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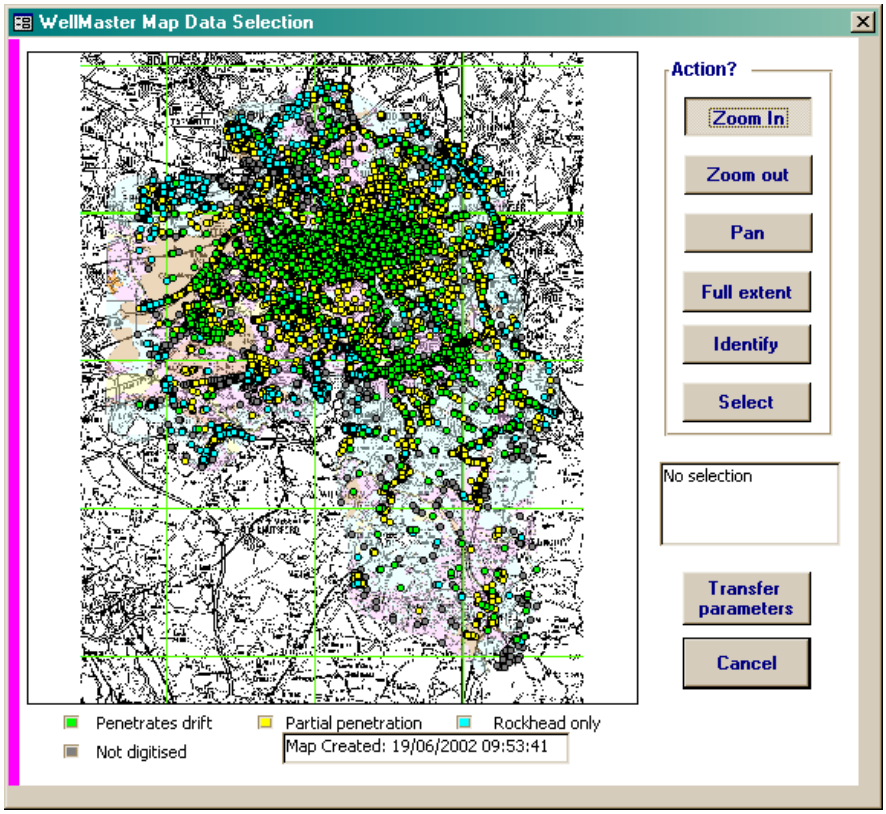
Digitisation of borehole logs for drift characterisation – Manchester-Macclesfield Pilot

Information Management Programme

Internal Report IR/02/069



BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/02/069

Digitisation of borehole logs for drift characterisation – Manchester-Macclesfield Pilot

A A McKenzie, E Hough

Key words

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Screenshot from WellMaster Drift browser application..

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Foreword

This report is the published product of a study by the British Geological Survey (BGS), in conjunction with the North West Region of the Environment Agency (the Agency). It covers work undertaken between October 2001 and April 2002, to digitise data on drift characteristics in the Manchester/Macclesfield area. This work was carried out as part of a collaborative project between the British Geological Survey and the Agency who funded the work as part of their 'Drift Infiltration Mapping Scoping Study'. Paul Jackson and Keith Seymour of the Agency provided advice and guidance on the Agency's requirements, and helpful comments on drafts of this report.

Thanks are due to Craig Buchan, James Woodier and James Carty who carried out the bulk of the data entry.

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Summary

In areas where aquifers are covered by drift and quaternary sediments, information on the nature of the superficial deposits is important for groundwater resource management and aquifer protection. The Environment Agency's North West Region commissioned the British Geological Survey to carry out a pilot exercise to digitise the drift characteristics in the Manchester – Macclesfield area, where an important Permo-Triassic aquifer is covered by a complex sequence of drift deposits.

The drift deposits in the area consist of glacial deposits that were laid down mainly during the Devensian, between 10,000 and approximately 100,000 years ago and non-glacial drift deposits that were laid down in association with modern fluvial activity, and are generally less than 10,000 years old. In the pilot area, the thickness of drift deposits generally increases towards the south and west, and can exceed 50 m.

There are over 11,000 borehole records within the area, mainly records of site investigation boreholes. Lithological data from these records was entered onto the BGS Borehole Geology Database, alongside a limited amount of hydrogeological data, and notes on the availability of more detailed data. With a very high density of boreholes in some urban areas, several strategies were examined for limiting the amount of data that required entry. The final approach adopted was to limit entry to one borehole per 200 metre by 200 metre square in areas of dense coverage.

The data entered have been extracted from the BGS corporate database to a stand-alone database for end user access. The application provided provides simple search strategies, and standardised reports, including an estimate of hydraulic conductivity of the drift deposits. Visualisation of the data as cross sections is possible using a public domain extension to the ESRI ArcView GIS.

The cost of data entry during the pilot study was approximately £6 per record. Scaling up data entry to the whole of the Agency North West Region, with approximately 100,000 boreholes in total would cost in excess of £500,000. It is possible that savings could be made through contracting out data entry, possibly overseas, but this requires further investigation.

1 Introduction

Information on drift geology is an essential component to the management and protection of national groundwater resources, the responsibility, in England and Wales, of the Environment Agency. However drift data is currently only available from disparate data sources. These include modern geological maps, and from the archives of borehole records held, in analogue form, by the BGS. BGS already holds some digital borehole log data, but existing digital datasets and digital datasets under development generally focus on solid geology, and rarely encompass detailed descriptions of drift lithology.

Access to this analogue data requires significant staff resources and processing the data to provide consistent overviews of drift lithology, either at specific sites or regionally, is rarely possible within sensible timescales. Access to a unified and quality controlled dataset which is derived from the full BGS borehole archive, providing spatial information through a GIS system for appraisal by a qualified geologist, would enable more efficient use of resources within both BGS and the Environment Agency.

Following a jointly funded BGS/Agency study into the hydrogeology of superficial clays (Klinck et al, 1993, 1997), and a study with BGS/Agency/Yorkshire Water Plc. on the tills of the Kingston-Upon-Hull area (Boland and Klinck, 1998), the Environment Agency North West Region formulated the 'Drift Infiltration Mapping Scoping Study', aimed at extending the methodologies developed during the earlier projects into a regional database and GIS system for use by the Agency in their regulatory role with regard to groundwater and waste management. It was agreed that this Environment Agency initiative would be jointly funded by the Agency and the BGS.

The pilot project's objectives were developed through a series of BGS and the Agency documents and meetings between staff. It was decided to focus efforts on data entry, rather than data interpretation, and to study a pilot area that covers the area of Permo-Triassic Sherwood Sandstone outcrop, or subcrop below drift, in the Manchester and Macclesfield area. See Figure 1 for the location of the pilot area. The project is complemented by three other BGS initiatives:

- an investigation of urban geology in the Manchester area that involves the integration in a GIS of information on 3-D geology, boreholes, current land use, historic potentially contaminative land use, groundwater and engineering geological properties for an area of greater Manchester including Trafford Park, Salford Quays, central and east Manchester. This project has carried out some digitisation of drift data
- Geohazard, a project extending the range of data and information suitable for geohazard assessment. This will enable the timely provision of information to the general public, commercial and government customers, enhancing their ability to make decisions related to geohazards. Amongst other issues, the project is scanning analogue records and digitising depth to bedrock nationally.
- WellMaster, a project to prepare a digital database of hydrogeological data based on the 100,000 water borehole and well records held by BGS.

From an Environment Agency perspective the long term goal of the project is to establish a database that provides point information on the thickness and lithology of the drift deposits across the whole of the North West Region of the Environment Agency drawn primarily from the borehole data contained within the BGS archives, with possible input from other existing sources within the Agency.

For BGS the digitisation of data contributes to several areas of survey and research. The data will be used for map production, and will provide a consistent, quality assured dataset on drift

lithologies, allowing the development and refinement of the Digital Geoscience Model of the UK. In the long term improved datasets can be used for answering enquirers and assessing environmental hazards and as a resource for developing conceptual models of recharge and other hydrogeological processes in drift terrains.

