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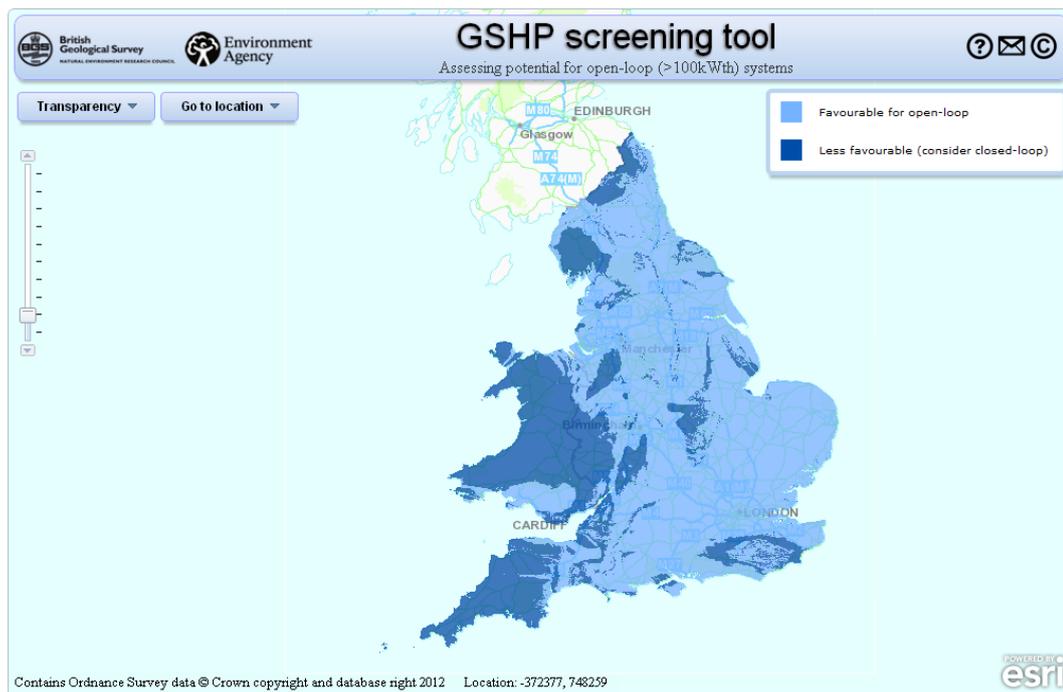


Environment Agency

Technical Guide - A screening tool for open-loop ground source heat pump schemes (England and Wales)

Energy Sciences Programme

Open Report OR/12/060



BRITISH GEOLOGICAL SURVEY

ENERGY SCIENCES PROGRAMME

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Technical Guide - A screening tool for open-loop ground source heat pump schemes (England and Wales)

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Screenshot of open-loop GSHP screening tool

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Foreword

This report presents a description and review of the methodology developed by the British Geological Survey (BGS) in collaboration with the Environment Agency (EA) to produce a screening tool for assessing the suitability for open-loop ground source heat pump installation (>100kW thermal capacity) in England and Wales.

The purpose of this document is to enable the users of this screening tool to have a better appreciation of what the data set shows and how the data set has been created. This provides the user with a better understanding of the potential applications and limitations of the data set.

Acknowledgements

A large number of individuals have contributed to the development of the GSHP screening tool. BGS specialists in hydrogeology, groundwater chemistry and geographic information systems have provided assistance at all stages of the study by compiling, attributing and processing of data, creating new GIS layers and developing the web viewer tool. Colleagues in the Environment Agency have provided data sets and licences and offered advice in regulatory matters. Many individuals, including experts from the GSHP industry have freely given their advice, and provided the subject knowledge to assist the development and validation of the GSHP dataset.

Of the many individuals who have contributed to the project, I would particularly like to thank the following (in alphabetical order):

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Furthermore, I would also like to thank Natural England (NE) and the Countryside Council for Wales (CCW) for providing the data on protected sites in England and Wales (available under an Open Government Licence).

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Summary

This report presents a description and review of the methodology developed by the British Geological Survey (BGS) in collaboration with the EA to produce a screening tool for assessing the suitability for open-loop ground source heat pump installation (>100kW thermal capacity) in England and Wales.

In part 1, the report provides some background information to this study and explains the content of the data layers that make up the screening tool.

Part 2 of the report presents relevant technical information relating to the development of the data set and the underlying data. It also addresses the uncertainties and limitations of this tool.

In part 3, a list of data sets and additional resources is given that can help with a more detailed assessment of suitability and the planning of open-loop GSHP schemes.

Please note that this tool provides only an initial assessment about whether the area may be suitable for an open-loop GSHP. You will need to undertake a detailed environmental and hydrogeological assessment of your site if you wish to install an open-loop GSHP.

