (µg/l)	50
Copper (mg/l)	2
Fluoride (mg/l)	1.5
Lead ((µg/l)	10
Mercury (µg/l)	1
Nickel (µg/l)	20
Nitrate (as mg/l NO_3)	50
Nitrite (as mg/l NO_2)[(iii)]	0.5
Pesticides-individual (µg/l)[(iv)]	0.1
Pesticides-total (µg/l)	0.5
Polycyclic aromatic hydrocarbons (µg/l)	0.1
Selenium (µg/l)	10
Trichloroethene and tetrachloroethene (perchloroethylene) (µg/l)	10
Total trihalomethanes (µg/l)	100
National requirements	**Concentration or value**
Aluminium (µg/l)	200
Colour (mg/l Pt/Co)	20
Iron (µg/l)	200
Manganese (µg/l)	50
Odour and taste	Acceptable to consumers and no abnormal change
Sodium (mg/l)	200
Tetrachloromethane ((µg/l)	3
Turbidity (NTU)[(v)]	4
Indicator parameters	
Ammonium (as mg/l NH_4)	0.5
Chloride (mg/l)	250
Clostridium perfringens (including spores) (number/100 ml)	0
Coliform bacteria (number/100 ml)[(vi)]	0
Colony count @ 22°C	No abnormal change
Electrical conductivity (SEC) @ 20°C (µS/cm)	2500
pH[(vii)]	≥6.5 and ≤9.5
Sulphate (mg/l)	250
Total organic carbon (TOC)	No abnormal change
Radioactive substances	**Concentration or value**
Indicative dose (mSv)	0.1
Radon (Bq/l)	100
Tritium (Bq/l)	100

Notes

(i) in bottled water
(ii) in bottled water, otherwise indicator parameter is no abnormal change
(iii) 0.1 mg/l at treatment works
(iv) except aldrin, dieldrin, heptachlor and heptachlor epoxide where the limit is 0.03 µg/l
(v) where influenced by surface water, 1 NTU indicator value
(vi) 0/250 ml for bottled water
(vii) not aggressive, ≥4.5 and ≤9.5 for bottles and containers