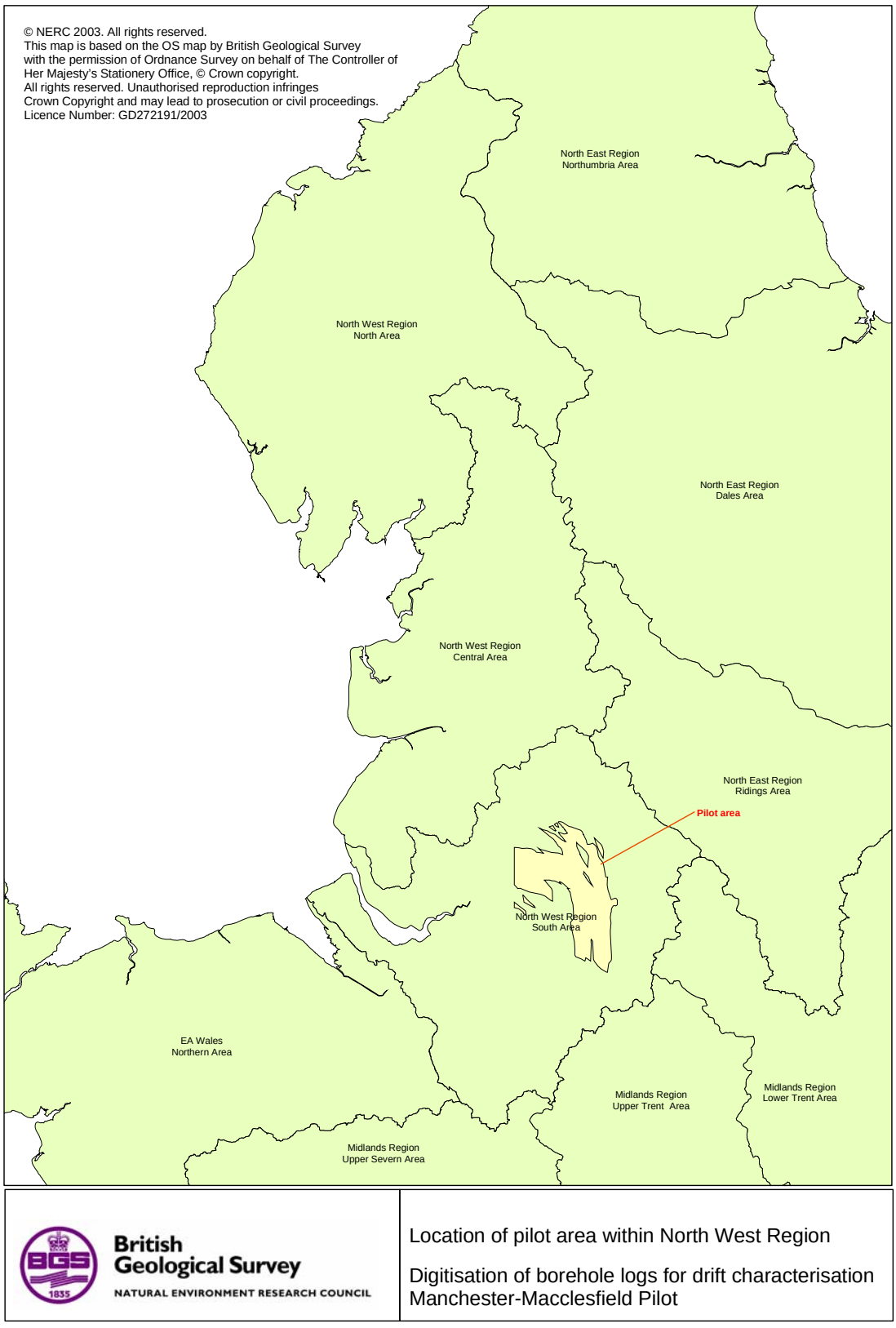

Figure 1 – Location of pilot area within North West Region

2 Objectives and Products of Scoping Project

Against the long term goal of a database that provides point information on the thickness and lithology of the drift deposits across the whole of the North West Region of the Environment Agency, the pilot project 'Drift Infiltration Mapping Scoping Study' seeks to establish the feasibility procedures for populating such a database and delivering it to end users. The experience gained from the project is designed to allow estimation of the cost of full regional implementation of the database.

The specific aims of the scoping study were broken down into four main components:

1. System issues
    - Establish system requirements in terms of hardware, software and compliance with the Agency and BGS standards, including other joint Agency/BGS databasing projects such as WellMaster. (WellMaster is a national Oracle database of hydrogeological data, with associated applications).
    - Assess how existing Agency databases can be integrated.
    - Assess how data from industry standard formats (e.g. AGS format, a standard ASCII format for interchange of Site Investigation data) can be imported.

2. Data issues
    - Investigate the uses of the data and the implications on data retrieval.
    - Review appropriate indexing and numbering systems.
    - Review lithostratigraphic and rock description lexicon dictionaries to ensure that they adequately address user needs.
    - Prepare data management procedures to allow regular updating and validation of data.
    - Review IPR data access and data ownership.
    - Examine methodologies for the selection of appropriate subsets of available borehole data.

3. Data entry
    - Develop preliminary databases covering a variety of geology and land use.

4. Reporting and phase 2 planning
    - Prepare a range of outputs appropriate to end-users.
    - Report on scoping project, to include costed proposals for extending the system to cover all data within the Agency NW Region.

3 User requirements

Listed below are the particular areas where information on drift is important and where the benefits would be realised. The project focuses on hydrogeological uses, but the benefits of digitisation and the user requirement is not entirely hydrogeological

3.1 END USERS

Within the Environment Agency the database will be available across the region for use by all interested groups for the purposes of performing regulatory assessments and developing projects.

Many, but not necessarily all, users will be qualified geologists or hydrogeologists.

Within BGS are likely to be mainly geologists who will access the data through existing database interfaces, but the data may also be presented to third parties as part of standard enquiries. Administrative staff will generally handle these enquiries.

3.2 HYDROGEOLOGICAL REQUIREMENTS

3.2.1 The assessment of groundwater vulnerability

For Environment Agency users the GIS data would supplement the routine appraisal of other internal records and published geological/hydrogeological information leading to an assessment of groundwater vulnerability. Specific Agency applications are as follows:

- Assessment of local ground conditions in the areas affected by pollution incidents
- Screening and/or assessments to determine the suitability of or requirements for:
    - Small sewage discharges to soakaway
    - Land spreading of waste
    - Sustainable urban drainage systems
    - Waste management activities
    - Potentially polluting industrial developments
- Estimating the likely significance of historically contaminated sites and advising on implementation of identification and remediation of contaminated land within the context of the Environmental Protection Act 1990: Part IIA contaminated land
- Advising local authorities on their strategic planning policies with respect to protecting groundwaters
- Advising third parties on the need for site-specific investigations or assessing their investigation proposals
- Improved development of nitrate vulnerable zones

3.2.2 Water resource management

- Generalised assessment of likely recharge mechanisms and development of conceptual and numerical models for groundwater resource assessments
- Identification of areas where site-specific investigations of drift mechanisms may be necessary
- Identification of groundwater catchments and development of the protection zone network
- Siting of observation boreholes and prediction of likely casing requirements when drilling observation boreholes

3.3 NON –HYDROGEOLOGICAL USER REQUIREMENTS

Although not specifically addressed within the project the data can be used for:

- Site specific engineering geological assessments and site specific geo-hazard assessments
- Development of conceptual models of quaternary geological and geomorphological processes.
- Validation of drift thickness contours produced from borehole logs.
- Geological map revision and validation.

3.4 DATA ACCESS REQUIREMENTS

While within BGS digital systems are available that allow direct access to information from digital downhole databases, these systems are designed for internal use by BGS staff, and do not satisfy the Agency user requirements

The interface to the database provided to the Agency was designed to satisfy the following requirements:

- Capable of operating as a stand- alone database on PCs within a Microsoft Office 97 environment, and within a Microsoft Office 2000 environment when that is introduced.
- Incorporate presentation functionality sufficient to allow qualified geologists to make interpretations and informed decisions. Usage may range from a quick check to a full study.
- Output of data from the drift database should be displayable alongside that from the WellMaster database.
- Allow visualisation of borehole logs and/or cross-sections.
- Allow relevant hydrogeological grouping of lithostratigraphy and lithology codes, for instance by linking together all lithologies where clay dominates, and allow reporting of this by borehole.
- Provide access to spatial estimates of drift thickness and clay thickness, or to the point data allowing the generation of such maps.
- Allow access to secondary data such as the degree of fissuring or weathering, consistency, water strike etc.

4 Data holdings

4.1 PROJECT AREA

The outcrop (and subcrop beneath drift) of the Permo-Triassic Sherwood Sandstone in the Manchester and Macclesfield area was selected as a pilot area. The area provides:

1. A variety of land use
2. Geological variety
3. A range of data density

The footprint covers all or part of 34 individual 5 km square 'quarter' sheets.

4.2 EXISTING PAPER RECORDS

Raw data for the drift characterisation project is held in the form of paper borehole logs by BGS at the National Geoscience Records Centre, Keyworth, Nottinghamshire. The quality of the original data held for the project area varies widely. Excellent, quality assured logs (drawn up using standard engineering terminology to British Standard BS5930; Plate 1) are held for many site investigation boreholes drilled after the mid 1970s. At the other end of the quality scale, boreholes drilled prior to the mid 1900s, and those drilled where the description of superficial deposit was not deemed important at the time of borehole logging (for example, some boreholes drilled for groundwater abstraction) commonly list no lithological variety in the Superficial Deposits. An example of a borehole log with poor descriptions of Superficial Deposit is shown in Plate 2. An interesting feature of the typical content of borehole logs is shown in Plate 3. Although this log has a fairly good resolution of classifying units within the drift (30 separate units described from 73 m), the quality of the descriptions of the units is poor, and not to any recognised standard. Features such as grain size, and the relative proportions of deposit in mixed deposits (e.g., 'Clay & Gravel') are not given, and descriptors such as colour are not given consistently for each unit. It is estimated that approximately 60-70% of the data used during the project post-dated the mid 1970s, and the majority of this data is of good quality; most of the data from the past 20 years was originally produced by site investigation companies, and as such was subject to some quality assurance by the originator of the data.

Table 1 – Borehole depths in pilot area

Depth range	% of boreholes in range
< 5 metres	37%
5 – 10 metres	33%
10 – 20 metres	19%
20 – 50 metres	6%
> 50 metres	5%

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During the pilot study, approximately 10% of borehole records were deemed unsuitable for digitisation, as they either proved no drift deposits (not including Made Ground) or because the original data was not scaled. The proportion of un-scaled data is much higher in records pre-dating 1970 than in modern SI logs. It should be noted that the pilot area is mostly drift-covered;

in areas where there is less drift-cover, it would be expected that a larger proportion of borehole records would not prove drift deposits, and therefore be unsuitable for use in a drift characterisation database.

Currently the data within the pilot area only exists as analogue paper files. A program of scanning is underway, so that in future there is the possibility of direct access to scans of the logs via CD or Internet

4.3 DIGITAL DATA

A limited amount of digital data was available before the project commenced. This included some digital borehole logs and hydrogeological data within the BGS WellMaster database. It was anticipated that geotechnical data in the Association of Geotechnical Specialists (AGS) digital format might be available. In practice no significant amounts of this data were identified. Nevertheless import routines have been developed by BGS to allow AGS format data to be read into the BGS corporate databases discussed in section 6.1 below.

4.4 DATA DISTRIBUTION

4.4.1 The Agency North West Region

The region contains approximately 95,000 records. The data distribution is shown in Figure 2.

Data coverage within the Agency North West Region becomes much sparser within northern Lancashire and Cumbria. In general, data density is highest in urban areas, in the coalfields (South Lancashire, Ingleton, Workington) and along major transport routes. Approximately 60% of all records within the region are within the South area of the North West Region.