1. About the data set

1.1 BACKGROUND

Ground source heat pumps (GSHPs) provide an energy-efficient, low-carbon alternative to traditional heating /cooling systems. For buildings with heating/cooling demands $> 100\text{kW}_{\text{th}}^*$, open-loop ground source heat pumps (GSHP) are generally more economically viable than closed-loop GSHP systems.

Successful planning and installation of these systems requires consideration of the underlying hydrogeology as well as of a number of economic conditions and regulatory requirements. These include the presence of an aquifer[†] which can provide the right quantity, quality and rate of water, reasonable pumping costs and conditions/regulatory requirements conducive to efficient abstraction (and discharge). To increase confidence at the early planning stage and to encourage the uptake of open-loop GSHP technology (where viable), the British Geological Survey (BGS) and the Environment Agency (EA) have collaborated to develop a screening tool that gives planners and developers an initial indication of the depth, productivity and quality of potential aquifers that exist in a given area.

The tool was developed in close consultation with experts from the ground source heat pump industry (ESI, Anglian Water, Carbon Zero Consulting) and considers the most relevant hydrogeological and economic parameters, namely

- Locations of bedrock aquifers and estimated productivity ranges
- Depth to the source
- Locations of protected areas

Where data are available, the tool also provides information on the scaling/corrosion potential of the groundwater, iron concentrations and licensed abstractions within a search radius (600m) around the location of interest.

The screening tool does not provide information on the availability or discharge of water from GSHP schemes. The Environment Agency's Catchment Abstraction Management Strategy (CAMS) sets out whether water is available to be licensed in a particular groundwater unit and is therefore key to any open-loop GSHP. For more information on this see Section 1.3.6. For more information on how the Environment Agency regulates discharge of water see the link in Section 3.2.1.

1.2 WHO MIGHT REQUIRE THE DATA

The GSHP screening tool indicates potentially viable areas for the installation of open-loop GSHP systems with a thermal capacity of at least 100 kilowatts. As such, it can assist planners and developers in identifying and selecting suitable sites during the early planning stages and can also support the assessment of existing sites with regards to their GSHP potential. Developed at the 1:250,000 scale for England and Wales, the data may also be of interest to local councils and government agencies, for example to assess the renewables potential and resource as part of a local development plan. Other users of these data may include building engineers, architects or organisations who are considering renewable potential across their estate.

* kWth = kilowatt-thermal (capacity of the scheme)

† An aquifer is an underground layer of water-bearing permeable rock from which groundwater can be usefully abstracted.

1.3 WHAT THE DATA SET SHOWS

The England and Wales GSHP screening tool consists of a set of data layers in Geographical Information System (GIS) format and database format. These layers are based on existing national scale data sets owned by the British Geological Survey and the Environment Agency. They also include data that are available under an Open Government licence and where such data were used, the sources are acknowledged accordingly. Based on these data sets, a methodology has been developed by hydrogeologists and information developers at the British Geological Survey that maps the suitability for open loop GSHP systems ($>100\text{kW}_{\text{th}}$) at the 1:250,000 scale. In the process, a set of new GIS data layers and database tables were derived which form the basis of the tool and are described in brief below:

1.3.1 Viability screening map

The basic requirements for open-loop GSHP installation is the availability of an aquifer of sufficient productivity and within a suitable depth from the surface. The viability (screening) map shows areas where these requirements are met, i.e. where aquifers with yields of at least 1L/s are present within 300m beneath the (topographic) surface. These conditions are considered favourable for open-loop GSHP installations with a capacity of $>100\text{kW}_{\text{th}}$ (for further explanation see sections 2.1.1 to 2.1.3).

Clicking on the viability map allows further exploration of the underlying data layer. This is only possible for areas that were mapped as ‘favourable’.

In areas shown as ‘less favourable’, closed loop GSHP may provide a suitable alternative. UK maps of the potential for (horizontal) closed-loop GSHP systems will soon be available through the ThermoMap project (see link in Section 3.3.4). For more information on closed-loop schemes and related environmental issues see the Energy Saving Trust websites (Section 3.3.3) and the Environment Agency’s “Good Practice Guide” (Section 3.2).

1.3.2 Bedrock aquifer potential layer

The ability of the subsurface to store and provide water (i.e. presence of an aquifer) is dependent on the underlying rocks and their properties (i.e. their permeability). Aquifers may occur at various depths and, in some areas, are covered by low permeability rocks or sediments (concealed aquifer). This layer shows if and where aquifers are present “at outcrop”[‡] and/or “concealed at depth”. The minimum flow requirement for a GSHP scheme with a capacity of 100kW_{th} is estimated to be about 2-5 L/s (see Appendix) and hence, only aquifers which can provide yields of at least 1 L/s (per borehole)[§] are mapped as suitable^{**}. Concealed aquifers are mapped only for the main geological formations that both, form important aquifers at depth and whose distribution is known (*Table 2*) and that can provide yields of at least 1 L/s. All estimates of aquifer productivity are based on best-case scenarios, i.e. the maximum possible yield from a single borehole.

The formation of karst topography can have a large effect on the hydrogeological behaviour and performance of the associated aquifers which are usually characterised by highly variable yields (spatially and temporally). This may affect the suitability for GSHP installations. Thus, where karst is known to occur, this is highlighted within this layer by providing a note in the “Comments” field. This layer only refers to karst formation but other areas exist where soluble rocks are present. A detailed map of the occurrence of such areas in the UK is available through BGS’ GeoSure data set (see Section 3).

[‡] This includes areas where the aquifer is covered by superficial deposits, which have not been mapped in this application.

[§] The yield ranges refer to the maximum yield that can be obtained from a single borehole.

^{**} It is assumed that higher yields can be achieved through multiple boreholes.

1.3.3 Depths to source layer

The depth from which the water is abstracted is of great economic importance for any GSHP installation as this determines the drilling and borehole installation costs as well as the pumping costs of the scheme. This layer shows the minimum drilling depths required to access the source. In this context, ‘source’ refers to the uppermost aquifer that is present at any location. In some instances, you may need to drill further into the aquifer to better access a reliable resource. The identified depth does not necessarily represent the depth to the water table, but in some areas refers to the thickness of the deposits (superficial deposits, confining rock formations) that have to be penetrated before reaching the aquifer.

1.3.4 Protected areas layer

A number of protection zones are defined in England and Wales to protect individual groundwater sources and to ensure that drinking water remains safe and clean (e.g. Source protection zones). There are also designated areas of natural beauty (National Parks) or areas that preserve a unique array of plants, wildlife, or geology (e.g. Sites of Special Scientific Interest, including Special Protection Areas and Special Areas of Conservation) which are protected by law. Activities within these areas are closely monitored and managed. Depending on the level of protection, permissions to abstract or discharge groundwater may be limited and/or subject to obtaining additional consent. This layer outlines the distribution of such protection zones in England and Wales^{††}. Location within a protected zone does not necessarily imply limitations for the operation of a GSHP scheme, except in areas where the designation is for water/temperature-dependent features. More details and maps of the areas are available from the links given in the Section 3, which will also provide the most up-to-date data on this.

1.3.5 Groundwater quality data

Open-loop GSHP systems use groundwater as the medium to supply or accept heat and hence, are susceptible to problems induced by poor groundwater quality. The principal concerns are scaling, corrosion and encrustation as they can affect the well performance as well as the life of the heat exchanger. The groundwater quality data included in this tool consist of a set of empirical indices and concentration thresholds that estimate

- (1) the tendency of the water to form/dissolve calcium carbonate scale:
 - a. Langelier Saturation Index (LSI)
 - b. Ryznar Stability Index (RSI)
- (2) the corrosiveness of the groundwater = Larson-Skold Corrosive Index (LSCI)
- (3) the potential for encrustation associated with high iron (Fe) concentration ($\geq 500 \mu\text{g Fe/L}$).

Langelier (LSI)*	Ryznar (RSI)**		Larson-Skold (LSCI)	
LSI > 0.4	RSI < 6	→	Ca-carbonate precipitation = scaling likely	LRSI < 0.8 → No corrosion
0.4 > LSI > -0.4	6 < RSI < 7	→	No dissolution/ no precipitation	0.8 < LRSI < 1.2 → Some corrosion possible
LSI < -0.4	RSI > 7	→	Ca-carbonate dissolution	LRSI > 1.2 → Corrosion likely

Table 1: Interpretation of scaling and corrosion indices
 (*some experts prefer LSI > 1.5 (up to 2.5) as the break point for scale formation and LSI < -1.5 as indication of aggressive water, ** some experts consider only waters at RSI < 4.5 as definitely scale forming and waters at RSI > 8.5 as clearly aggressive.)

^{††} Data correct on 14 October 2014

The scaling/corrosion tendency of the water (1,2) is controlled by the water temperature. The values given in the tool refer to in-situ groundwater temperatures as measured at the time of sample collection. Guidelines on how to interpret these data are given in Table1.

Groundwater quality can vary largely, spatially (with depths and between locations) as well as temporally. This makes interpolation between sampling points difficult and in many cases meaningless. Accordingly, the tool only provides groundwater quality data where actual groundwater sampling points are present within 600m radius of the search location. These data can include samples from surveys carried out at different times and collected from different aquifers (including superficial deposits which are not otherwise considered by the tool) and depths. Hence, the data do not necessarily relate to the water source identified in the bedrock aquifer layer.

The data are provided by the tool to give a general indication of the groundwater chemistry that can be expected around the area of interest. More detailed information on the groundwater chemistry of UK's major and minor aquifers is available from BGS'EA's Baseline project (see links in Section 3).