By analogy with national data acquisition rates, it may be expected that records of approximately 5000 new, or newly located, boreholes within the region will be received each year by BGS.

4.4.2 The Agency North West Region South Area

The South area contains approximately 57,000 records

Data coverage within the northern part of the South area is in general good, being densest in the urban conurbations (Greater Manchester, Merseyside), the South Lancashire Coalfield and coastal areas. Further south, coverage thins out, becoming concentrated in towns and along major roads. Data coverage is also sparse along the extreme eastern and northern margins of the area (the Pennine fringe); incidentally, these areas broadly correspond to where drift is absent.

4.4.3 Pilot area

The pilot area contains approximately 11,000 records. Their distribution is shown in Figure 3.

Data coverage within the pilot area is heavily concentrated within the northern part of the area, in the urban areas of Manchester and Salford. The amount of boreholes available for input for the parts of 10k quarter sheets within the pilot area varied from zero (Chelford) to nearly 3,500 (Manchester and Salford).

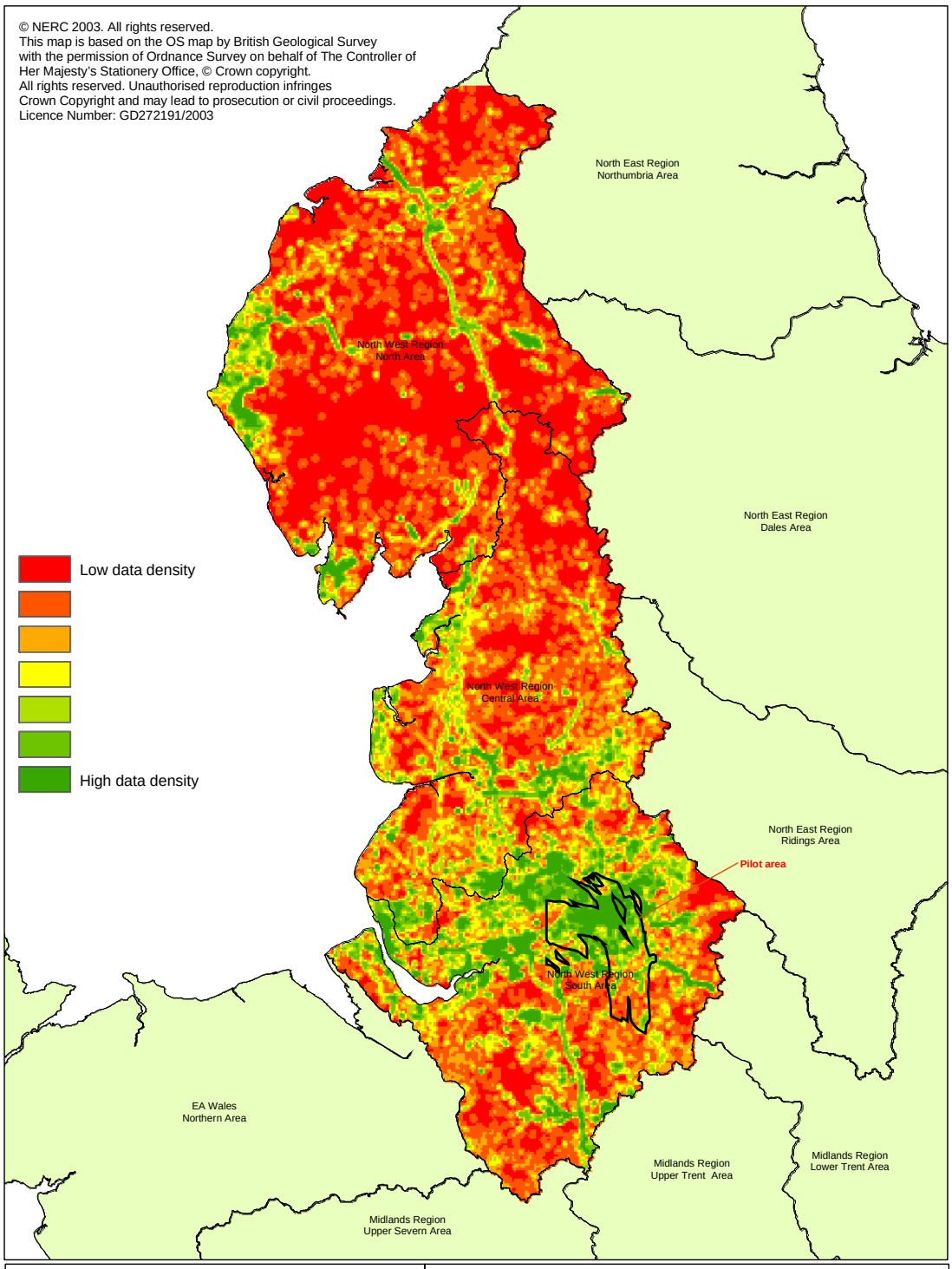


Figure 2 – Map of North West Region with region boundaries + data density

Figure 3 - Distribution of boreholes over pilot study area

5 Geological context

5.1 GEOLOGY WITHIN THE AGENCY NORTH-WEST REGION

The Agency North West Region can be split up into six major solid geological terrains, shown in Figure 4 and listed below:

Table 2 – Geological terrains

Geological Terrain	Major occurrences within the Agency North West Region
Mercia Mudstone Group	Cheshire, Fylde & Lancashire coast, North Cumbria
Sherwood Sandstone Group	Cheshire, west Lancashire, Vale of Eden, west Cumbria
Coal Measures	South Lancashire, north and west Cumbria
Millstone Grit	Central and north Lancashire, east Cheshire
Carboniferous Limestone	North Lancashire, Cumbria
Lower Palaeozoic and Granites	Central Cumbria

Two of these terrains do not occur within the region's South Area: Carboniferous Limestone and Lower Palaeozoic and Granites. Carboniferous Limestone is comprised of interbedded limestone, mudstone and sandstone. The Lower Palaeozoic strata and granites occur within the central Cumbria district. They are lithologically diverse, including slate, sandstone, mudstone and igneous and metamorphic rocks.

Drift cover north of the South area is variable. In general, drift cover would be expected to be thin or be absent from the higher ground, and be thicker on the crop of the Sherwood Sandstone and Mercia Mudstone. The drift cover is shown in Plate 4.

Made Ground underlies most urban, built-over and landscaped areas. Within the region made ground will generally be associated with the major conurbations within the southern part of the region. In rural areas Made Ground will become much less of an issue, but will still be encountered in association with major transport routes, landfill sites and miscellaneous areas, some of which may be associated with the main population centres, such as Lancaster and Kendal.

5.2 THE AGENCY NORTH-WEST REGION SOUTH AREA

The pilot area lies entirely within the North West region's South area. In broadest geological terms, the area covers the northern and central parts of the Cheshire Basin, the Llyn-Rossendale ridge (between the East Irish Sea and Cheshire Basins; Wirral and Liverpool) and parts of the South Lancashire Coalfield and south-western Pennines.

The main solid stratigraphic units encountered, in addition to the Permo Triassic units discussed below in the context of the pilot area, are the Mercia Mudstone, Coal Measures and Millstone

Grit units. The Mercia Mudstone comprises mudstone with halite and subordinate sandstone units. The Coal Measures and Millstone Grit typically comprise interbedded sandstone and mudstone, with thin beds of coal, ironstone and fireclay. Issues such as halite dissolution and 'wet rockhead' (collapsed strata above dissolved halite) within the Mercia Mudstone, and mining voids after coal and fireclay within the Coal Measures and Millstone Grit would become relevant within these strata.

Drift cover is thickest and most extensive in the southern and western parts of the area, which roughly correspond to the Permo-Triassic crop (Sherwood Sandstone and Mercia Mudstone groups). Drift cover becomes generally more patchy and thinner on the crops of the Coal Measures and Millstone Grit, and is mostly absent on the Pennine uplands to the extreme east and north of the area. Drift deposits in addition to those encountered during the pilot study include Coastal-Zone Deposits, Blown Sand and Estuarine Deposits associated with the Mersey.

Coverage of Made Ground is likely to be most abundant in the urban areas of Manchester (the majority of which, excluding Sale, Altrincham and west Stockport has been covered by the pilot area). Significant Made Ground would also be expected in the Liverpool-Birkenhead area, and other large towns, as well as along major transport routes and landfills.