The screening tool does not assess the impact of an open-loop GSHP scheme on groundwater quality. You need to discuss with the Environment Agency the environmental limitations of discharging heat from a particular scheme.

1.3.6 Existing licensed abstraction data

This data set shows a snap shot as of 12 August 2011 of abstraction volumes that have been licensed by the Environment Agency in a given area^{††} for all available aquifers (including superficial deposits). These are **not actual abstractions** but the maximum daily amount that a licence holder is permitted to abstract. This information is relevant because:

- (1) it provides an indication of the volumes that can be abstracted (from one or multiple boreholes) within the area of interest.
- (2) it highlights areas where large abstractions exist and, hence, where water availability may be limited, reducing the likelihood of a permit being issued
- (3) it shows where there is an increased risk of interference between abstractions, potentially impacting on the efficiency of the scheme.

It is important to note that a maximum of 10 data values is shown for each borehole that is present within a radius of 600m around the search location, but that these values refer to the total daily abstraction allowance granted under the licence (which may consist of more than one borehole) and not necessarily to the amount licensed at that particular borehole. In other words, **the given values can represent the combined licensed yield from multiple boreholes**. Consequently, where two or more abstraction values are displayed for a search location, these may refer to the same licence (in which case they have the same value). Conversely, they could be boreholes that abstract from different aquifers and/or depths.

The information is not indicative of the size/volume of the licence that can be agreed with the Environment Agency as this will depend on the availability of water in the area. The data does not reflect actual abstraction, which could be less than the licenced volume.

You can find out how much water is available in your area by viewing the Environment Agency Catchment Abstraction Management Strategy for your area (see web link in Section 3.2.2.). Please call the Environment Agency as early as possible to discuss your abstraction and discharge needs on 03708 506 506.

^{††} Data correct on 14 October 2012

1.4 SUSTAINABILITY

It is important that the sustainability of the scheme is considered before installing an open loop GSHP system. **Sustainability is not considered by this tool.** It is the responsibility of the scheme owner to ensure that all issues that may affect the sustainability of the proposed scheme (and its impact on existing schemes nearby) have been investigated and accounted for during the planning and design stages of the scheme.

Such issues include, for example, thermal interference between GSHP systems (e.g., where the scheme is installed close to existing schemes/ in an area where a large number of schemes is installed), thermal break-through (e.g. where abstraction and injection borehole are located too close to each other) or unbalanced thermal loads (e.g. where heating and cooling demands differ, hence causing a decrease/increase in the ambient groundwater temperature). Some schemes had to be abandoned where these issues were not considered.

2 Technical Information

2.1 CREATION OF THE DATA SET

2.1.1 Viability screening map

This layer was derived by combining the layers

- bedrock aquifer potential and
- depth to source.

Areas where the aquifer potential was classed as “moderate aquifer”, “good aquifer” and/or “concealed aquifer at depth” were mapped as suitable provided that the depth to source was ≤ 300 m^{§§}.

2.1.2 Bedrock Aquifer potential layer

The map was derived from the 1:250,000 map of geological bedrock formations (DiGMapGB 250). Using the experience and knowledge of hydrogeologists at the BGS, each unit was attributed according to its potential of providing

- no suitable aquifer (including all aquifers with productivity <1 L/s)
- moderate aquifer (1- 6 L/s)
- good aquifer (> 6 L/s).

The yield range associated with each class refers to the maximum yield that can be obtained from a single borehole.

In some areas, aquifers are covered by less permeable rocks or sediments (concealed aquifer) and these were mapped as

- concealed aquifer at depth.

The occurrence and distribution of concealed aquifers was estimated from BGS subsurface contour data (1: 1,000,000 scale) for the geological units listed in Table 2. These are the most important hydrogeological units/ geological formations that can provide productive aquifers at depth. Other formations, including superficial deposits, can also provide aquifers locally, but these have not been included here.

The depths to which the individual formations are assumed to provide aquifers are listed in Table 2. These were determined from existing borehole records and considering the guideline default values for groundwater body thickness as defined by the UK Technical Advisory Group for the Water Framework Directive (UKTAG Guidance: Defining & Reporting on Groundwater Bodies). The maximum extent of the aquifer was mapped here, even if not all parts may be useable for GSHP installation (e.g., depths >300 m are presently considered unsuitable due to the high drilling/installation costs).

^{§§} Aquifers may be present at depth >300 m, but these are considered unsuitable due to the high drilling/borehole installation costs. Furthermore, aquifers are generally less productive at significant depths than nearer the surface.

Aquifer/Geological unit	Maximum depths of aquifer
Chalk	400 m
Lower Greensand	400 m
Corallian	200 m
Great Oolite	150 m
Inferior Oolite	200 m
Sherwood Sandstone	400 m
Magnesian Limestone	200 m

Table 2: Aquifer units and maximum depths of aquifer extent

2.1.3 Depths to source

This layer was derived from different BGS data sets, listed in Table 3, using the following rules:

- 1) Where the aquifer is unconfined (i.e. not covered by superficial deposits or other rock formations), the depth to source is mapped as the depth to the groundwater table as estimated from river head space (RHS) data (see Table 3).
- 2) Where the aquifer is covered by superficial deposits (but not otherwise concealed, e.g., by less permeable bedrock), the depths to source is mapped as the deeper of the two, the thickness of the superficial deposits (ASTM) or the depths to the groundwater table (RHS) (see Table 3). The rationale behind this is that (a) the drilling has to penetrate any confining deposit and (b) the borehole needs to be drilled to (at least) the depth of the groundwater table in order to be able to abstract water.
- 3) Where the aquifer is concealed by less permeable rock formations (i.e., concealed at depth), the depth to source is taken to be the base of the concealing unit/the top of the aquifer. The geological units which are considered to provide aquifers at depths are listed in Table 2.

Data set name	Scale	Coverage	Interpretation
ASTM – Superficial thickness	1:50,000	National	Thickness of superficial depots
RHS- River head space	1:50,000	National	Depths to groundwater table
Atlas GIS data	1:1,000,000	Available for selected geological units in England to a depth of 2 km	Depths contours
Additional data sets and maps	various	variable	Support mapping of sub-surface geology/ depth distribution of geological units

Table 3: BGS data sets used for creating depth-to-source layer

2.1.4 Protected areas layer

This layer was derived by overlaying the following separate layers:

- **Source Protection Zones (SPZ)**
(Derived from GIS layers provided by the Environment Agency by aggregating all zones (1-3) into a single category)
- **National Parks in England and Wales**
(Mapped from GIS layers provided by Natural England (NE) and by the Countryside Council for Wales (CCW) under an Open Government Licence)
- **Sites of Special Scientific Interest (SSSIs)**
(Mapped from GIS layers provided by Natural England (NE) and by the Countryside Council for Wales (CCW) under an Open Government Licence)
Included in the SSSI designation are Nature Reserves (NNRs) or Local Nature Reserves (LNRs) as well as all sites that are internationally important for their wildlife, i.e., designated as Special Areas of Conservation (SACs), Special Protection Areas (SPAs) or Ramsar sites.

2.1.5 Groundwater quality database

The input data for this layer are derived from BGS' national groundwater chemistry database by extracting all sampling points for which complete analysis data are available. A complete analysis set, within the context of this study, includes: temperature (T)^{***}, pH, specific electrical conductance (SEC), alkalinity and calcium (Ca²⁺) concentrations as well as concentrations of sulphate (SO₄²⁻) and chloride (Cl⁻), where available. Mass concentrations (e.g., mg/L) were converted to equivalent concentrations (e.g., meq/L) and indices were calculated as described below. The data set also includes BGS groundwater sampling points in England and Wales for which iron concentrations are available. Please note that the spatial coverage of this layer is very low and that groundwater quality data are only available for about 2% of the mapped area.

LANGEЛИER SATURATION INDEX (LSI) AND RYZNAR STABILITY INDEX (RSI)

The LSI and RSI are empirically-derived indices that describe the tendency of the water to precipitate (i.e., deposit) or dissolve calcium carbonate (CaCO₃) by considering the saturation of the water with respect to this mineral phase. When interpreting these indices, it is important to remember that the saturation of a water with respect to a mineral phase is temperature-dependent and that this is considered in the calculation of these indices. Here, the indices were calculated using groundwater temperatures measured during field sampling surveys. Hence the index values represent the behaviour of the water at abstraction temperature. These values may change when different water temperatures (e.g., circulation/ injection temperature) are used for the calculations.

LSI and RSI are often used and interpreted conjunctively and can be calculated as follows:

$$LSI = pH - pHs \quad \text{Equation (1)}$$

$$RSI = 2pHs - pH \quad \text{Equation (2)}$$

where pHs is the saturation pH calculated as:

*** as measured before/during sample collection.

$$pHs = (9.3 + A + B) - (C + D) \quad \text{Equation (3)}$$

with

$$A = \frac{\log_{10}[TDS]-1}{10} \quad \text{Equation (4)}$$

$$B = -13.12 * \log_{10}[T + 273] + 34.55 \quad \text{Equation (5)}$$

$$C = \log_{10}[Ca^{2+} \text{ as } CaCO_3] - 0.4 \quad \text{Equation (6)}$$

$$D = \log_{10}[Alkalinity \text{ as } CaCO_3] \quad \text{Equation (7)}$$

Concentrations of total dissolved solids (TDS) were estimated from the measured specific electrical conductance (SEC) using a conversion factor of 0.42.