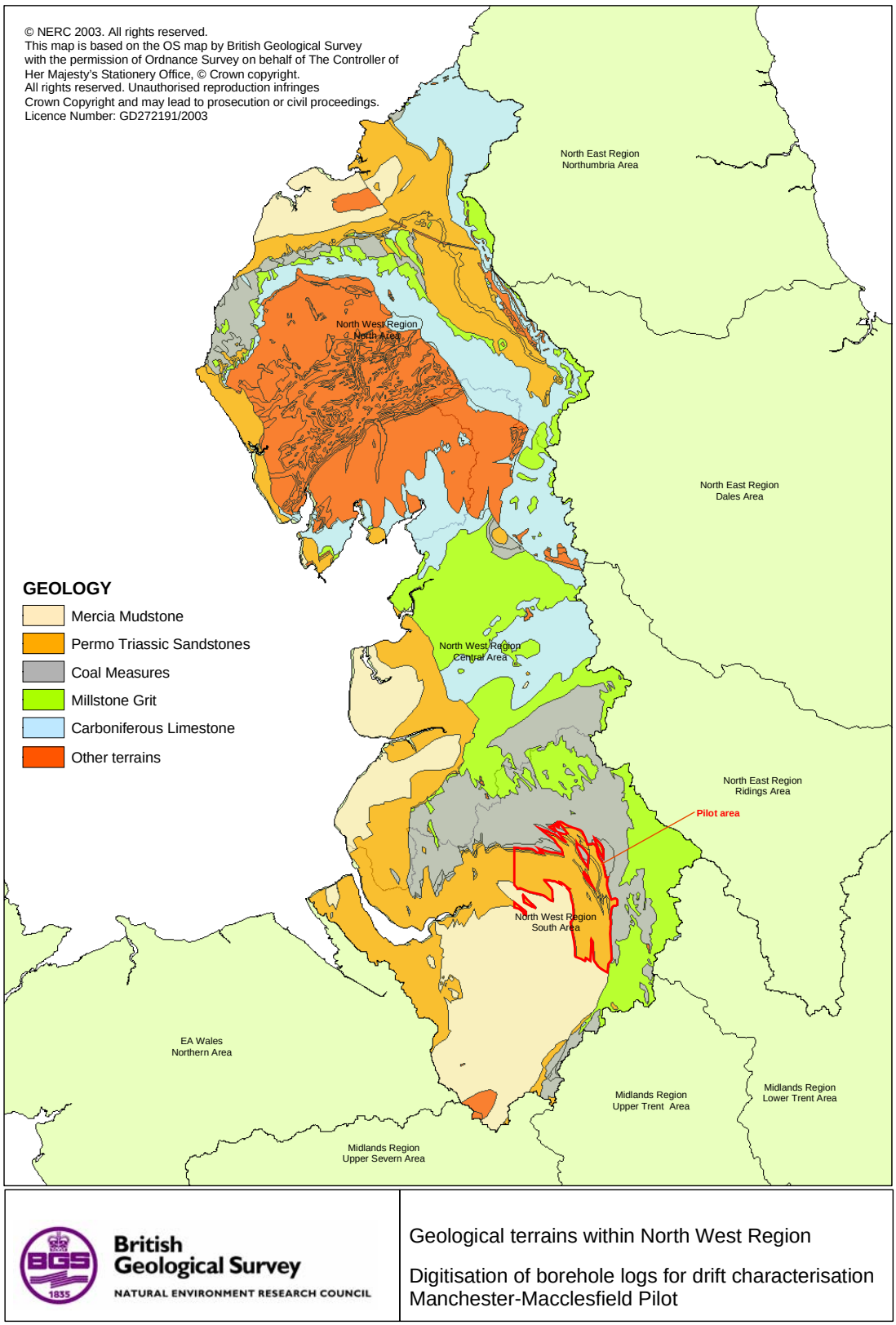


Figure 4 – Geological terrains within North West Region

5.3 PILOT AREA

3 Geological Map sheets cover the pilot area at 1:50,000 scale, each with editions covering the solid geology and drift sequence. Although the maps were published in the late 1960s and 1970s, original surveying was done much earlier. Table 23 lists the mapping. Each sheet is accompanied by a Geological memoir (Tonks et al, 1931, Taylor et al, 1963 and Evans, 1968).

Table 3 – Printed geological maps covering pilot area

Map Sheet	Map Number	Date Surveyed	Date Published
Manchester (Solid)	85	1924-1927	1975
Manchester (Drift)	85	1924-1927	1970
Stockport (Solid)	98	1931-51	1977
Stockport (Drift)	98	1931-51	1962
Macclesfield (Solid)	110	1956-60	1968
Macclesfield (Drift)	110	1956-60	1968

5.3.1 Solid Geology

The solid geology underlying the pilot area comprises part of the sedimentary fill from the north-eastern part of the Permo-Triassic Cheshire Basin. The Sherwood Sandstone Group within the pilot area comprises six stratigraphical formations, in ascending order, Collyhurst Sandstone, Kinnerton Sandstone, Manchester Marls, Chester Pebble Beds, Wilmslow Sandstone and Helsby Sandstone. Sandstone is the major lithology within the Sherwood Sandstone Group; mudstone lithologies dominate the Manchester Marls, and parts of the Chester Pebble Beds and Helsby Sandstone Formations. Identification of these formations is generally not possible north of the Stockport-Sale areas. The solid geology is outlined in Plate 5.

5.3.2 Drift Geology

Drift deposits are present over the majority of the pilot area. The origin of drift deposits may be attributed to either glacial or non-glacial processes. The main drift deposits present within the pilot area are listed in Table 4, categorised into deposits resulting from glacial and non-glacial processes, and are mapped in Plate 6.

Table 4 – The origin of the main drift deposits within the pilot area

Drift deposits deposited by glacial processes	Drift deposits deposited by non-glacial processes
Glacial Till	Alluvium
Glaciofluvial Sand and Gravel	River Terrace Deposits
Glaciolacustrine Clay (‘brickearth’)	Peat

Glacial deposits were laid down mainly during the Devensian, between 10,000 and approximately 100,000 years ago, and were sourced from either the Irish Sea or Pennine ice sheets. Non-glacial drift deposits were predominantly laid down in association with modern fluvial activity, and are generally less than 10,000 years old. In the pilot area, the thickness of drift deposits generally increases towards the south and west, and can exceed 50 m. The sub-drift surface is incised in many places by drift-filled buried channels and hollows, some of which may be pre-cursors to modern fluvial courses.

5.3.3 Made Ground

Within the pilot area, Made Ground is ubiquitous in the urban north and Stockport. Although rare in the more rural areas, Made Ground is still found, for example, associated with factory sites, landfill sites and transport routes (road, rail and canal embankments, and airfields). Made Ground can be deposited either on the natural land surface, or infilling excavations. No attempt has been made to sub-classify Made Ground with regard to composition.

Made ground mapping is not available for the pilot area.

6 Databases and digitisation

6.1 DATABASES

BGS have established a suite of database tables, held within an Oracle relational database, for managing borehole data. These databases include:

Table 5 – Oracle database tables used for borehole data

Table	Description	Index
SOBI - Single Onshore Borehole Index	Holds basic information on borehole location, names, depths and dates of drilling for all boreholes known by BGS	Indexed by NGDC Identifier.
Well_Identity	Holds basic information on the subset of SOBI where the purpose of drilling is hydrogeological. Part of the 'WellMaster' database.	Indexed by Hydro Identifier, and cross referenced to NGDC Identifier
Borehole_Geology	Holds down-hole geological log data, including lithostratigraphy, and rock types for discrete intervals	Indexed by NGDC Identifier and depth
Borehole_Geology_Properties	Holds additional data referring to attributes of discrete intervals.	Unique key to Borehole_Geology
Water_Strike	An attribute table for WellMaster, holds depths at which water was struck in boreholes	Indexed by NGDC Identifier
Rest_Water_Level	An attribute table for WellMaster, holds depths at which rest water was measured in boreholes.	Indexed by NGDC Identifier and date.
Drift_Attribution	A project specific database developed for the Drift Characterisation project, holding water strike data and details on the availability of extended datasets. The data held in this database was transferred to Water_strike and Rest_Water_level after digitisation.	Indexed by NGDC Identifier.

See Appendix 1, Database structure, for entity relationship diagrams of SOBI and Borehole Geology.

The principle focus of data entry for this project has been entry to the Borehole Geology database that holds downhole lithological /lithostratigraphical data (with lithological unit bound properties where appropriate) for boreholes identified within the Single Onshore Borehole Index (SOBI). This database has the ability to store multiple interpretations for each borehole. This facility is necessary to allow the use of the database at a range of scales. The database can also hold properties assigned to each coded lithological unit within a log. Current examples of

borehole geology properties are; porosity, Munsell colour, grainsize, and water struck, but the system allows extension to cover other properties.

While fully capable of holding limited hydrogeological attribution, Borehole Geology is not well suited to the repetitive entry of this type of information, and for project purposes a separate application was used to enter depths of water strike, information on rest water levels and notes on the presence of additional data, within the archive, on hydrogeology, geochemistry or engineering properties.

There was some data already entered into the borehole_geology tables within the pilot area. This includes some lithostratigraphic data entered as part of the Manchester project, and depth to bedrock, entered as part of the BGS geoHazard programme.

6.2 DICTIONARIES

Dictionaries of standard lithostratigraphies and rock types control data entry to the Borehole Geology database. The relevant dictionary entries for the pilot area are summarised in Appendix 2 for Lithostratigraphic codes, and Appendix 3 for Rock Classification Codes.

A limitation of the existing dictionaries is that, for compatibility with existing records and maps, they include a number of alternative entries for similar units, as well as obsolete terminology. Data entry practice has been to enter the code that most closely represents the description on the original record, however for unconsolidated deposits ‘rock’ type descriptions are increasingly interpreted to follow the BS5930 guidance for site investigation, which sets out a scheme for their description and codification. . Appendix 4 contains the guidance notes used to guide staff during data entry. Nevertheless, with previously entered data, and the range of terms used on the original logs, approximately 130 different rock types were recorded, with nearly 100 being drift lithologies, 70 in the BS5930 scheme and 30 legacy terms.

To aid end-user interpretation, a dictionary has been constructed, translating obsolete drift terminologies into the new scheme, and additionally classifying drift lithologies in terms of hydraulic conductivity. Hydraulic conductivity classification followed the US Department of Interior, Groundwater Manual, scheme outlined in Brassington, 1988 (see Table 6). Inevitably some lithological terms used on logs are sufficiently ambiguous to make classifications subjective. In particular where lithologies are undifferentiated, interpretation may depend on data end-use, with different assumptions required in assessment of aquifer vulnerability versus the assessment of aquifer recharge. The current classification was initially made with a bias towards groundwater vulnerability, hence unknown lithologies are assumed to have high hydraulic conductivities. This dictionary is included as Appendix 5, but it should be noted that classifications, especially of hydraulic conductivity, are subject to review.

Table 6 – Hydraulic conductivity classification

Classification	Range (m/d)	Description
VHIGH	$> 10^{3}$	Clean gravel
HIGH	$10 - 10^{3}$	Clean sand
MODERATE	$10^{-2} - 10$	Fine sand + clean silt
LOW	$10^{-2} - 10^{-4}$	Silt, mixtures of sand, silt, clay
VLOW	$<10^{-4}$	Clay

6.3 METHODOLOGIES FOR SELECTING AND SUB-SETTING DATA

The original project concept included the concept of the selection of a subset of the available paper records to allow a greater geographic area to be covered. It was initially hoped that this step could be avoided by increasing the staff resource associated with data entry. However as the project progressed concurrent data acquisition increased the number of available records within the project pilot area and it became clear that it would not be possible to digitise all the data.

Several options were reviewed for sub-setting the data, aiming to reduce the number of records to be digitised to approximately 7500, in the expectation that approximately 2 out of every 3 boreholes would have useful data on drift:

- Eliminate boreholes proving only Made Ground

  Pros: Data would not add much to the model of drift characterisation within the project area; Made Ground is currently input as undifferentiated (i.e., all we get for our effort is a thickness)

  Cons: These boreholes are generally easy to input; we would not save much time not inputting these; Water strikes have been recorded within Made Ground

- Eliminate trial pits

  Pros: Trial pits are generally time-consuming to input and shallow; would save a fair amount of time

  Cons: Estimate less than 1000 trial pits in the project area

- Eliminate boreholes and trial pits less than 5 m deep

  Pros: Would bring the total number of records in the project area down to an estimated 7500; includes most trial pits and boreholes proving Made Ground

  Cons: loss of much shallow data

- Do not code boreholes added to SOBI post August 2001

  Pros: Would bring the number of boreholes to input down to approximately 7800; this number would be less if the cut-off date was earlier

  Cons: loss of much data

- Do not re-interpret boreholes entered for the Manchester Urban Project

  Pros: Would bring the number of boreholes to input down to approximately 7100

  Cons: Data not coded using the guidelines for this project, namely, data not coded using new lithological coding scheme, and some lithological units have been ‘lumped’ together

- Spatial sampling of data, i.e. select a single borehole per 200 m square in areas with dense datasets

  Pros: This gives a coverage of around 600 boreholes per 5km square, and the sub-setting is only required within areas of very dense borehole coverage, generally major urban centres.

Cons: May miss heterogeneity in areas of complex drift, selection of a representative borehole within a sub-square is, of necessity, subjective.

Table 7 – Results of various sub-setting strategies

	Number of boreholes
Total	11759
Not made ground	7800 (Estimated)
No trial pits	10500 (Estimated)
Only data > 5m depth	7407
Boreholes pre August 2001	7995
No reinterpretation	7100 (Estimated)
Spatial sampling	7458

Following discussion with the Environment Agency it was decided to adopt a spatial sampling strategy, cutting down data entry in areas of very dense coverage to one borehole in every 200-metre square. The choice of borehole within the 200-metre square was left to the discretion of the digitiser, to ensure that an appropriate level of detail is available.

For each borehole entered data entry has focused on the lithostratigraphy and rock type within the drift sequence. Data entry below drift has been confined to the first rockhead lithostratigraphy.

6.4 OUTPUT DATABASE

To allow end user access to the data entered into the central Oracle databases a Microsoft Access 97 application, previously developed as a framework for delivering WellMaster data to end users, has been adapted to drift characterisation data. The Oracle tables SOBI and borehole_geology and their associated dictionaries have been queried using a spatial query based on a 5 kilometre buffer around the pilot area, to produce a snapshot of the data within a Microsoft Access database.

End users can access the data from the output database in a variety of ways.

1. User can use the interface provided with the Microsoft Access database to prepare reports against a variety of spatial query criteria. The reports can be printed, or exported to Word or Excel using standard Microsoft application software.
2. Data can be extracted directly from the Microsoft Access database for inclusion in other applications by opening the database and exporting the relevant tables or table subsets.
3. The data can be viewed in a GIS by import of provided ESRI shape files. These record borehole location, digitisation status, borehole depth and depth to rockhead.

The output database tables, in particular SOBI, have been modified by the addition of extra columns recording the presence of extra hydrogeological, geotechnical or geochemical information within BGS archives, and also providing a Digital Elevation Model (DEM) derived land surface elevation, allowing the expression of borehole logs as metres below ground level and metres above Ordnance Datum. It should be noted that the DEM derived surface elevation is often significantly different to the surface elevation recorded on the original paper logs. While in some cases this may be due to changes in land surface (for instance post drilling excavation or infill), many other discrepancies may be the result of errors, especially in the conversion of heights recorded in metres.

The presence of multiple interpretations of the same log led to particular problems with analysis of hydraulic conductivity, where units are aggregated. This was addressed by carrying out a review of boreholes where there were multiple interpretations, and selecting a preferred interpretation; priority was given to interpretations made for this project, followed by interpretations where detailed geological data had been entered.

6.5 MICROSOFT ACCESS USER INTERFACE

The Microsoft Access application WellMasterDrift has been designed to facilitate end user access to the data. Users are initially presented with a screen allowing access to three levels of query; index queries to highlight data availability, summary queries to present data, and detailed queries to allow access to all data for a given site, as well as to dictionaries.

All queries share a common tabbed interface that allows a range of methods for selection of the dataset of interest. These include:

- Selection of data by use of a 5 kilometre National Grid Quarter Sheet – e.g. SJ89NW
- Selection of an individual borehole record by use of its SOBI identifier, which is made up of the Quarter Sheet and a unique accession number – e.g. SJ89NW/1
- Selection by entering NGR coordinates for a rectangle or by selecting a circle centre and associated radius.

- Selection by entering the WellMaster identifier of a borehole, which is made up of the National Grid 10km sheet number and a unique accession number. (This is the number used for water well records by BGS Wallingford and North West Region of the Agency, it is not assigned to all data points within the system.)
- Selection through a simple map interface, that presents the distribution of boreholes, overlain on a raster map background. The raster map was generated from 1:250,000 Ordnance Survey Raster topography draped with the1:50,000 BGS Drift map. The borehole data are colour coded to show data availability and to record drift penetration.

The following reports are available (examples are included in Appendix 6):

- Index report showing boreholes within selection with Location name, NGR, Depth, whether rockhead was reached, and then the availability of additional geological, geotechnical, water data or chemistry data. A second version of the index report is available which includes the boreholes WellMaster ID number. It is then possible to select the WellMaster application (a separate MS Access application) and examine the hydrogeological details of the selected borehole.
- Summary report showing depth to rockhead
- Summary report showing a summary of the geology penetrated for each borehole.
- Summary report on hydraulic conductivity, showing aggregate thicknesses of drift according to a hydraulic conductivity classification.
- Summary report with rest water levels.
- Summary report with water strikes.
- Detailed report showing all data for an individual borehole.
- Dictionary report for Lithostratigraphy
- Dictionary report for Lithology, including hydraulic conductivity codes.

To allow access to WellMaster data

6.6 VISUALISATION + OTHER OUTPUTS

The output from the Microsoft Access application is of text only. Internal BGS users can query the borehole_geology database directly, and return data as graphical logs using an application developed internally. Example output from this system is shown in Appendix 6.

For external users the data within the borehole_geology database may be exported to a variety of software packages to allow visualisation.

To visualise data spatially the data may be read into a GIS package such as ESRI Arc GIS or ArcView. This approach also allows the generation of borehole logs as cross sections through an area of interest. This facility can be provided through several commercial software packages, but can also be achieved through the use of public domain ESRI ArcView extensions. The data for the pilot area has been included within an ArcView project using the Borehole Data Display (BDD) extension developed by the University of Washington (Blouke et al, 2002). This allows the user to select one or more boreholes along a line of section, and visualise either the lithological units within the borehole or the lithostratigraphic units. User defined symbologies are available, and the interface is accessible to staff with a basic familiarity with the ArcView interface. Examples of cross sections are included in Appendix 6.

6.7 IPR

The IPR of borehole data frequently resides with the original data provider, which may be a public body or a private sector contractor or consultant. However digitisation of the data has the effect of creating a new dataset, which is subject to its own IPR.

The IPR of the data digitised during this project is governed by Section 6 of the project memorandum, under which agreement BGS grants the Agency free and irrevocable rights to use the database for its own internal business, and rights for the use of the data by consultants and contractors working for the Agency. External consultants should be granted an individual licence by BGS, although no costs are associated with this.

7 Scaling up to regional level

7.1 NUMBER OF RECORDS

There are currently approximately 95,000 records within the Agency North-West Region (See Plate 7). Of these, approximately 57,000 are within the South area. Within the pilot area there were 11,000 records (see Plate 8), although this may be a slightly anomalous number – during the digitisation allied work resulted in the identification of a considerable number of records previously unknown to BGS. By analogy it might be expected that there may be well over 140,000 records within the North West region, were similar effort to go into data acquisition in other metropolitan areas, however it is assumed that similar subsetting strategies would be used, so calculations and costings below are based on a figure of 95,000 records (less 7000 already digitised. During the pilot project, the total number of records actually requiring digitisation was reduced by 30% by capping data entry at 600 records per 5-kilometre square 30%, but the pilot study was carried out in an area that is relatively urbanised, compared to the region as a whole.

Table 8 summarises the boreholes by the Agency area, and also gives a breakdown of their distribution over differing drift deposits (based on mapping of drift at a scale of 1:625,000).

Table 8 – Distribution of boreholes by the Agency's three areas within North West region, classified by superficial deposits mapped at the surface.