LARSON SKOLD CORROSIVE INDEX (LSCI)

The LSCI is also empirically-derived and describes the corrosivity of water towards mild steel. It is the ratio of chloride and sulphate to alkalinity:

$$LSCI = (Cl^- + SO_4^{2-}) / (HCO_3^- + CO_3^{2-}) \quad \text{Equation (8)}$$

where

HCO_3^- = bicarbonate concentration (meq/L)

CO_3^{2-} = carbonate concentration (meq/L)

Cl^- = chloride concentration (meq/L)

SO_4^{2-} = sulphate concentration (meq/L).

Measured concentrations of dissolved carbonate (CO_3^{2+}) were estimated from the equilibrium equation:

$$\frac{[H^+][CO_3^{2-}]}{HCO_3^-} = K_2 = 10^{-10.33} \quad \text{Equation (9)}$$

where

$$H^+ = 10^{-pH} \quad \text{Equation (10)}$$

IRON CONCENTRATIONS

Concentrations of dissolved iron (Fe) in the groundwater in England and Wales are available from BGS' national groundwater chemistry database. These are grouped into concentrations of $< 500 \mu\text{g Fe L}^{-1}$ and $\geq 500 \mu\text{g Fe L}^{-1}$ and included in this tool to indicate low or high risk of encrustation, respectively.

The tool returns all data points that are present within a radius of 600m around the search location and hence, includes data from different aquifers and depths. Where more than one analysis is available at a given sampling point, e.g., at a regular monitoring site, these data are included in the database of this tool to reflect the temporal variability in groundwater composition. However, the display in the results table is limited to 10 entries in order to keep the

output manageable. Where more than 10 data values are found, the range and mean of these samples is displayed in the table as well as the number of values (samples) that were found.

2.1.6 Existing licensed abstraction database

This layer is based on maximum daily abstraction (MDA) data for England and Wales that were available from the Environment Agency National Abstraction Licensing Database (NALD) on 12 August 2011. This database provides MDA values for each existing licence and these values are directly integrated in this tool. It is important to note that the MDA values are assigned per licence, not per borehole or well. Hence, where a licence consists of more than one borehole, the same MDA value is assigned to the location of each borehole that is part of this licence.

The data in the National Abstraction Licensing database (NALD) is restricted due to national security. In line with data restrictions, the tool returns all data points within 600m of the search location without giving the precise location of the abstractions. A maximum of 10 data values are displayed in the results table. These are not given in any particular order and can refer to abstractions from different aquifers and depths or to boreholes that are part of the same licence (in which case they have the same MDA value).

2.2 DATASET HISTORY

This is the first version of the GSHP screening tool. This data set is the result of a collaborative project between the BGS and the EA. At the time of writing this guide, there are no plans to update this screening tool and associated databases.

2.3 COVERAGE

The dataset covers all of England and Wales at 1:250,000 scale excluding any offshore areas/ islands.

2.4 LIMITATIONS AND UNCERTAINTIES

2.4.1 Limitations

- The GSHP screening tool is not updated. It is based on, and limited to, the data that were available from various databases at the time this data set was created between August 2011 and April 2012.
- The GSHP screening tool is developed for open-loop, non-domestic schemes with >100kW capacity.
- The GSHP screening tool has been developed at the 1:250, 000 scale and must not be used at larger scales. It does not provide definite answers at the site scale and all spatial searches against the data should be done with a minimum 250m buffer.
- This tool is intended to be viewed onscreen only. Some of the data supporting this screening tool is restricted due to national security. Information that is freely available can be found in Section 3.
- The tool only considers the main hydrogeological units in Table 2 as providing bedrock aquifers at depths. Other formations can also provide concealed aquifers locally, but these have not been included here.