DRIFT	North Area		Central Area		South-Area		Total	
Total Boreholes in area	17195		20722		56682		94599	
Boreholes on drift	15309	89%	19048	92%	52603	92%	86960	92%
Alluvium	2285	13%	2425	12%	4393	8%	9103	10%
Blown sand	104	0.60%	2033	10%	2495	4%	4632	5%
Boulder clay and moranic drift	10872	63%	11805	57%	34336	60%	57013	60%
Glacial sand and gravel	815	5%	1533	7%	4666	8%	7014	7%
Peat	526	3%	903	4%	811	1.50%	2240	2%
Raised beach and marine deposits	371	2%	11	0.05%	0	0%	382	0%
River terrace deposits (mainly sand and gravel)	336	2%	338	1.50%	5893	10%	6567	7%
Landslip	0	0%	0	0%	9	0.01%	9	0%

7.2 RESOURCES REQUIRED TO EXTEND WORK

During the present pilot study, the following work rates have been found to be reasonable assessments, based on the current project protocols (using data inputters with a sound background in geology, inputting on the current Borehole Geology system, using a separate

'additional hydrogeological data' database, and using a filter on OS 25 square kilometre quarter sheets with in excess of 625 records per sheet):

Geological data input + water strike data: 50-80 records per data inputter per day; approximately 90% of available data is suitable for input within the pilot area; approximately 50% of available data records a water strike

Geological data input using a filter on high density quarter sheets: 50 records per data inputter per day

Additional hydrogeological data: 100 records per day per data inputter per day, depending on the quality and clarity of the original data; approximately 30% of available data record additional hydrogeological data

Initial estimates of time it would take to extend the drift characterisation project to the three areas of the region, and to the complete North West region are given in Table 9. The estimates assume that 90% of the total number of boreholes within the region have data to be entered, this does not take into account the fact that 10% of boreholes are drilled in areas with thin or absent drift coverage, the slight overestimation of task complexity will probably be compensated for by future data acquisition that will inflate the number of records:

Table 9 – Estimates of data entry manpower required to extend the project

	Number of sites		Days required				
			Lithology entry		Additional data entry	Total	
	Total Sites	Remain to be digitised	50/day	80/day		50/day	Total 80/day
South Area	56822	49822	897	560			
Central Area	20722	20722	373	233	62	435	295
North Area	17195	17195	310	193	52	361	245
Total North West Region	94739	87739	1579	987	263	1843	1250

With these assumptions the completion of digitisation of drift records for the Agency North West region would take between 1250 and 1850 man/days (6.25 to 9.25 man/years).

To these figures for data entry manpower it will be necessary to add time for technical development, geological interpretation and supervision of data entry. Technical development is assumed to require 30 man/days per annum, geological interpretation and supervision will require 60 man/days per annum, management would require a further 15 days/annum.

While the approach followed within the pilot area, of digitising all records, will provide satisfactory coverage within urban areas, and within the more densely developed rural areas, there will be substantial areas, especially in the North area, where there are no boreholes at all over discrete areas of outcrop, and many areas where the borehole density is so low that accurate extrapolation of lithological characteristics on the basis of borehole data is likely to be unreliable. Where there are very few records, and an alternative approach to drift characterisation, perhaps based on drift domain mapping, may be necessary to complement the digitisation. This does not mean that it is not worth digitising the data in rural areas– it will be important to gather whatever data are available. A possible approach to drift characterisation through the mapping of hydrogeological domains has been described by McMillan et al, 2000, for the Sellafield area. Field mapping and remote sensing was used to identify Quaternary

geological domains, which were then translated into hydrogeological domains by reviewing drilling and trial pit records to develop a conceptual model recognizing units that are hydrogeologically similar. Bridge et al, 2001, also used the approach. In a study commissioned by the Agency on the Alberbury groundwater unit, Shropshire, existing borehole records were used to rationalise the marked lateral and vertical variability encountered in the superficial drift deposits of the Severn valley. It proved possible, by constructing a series of stratigraphic cross-sections, to rationalise and classify the drift into a relatively small number of hydrogeological domains and sub-domains. The resulting domain map distinguished zones in which differing hydrogeological behaviours can be expected.

These approaches have relied on fairly detailed local investigations, but the approach could be applied over wider areas by combining the available borehole information, drift thickness, 1:50,000 scale mapping and information on topography to mapped drift deposits in rural areas. This has not been included in the costings below, which focus on the digitisation of records.

7.3 TIMINGS

The extension of the project to cover the whole of the North West Region of the Agency will, as discussed above, require significant staff inputs for digitising. From experience with similar projects a data entry team of 3 to 4 staff would be manageable. This would allow a 3 year project to be formulated, with approximately 30,000 records covered in a year of digitising (actual data entry will be slightly less than this, given percentages of records without data.

Recruitment of staff (normally newly qualified geologists) to carry out these tasks has normally proven feasible, but inevitably over a three-year period we would expect significant staff turnover. This will mean that actual staff deployment will vary from 2 to 4, with an average of 3 staff.

This would allow digitisation of the Southern area by about month 20 of a 36 month project, the Central area by month 28 and completion of the Northern area in month 36.

7.4 COSTINGS TO EXTEND WORK

The proposed programme of work would require the following resources. Costs are indicative and assume that this work is carried out as a commercial contract. While access to the data in digital format would benefit not only the Agency, but also BGS, limited resources are available within BGS for the digitisation of data, and any decisions on BGS investment would need to be taken with due regard to other digitisation priorities.

Table 10 – Approximate costings for completion of digitisation – North West Region

	Year 1	Year 2	Year 3	Total
Digitisation	£140,000	£144,000	£148,000	£432,000
Technical development	£8,500	£9,000	£9,000	£26,500
Supervision	£22,000	£22,500	£23,000	£67,500
Management	£7000	£7500	£8000	£22,500
Other costs	£5000	£2000	£2000	£9,000
Totals	£182,500	£185,000	£190,000	£557,500

These rates are based on an overhead inclusive rate for an Assistant Scientific Officer of £178 per day, and the approximate cost per record digitised will between £6.00 and £6.50. This figure is very similar to the cost of digitising hydrogeological data into the WellMaster database[1].

Clearly complete digitisation will require substantial financial resources, and it may be worth further exploration of strategies for the selection and refinement of the data to reduce costs.

As BGS would almost inevitably have to recruit staff to carry out the digitisation, it will be worth considering the contracting out of the digitisation. The technical supervision element, calculated as approximately 6 man/days per month would need to be added to the cost of any commercial data entry costs, unless digitisation was carried out by an organisation with substantial in-house geological expertise. Contracting could be carried in a variety of ways –staff could be brought into the BGs offices, or as records will be available as digital images digitisation could be carried out at the contractors premises, opening up the possibility of using an offshore data entry specialist. This should be possible, which can be sent to a data entry specialist without risking valuable original data. Savings of up to 40% of data entry costs may be achievable, assuming that supervision costs did not rise significantly this might reduce project costs by as much as £100,000. By contracting out it may also be possible to complete digitisation in a much shorter period, with further savings from reduced management costs.

Assuming that the data were digitised as a commercial contract on behalf of the Agency, such a contract would cover all licensing fees and the IPR, as within the pilot study, would allow data to be passed to consultants and contractors for specific tasks, as long as records were kept and data returned or destroyed at the end of any project.

Database maintenance costs would be minimal, but adding new data, at approximately £6.50 a record might cost £16,000 based on the addition of 2500 new records each year.

A possible alternative approach would be to use scanned copies of borehole logs directly, without digitisation. There are, as yet, some unresolved issues with respect to IPR of digital copies of borehole logs donated to the BGS, but assuming that these are resolved, direct access to the original logs via an Extranet link would provide end users with all available lithological data. The data would, however, not be digitally searchable, or available for use in the automatic generation of reports or cross sections. The costs of providing such access would have to be established by the BGS National Geosciences Data Centre.

[1] WellMaster digitisation is currently undertaken as a joint venture between the Environment Agency and the BGS, the Agency contribution is approximately 30% of the total costs of digitisation.

8 Conclusions

The project has shown that it is technically feasible, but expensive, to digitise drift lithostratigraphy, and to use the digital information to allow rapid assessment of drift conditions within an area.

Data entry rates of between 50 and 80 records per person per day were achieved, using newly qualified geologists for data entry.

Approximately 90% of available analogue records were found to have useable lithological data, with approximately 50% having some form of information on groundwater conditions.

Original records were varied in there overall, quality, and in the way in which lithological data were recorded. Over 130 individual lithologies were recorded, 100 representing drift deposits. These were reduced to approximately 70 deposits in a scheme based on BS5930.

A range of trial outputs were generated, including a Microsoft Access database with simple GIS front end, maps produced in Arc GIS and borehole logs.

The process of digitisation is not cheap, with costs ranging from £4 to £6 a record, so scaling up to the 95,000 records within the North West Agency region will be a substantial undertaking. By deploying an average of three staff, the task could be completed in three years.

The benefits of digitisation are that it allows detailed database interrogation to return, for instance, aggregate thicknesses of low hydraulic conductivity materials within a given area, or to provide isopachytes of a given unit. These benefits, however, mainly accrue when sufficient data are available within a given drift unit for meaningful interpolation to be carried out. In many rural areas borehole coverage is so sparse that meaningful interpolation between boreholes will not be possible.