- The potential of superficial deposits to provide productive aquifers is also not considered by this tool.
- Estimates of bedrock aquifer productivity are based on best-case scenarios, i.e. the maximum possible yield from a single borehole.
- The tool does not consider the reduction in aquifer productivity near the outcrop boundaries due to decreasing thickness of the aquifer, i.e., aquifer thinning. As a result, there is a higher degree of uncertainty regarding the predicted aquifer potential near these boundaries which needs to be considered when using the tool. This is particularly important at boundaries between the base of a productive unit (aquifer) and the top of a less productive unit (no suitable aquifer).
- The tool does not consider the suitability of the subsurface to accept water, i.e. the suitability for re-injecting water. Such information needs to be obtained from site-specific investigations or field tests. There are also alternative methods for discharging the water that do not rely on the subsurface properties, e.g. discharge via the sewer system or to surface water courses. Permission from the EA and/or the relevant water company will be required for the proposed discharges.
- Sustainability of the open loop GSHP system is not considered by this tool and this is not within the remit of the EA or BGS. This may be an issue in areas where a large number of schemes have been installed within a certain area and where thermal interference between these systems can occur. Similarly, incorrect design can reduce the sustainability of a scheme significantly and some systems had to be abandoned due to this. You should discuss this with your installer, as changes to environmental permission may not be allowed.
- Being in a favourable area does not guarantee you will obtain the environmental permissions you require for an open-loop scheme, as the tool does not consider local variations, water availability or discharge of water from the scheme. The Environment Agency will always require developers to obtain more detailed, site-specific information, for example by applying for Groundwater Investigation Consent.
- The existing abstraction data **can represent the combined licensed yield from multiple boreholes**. For example, where two or more abstraction values are displayed for a search location, these may refer to the same licence (in which case they have the same value). Conversely, they could be boreholes that abstract from different aquifers and/or depths.
- The groundwater quality and existing abstraction licence data layers both incorporate information on superficial deposits (overlying the bedrock) which are not otherwise considered by this tool. Values returned by these layers do not necessarily relate to the main source identified in the bedrock aquifer potential / depth to source layers.

2.4.2 Potential risk factors and hazards

The potential for karst affecting yields is covered (Section 1.3.2), but there are a number of other risk factors which are not considered in this tool, but which can affect the suitability of a site for open-loop GSHP installations.

Risk factors that need to be considered before committing to the installation of an open-loop GSHP include:

- locations of mine workings and shafts
- locations of known or suspected contamination
- underground infrastructure restrictions
- ambient temperature changes
- areas where geohazards may occur
- presence of evaporites (salt, gypsum (including anhydrite)) in the subsurface.

For example, where soluble rocks (limestone, chalk, dolomite, gypsum, salt) are present at or below the surface, these can contain caves, cavities and open fissures. Where these are filled with sediments, changes in the groundwater flow regime, as induced by the abstraction and/or injection of groundwater, can cause the filling material to be washed out of the cavities resulting in destabilisation, collapse or surface subsidence. In chalk and limestone this is particularly an issue where the potential aquifer is only covered by a small thickness of other lithologies. In highly soluble rocks, such as salt or gypsum, fluctuations in groundwater levels or increased water flow can also enhance the dissolution of the rock, leading to expansion of the cavities, destabilisation and collapse. In areas where gypsum is present, it is important that drilling does not introduce water into underlying anhydrite, and that the sulphate content of the abstraction and injection water is similar. Hence, groundwater abstraction/injection may not be viable at locations where salt or gypsum are known to be present.

Areas where landslides, cambering or shallow mining are present also need to be treated with caution as the addition of water to the ground can trigger landslides and subsidence movements in these situations.

Relevant information is available from various sources, including BGS, the EA, Coal Authority and local authorities (pollution incidents, contaminated land register). Guidance on the correct design and installation of GSHP system can be obtained from the Ground Source heat pump association and the Geotrainet.EU project (see links in Section 3). In addition, BGS offers detailed information for geohazard assessments relating to mining, collapsible deposits, compressible ground, soluble rocks, running sand, landslides, and shrink-swell. Further details on the relevant sources and data sets are provided in Section 3.

3 Additional resources

3.1 BRITISH GEOLOGICAL SURVEY

The BGS provides expert services and impartial advice in all areas of geosciences. It holds a wide range of geoscientific data sets, including the outputs of the BGS survey and research programmes and BGS' substantial national data holdings. This data coupled with in-house geoscientific knowledge are combined to provide products and services relevant to a wide range of users. Selected products and information that are relevant for anyone interested in the planning and installation of open-loop GSHPs are listed below.

3.1.1 GeoSure dataset (Part of BGS' Ground Stability Hazard datasets)

GeoSure national datasets provide geological information about potential ground movement or subsidence caused by collapsible deposits, compressible ground, landslides, running sands, shrink swell or soluble rocks. Further information are available at:

<http://www.bgs.ac.uk/products/geosure/home.html>

3.1.2 Non-coal Mining Hazards dataset

The Mining Hazard (not including coal) dataset provides essential information for planners and developers building in areas of former shallow underground mine workings that may collapse. It draws together a diverse range of material derived from geology, literature searches and expert knowledge to map voids resulting from past underground mining activity. Note that mining of coals is excluded from this dataset. For further information see: <http://www.bgs.ac.uk/products/geohazards/miningHazard.html>

Enquiries on past coal mining should be directed to the Coal Authority (<http://coal.decc.gov.uk/>).

3.1.3 Corrosivity (ferrous) dataset

The dataset identifies where the ground conditions beneath the topsoil have potentially 'corrosive' or 'aggressive' characteristics, i.e. are likely to cause corrosion of underground ductile iron assets.