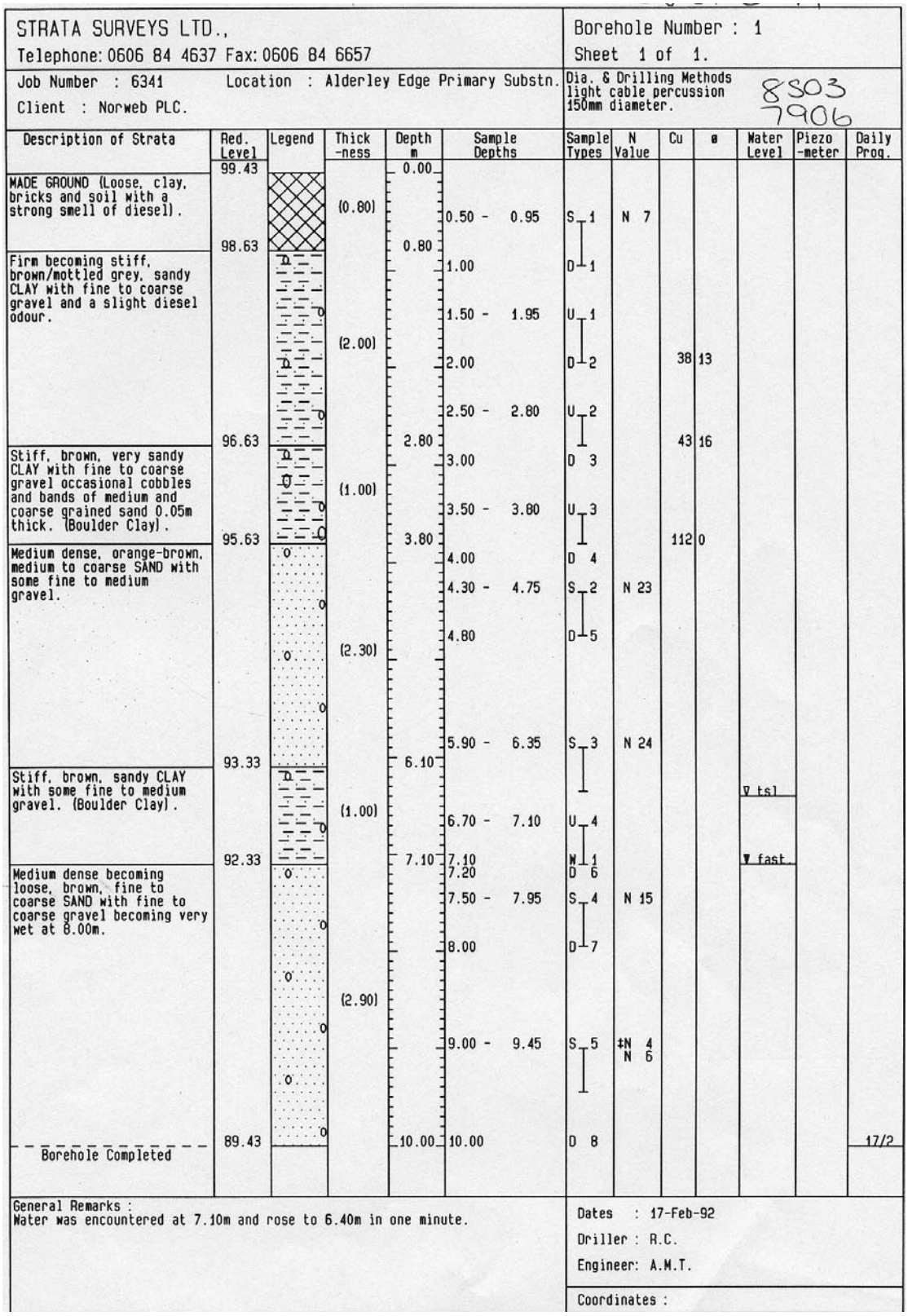
In these circumstances it may be as useful to provide end users with direct access to original records via access to scanned copies of borehole logs, coupled with access to existing digital maps of drift thickness. BGS have recently completed a programme of scanning all borehole records, and while these are at present only available within the BGS, there is no conceptual reason why external organisations, such as the Environment Agency, should not have access via an Extranet or VPN. BGS and the Agency should meet to establish what institutional and technical challenges need to be overcome to implement this facility.

Digitisation could then be limited to areas that are a) where drift overlies groundwater resources requiring protection and b) where data density justifies digitisation. An approach of this type might reduce digitisation costs by 10-20%, allowing for the fact that the total number of boreholes in rural areas is low, and that a substantial proportion of the region is underlain by aquifers.

Although WellMaster digitisation does not normally deliver detailed lithological description of drift deposits, the Wellmaster programme will be examining ways of delivering geological and hydrogeological data to end users within the Environment Agency, and may provide a mechanism for disseminating detailed drift data where it is available.

Although the scale of investment required for regional level drift digitisation, let alone national scale digitisation, is very large, the benefits of carrying out this work would be significant for a wide range of end users. BGS will formulate a proposal for national scale drift digitisation, and investigate potential sources of funding. To reduce the costs the possibility of off-shore contract digitisation will be investigated, given the availability of scanned versions of the original borehole records.

Plate 1 – Borehole log completed to British Standard



STRATA SURVEYS LTD.,
Telephone: 0606 84 4637 Fax: 0606 84 6657

Borehole Number : 1
Sheet 1 of 1.

Job Number : 6341
Client : Norweb PLC.

Location : Alderley Edge Primary Substn.

Dia. & Drilling Methods
light cable percussion
150mm diameter.

8503
7906

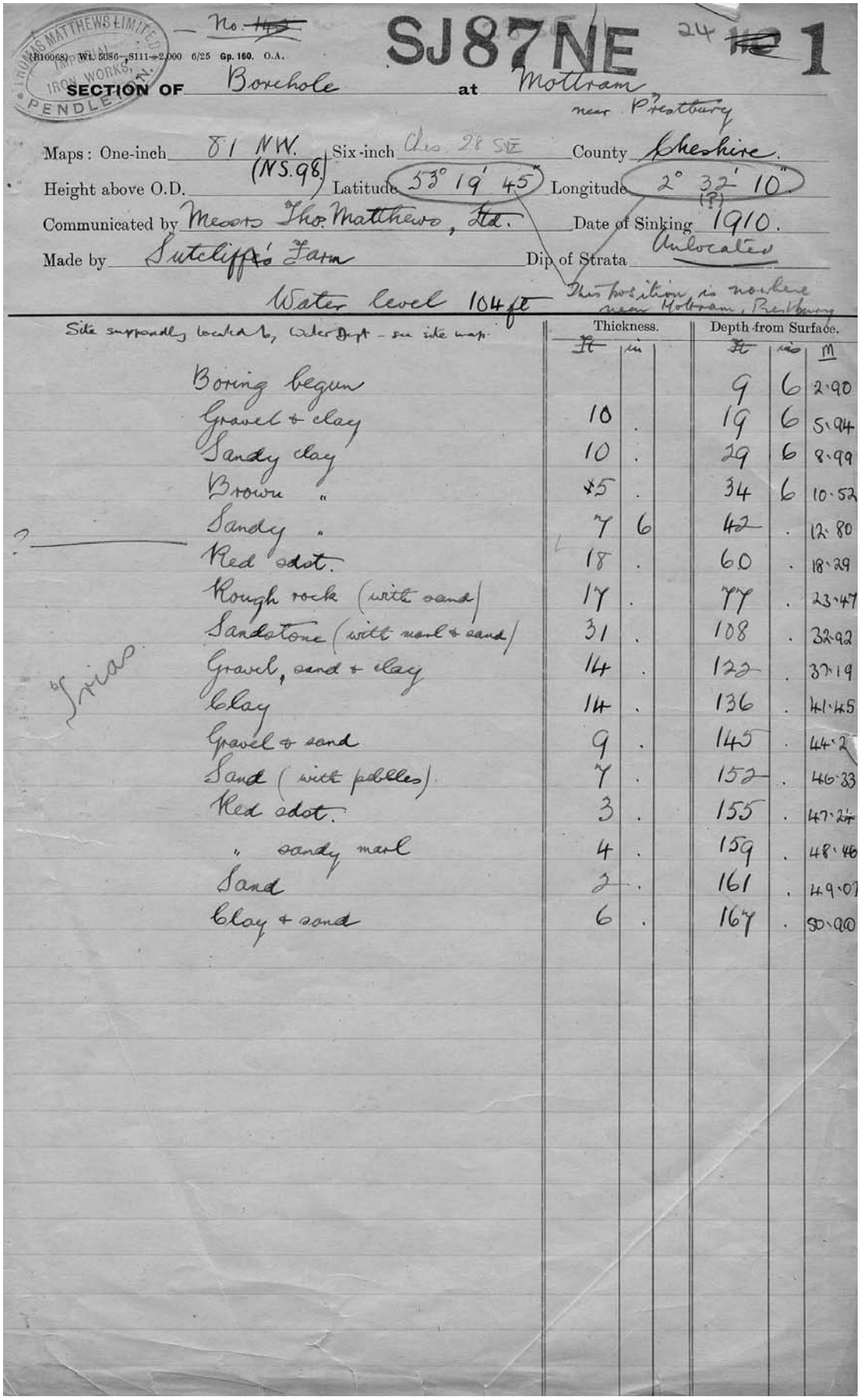
Description of Strata	Red. Level	Legend	Thick -ness	Depth m	Sample Depths	Sample Types	N Value	Cu	ø	Water Level	Piezo -meter	Daily Prog.
	99.43			0.00								
MADE GROUND (Loose, clay, bricks and soil with a strong smell of diesel).			(0.80)		0.50 - 0.95	S 1	N 7					
	98.63			0.80								
Firm becoming stiff, brown/mottled grey, sandy CLAY with fine to coarse gravel and a slight diesel odour.					1.00	D 1						
					1.50 - 1.95	U 1						
			(2.00)		2.00	D 2		38	13			
					2.50 - 2.80	U 2						
	96.63			2.80				43	16			
Stiff, brown, very sandy CLAY with fine to coarse gravel occasional cobbles and bands of medium and coarse grained sand 0.05m thick. (Boulder Clay).					3.00	D 3						
			(1.00)		3.50 - 3.80	U 3						
	95.63			3.80				112	0			
Medium dense, orange-brown, medium to coarse SAND with some fine to medium gravel.					4.00	D 4						
					4.30 - 4.75	S 2	N 23					
					4.80	D 5						
			(2.30)									
					5.90 - 6.35	S 3	N 24					
	93.33			6.10								
Stiff, brown, sandy CLAY with some fine to medium gravel. (Boulder Clay).										▽ tsl		
			(1.00)		6.70 - 7.10	U 4						
	92.33			7.10	7.10	W 1				▼ fast.		
Medium dense becoming loose, brown, fine to coarse SAND with fine to coarse gravel becoming very wet at 8.00m.					7.20	D 6						
					7.50 - 7.95	S 4	N 15					
					8.00	D 7						
			(2.90)									
					9.00 - 9.45	S 5	‡N 4 N 6					
	89.43			10.00	10.00	D 8						17/2
Borehole Completed												

General Remarks :
Water was encountered at 7.10m and rose to 6.40m in one minute.

Dates : 17-Feb-92
Driller : R.C.
Engineer: A.M.T.