3.1.4 BGS GeoReports

GeoReports provides cost-effective access to unique sources of published and unpublished geological data, combined with expert advice from BGS scientists who know about your local area. Different standard and bespoke modules are available, including modules relevant for Ground Source Heat Pump (open and closed-loop) installations, ground stability assessments, or for detailed geological point prognosis or area assessments. A complete list of the available Georeports and further information are available at:

<http://shop.bgs.ac.uk/georeports/>

3.1.5 Groundwater Chemistry (Baseline project)

Between 1999 and 2005 British Geological Survey (BGS) and the Environment Agency (EA) undertook a collaborative project called The Natural (Baseline) Quality of Groundwaters in England and Wales. The project investigated the baseline quality of groundwater in aquifers or aquifer blocks in 23 study areas producing a report on each area as well as a report that synthesised all the results. The reports are available at

http://www.bgs.ac.uk/research/groundwater/UKbaseline/Baseline_study_results.html

Further information on all the digital data and services provided by the BGS can be found on our website at <http://www.bgs.ac.uk/data/home.html> or by contacting:

Central Enquiries
British Geological Survey
Kingsley Dunham Centre
Keyworth
Nottingham
NG12 5GG
Direct tel. +44(0)115 936 3143
Fax. +44(0)115 9363150
email enquiries@bgs.ac.uk

3.2 ENVIRONMENT AGENCY

3.2.1 Regulation of Ground Source Heat Pumps

<http://www.environment-agency.gov.uk/business/topics/128133.aspx>

Tel: 03708 506 506

3.2.2 Availability of Water: Catchment Abstraction Management Strategies

<http://www.environment-agency.gov.uk/business/topics/water/119927.aspx>

3.2.3 Groundwater Source Protection Zones (SPZ)

<http://www.environment-agency.gov.uk/homeandleisure/37833.aspx>

3.2.4 Abstraction and flow pressures on groundwater in England and Wales

<http://www.environment-agency.gov.uk/research/planning/33332.aspx>

3.2.5 Environmental Good Practice Guide for Ground Source Heating and Cooling

<http://www.environment-agency.gov.uk/business/topics/128133.aspx>

3.2.6 Pollution Incidents

www.environment-agency.gov.uk/homeandleisure/37821.aspx

3.3 OTHERS

3.3.1 Sites of Special Scientific Interest (SSSI)

England:

<http://www.naturalengland.org.uk/ourwork/conservation/designatedareas/ssi/default.aspx>

Wales:

<http://www.ccw.gov.uk/landscape--wildlife/protecting-our-landscape/special-landscapes-sites.aspx>

3.3.2 Ground Source Heat Pump Association

<http://www.gshp.org.uk/>

3.3.3 Energy Saving Trust (Information on closed loop systems)

<http://www.energysavingtrust.org.uk/Generating-energy/Choosing-a-renewable-technology/Ground-source-heat-pumps>

3.3.4 ThermoMap Project (Mapping the potential for horizontal closed-loop systems)

<http://www.thermomap-project.eu/>

3.3.5 Geotrained - Geo-Education for a sustainable geothermal heating and cooling market

<http://www.geotrained.eu>

Geotrained manual for designers of shallow geothermal systems

<http://www.geoexchange.ro/Geotrained%20Manual%20pentru%20proiectanti.pdf>

Appendix 1 - Calculation of minimum flow requirements

The minimum flow requirements of a 100kW schemes were estimated in order to assign meaningful classes of aquifer potential. Calculations were based on the peak load requirement of 100kW using the equation:

$$Q = \frac{q}{\Delta T S_{VC Water}} \quad (\text{Equation 1})$$

In which:

Q	=	required groundwater flow (L s ⁻¹)		
q	=	Heating or cooling load requirement (W)	=	100,000 W
ΔT	=	Temperature drop or rise as result of heat exchange (K)	=	variable
S _{VC water}	=	Specific heat capacity of water (J L ⁻¹ K ⁻¹)	=	4180 J L ⁻¹ K ⁻¹

For temperature differentials (ΔT) in the range of 2–10K, this gives the following flow requirements (Q) (Table 4):

ΔT (K)	Q (L s ⁻¹)
2	12.0
5	4.8
10	2.4

Table 4: Minimum flow requirements for 100kW scheme and different temperature differentials

Considering these results and assuming that temperature differentials usually lie between 5-10 K^{†††} it is concluded that minimum flows of 2-5 L s⁻¹ are required for the operation of a 100kW GSHP scheme. These yields may be achieved through the installation of multiple boreholes, hence it was decided that any aquifer with a productivity of > 1 L s⁻¹ could serve as a suitable source.

^{†††} The Environment Agency's "Environmental good practice guide for ground source heating and cooling" (<http://www.environment-agency.gov.uk/business/topics/128133.aspx>) proposes a maximum temperature differential of 8K for discharge to surface waters and 10K for discharge to groundwater with a maximum temperature of 25°C.