Coordinates :

Plate 2 – Poor quality borehole log



No. ~~115~~ SJ87NE 24 ~~112~~ 1

(R10068) Wt. 5036—S111—2,000 6/25 Gp. 160. O.A.

THOMAS MATTHEWS LIMITED IRON WORKS, PENDLETON.

SECTION OF Borehole at Mottram near Prestbury

Maps: One-inch 81 NW. (NS.98) Six-inch Ches. 28 SE County Cheshire.

Height above O.D. Latitude 53° 19' 45" Longitude 2° 32' 10" (?)

Communicated by Messrs Tho. Matthews, Ltd. Date of Sinking 1910.

Made by Sutcliffe's Farm Dip of Strata Undulated

Water level 104 ft

This position is nowhere near Mottram, Prestbury

Site supposedly located by, Water Dept - see site map.

	Thickness. ft	in	Depth from Surface. ft	in	M
Boring begun			9	6	2·90
Gravel & clay	10	.	19	6	5·94
Sandy clay	10	.	29	6	8·99
Brown "	5	.	34	6	10·52
Sandy "	7	6	42	.	12·80
Red adat.	18	.	60	.	18·29
Rough rock (with sand)	17	.	77	.	23·47
Sandstone (with marl & sand)	31	.	108	.	32·92
Gravel, sand & clay	14	.	122	.	37·19
Clay	14	.	136	.	41·45
Gravel & sand	9	.	145	.	44·2
Sand (with pebbles)	7	.	152	.	46·33
Red adat.	3	.	155	.	47·24
" sandy marl	4	.	159	.	48·46
Sand	2	.	161	.	49·07
Clay & sand	6	.	167	.	50·90

Plate 3 – Good quality borehole log

2

SS 87 NE/3

(For Survey use only) Geological Classification	Nature of Strata. If measurements start below ground surface, state how far ..	Thickness Feet	Thickness Inches	Depth Feet	Depth Inches	Depth in metres
	Topsoil.	1	6	1	6	0.46
	Sandy Clay & Gravel.	1	0	2	6	0.76
	Mottled Clay with sand & Pebbles.	3	6	6	0	1.83
	Mottled Sandy Clay.	1	0	7	0	2.13
	Red Sand.	3	0	10	0	3.05
	Pebbly Clay.	4	6	14	6	4.42
	Large Gravel & coarse Sand.	1	2	15	8	4.78
	Clay & Gravel.	8	4	24	0	7.32
	Conglomerate.	3	6	27	6	8.38
	Sandy Clay.	2	6	30	0	9.14
	Conglomerate.	2	3	32	3	9.83
	Coarse Sand.	5	0	37	3	11.35
	Clay with some Gravel.	11	3	48	6	14.78
	Gravel boulders & Clay.	1	6	50	0	15.24
	Light Brown Sand.	11	10	61	10	18.85
Drift.	Clay & Gravel.	38	8	100	6	30.63
	Silty Sand & Gravel.	9	6	110	0	33.53
	Brown Clay & Pebbles.	24	0	134	0	40.84
	Small Gravel.	2	0	136	0	41.45
	Brown Clay.	19	3	155	3	47.32
	Brown Clay with Boulders.	8	9	164	0	49.99
	Conglomerate.	4	0	168	0	51.21
	Brown Clay.	1	0	169	0	51.51
	Hard packed Gravel.	13	2	182	2	55.53
	Clay & Gravel.	3	3	185	5	56.52
	Hard Packed Gravel.	11	9	197	2	60.10
	Sandy Silts.	16	10	214	0	65.23
	Sandy Clay.	4	0	218	0	66.45
	Silty Sand & Clay.	3	0	221	0	67.36
	Sandy Clay.	19	0	240	0	73.15
Upper Mottled Sandstone	Sandstone.	284	0	524	0	159.72
	Sandstone & Marl.	32	0	556	0	169.47
		556	0	556	0	

CEB 11/5/70

Plate 4 – Drift Coverage within Agency North West Region

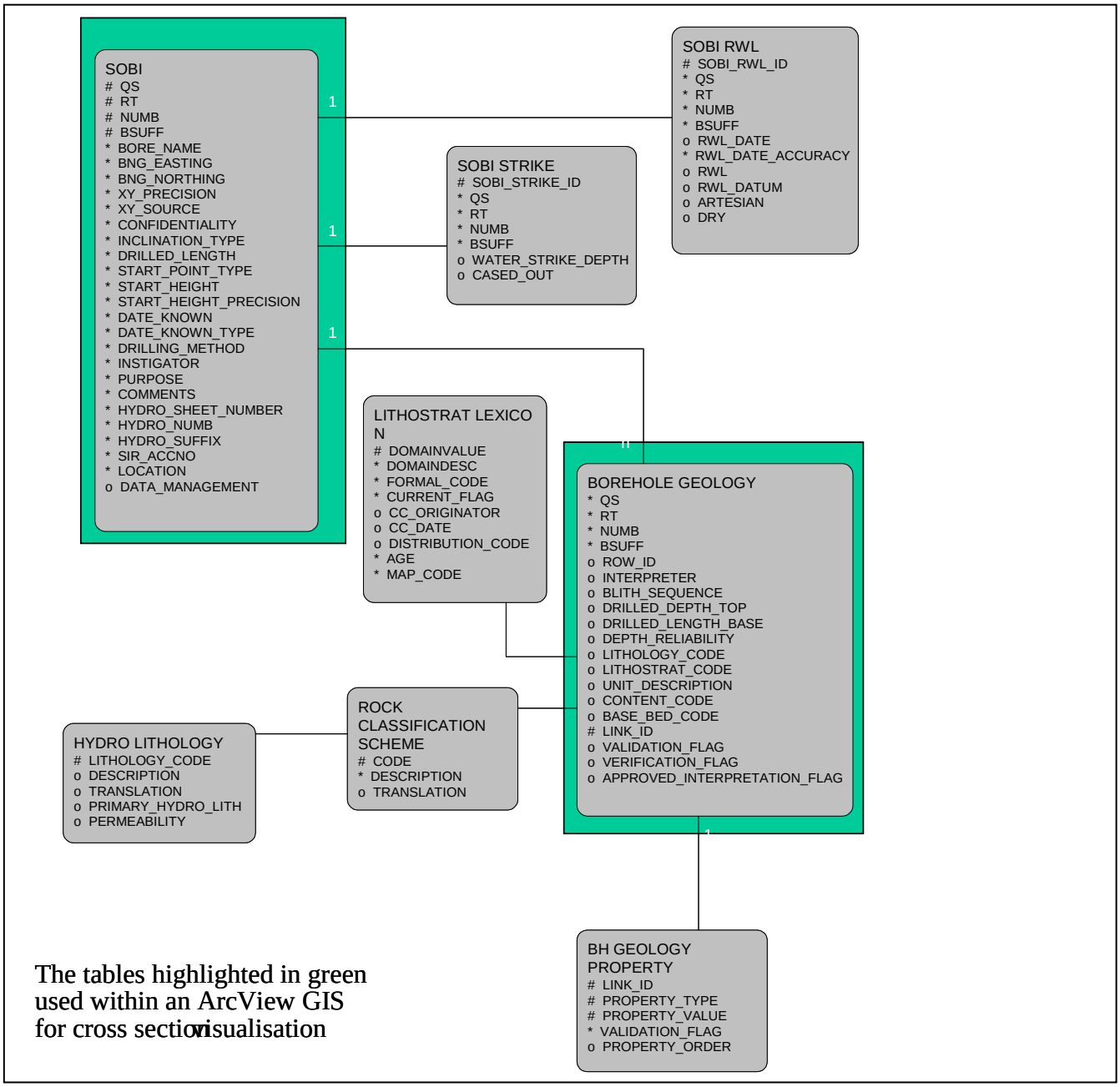
Plate 5 – Solid Geology of Pilot Study Area

Plate 6 – Drift Coverage within pilot study area

Plate 7 – Distribution of boreholes over Agency North West Region

Plate 8 – Distribution of boreholes over pilot study area

Appendix 1 Database structure



Appendix 3 Dictionary of Lithostratigraphic Codes used.

DOMAINVALUE	DOMAINDESC
ALV	ALLUVIUM
ARG	ARDWICK GROUP [OBSOLETE NAME AND CODE: SEE WAWK]
B3QC	BRADFORD THREEQUARTERS COAL [SOUTH LANCASHIRE]
BNP	BUNTER PEBBLE BEDS [OBSOLETE NAME AND CODE]
BR4FT	BRADFORD FOUR FOOT COAL [SOUTH LANCASHIRE]
BRK	BRICKEARTH
CAMB	CAMBRIENSE MARINE BAND
CHTC	CHARLOTTE COAL [SOUTH LANCASHIRE]
CM	COAL MEASURES GROUP
CPB	CHESTER PEBBLE BEDS FORMATION
CS	COLLYHURST SANDSTONE FORMATION
CSM	CALCIFEROUS SANDSTONE MEASURES [OBSOLETE NAME AND CODE: SEE SYG]
DELA	DELAMERE SANDSTONE MEMBER
DRFT	DRIFT [UNDIFFERENTIATED]
DRTL	DARTINGTON LIMESTONE MEMBER
DRTM	DARTMOUTH GROUP
FLUV	FLUVIAL DEPOSITS [UNDIFFERENTIATED]
FRM	FRODSHAM SANDSTONE MEMBER
GDH	GLACIAL DEPOSITS, HETEROGENEOUS
GDU	GLACIAL DEPOSITS [UNDIFFERENTIATED]
GFDU	GLACIOFLUVIAL DEPOSITS [UNDIFFERENTIATED]
GFSG	GLACIOFLUVIAL SAND AND GRAVEL
GLLD	GLACIOLACUSTRINE DEPOSITS [UNDIFFERENTIATED]
GSG	GLACIAL SAND AND GRAVEL
GSU	UPPER GWESPYR SANDSTONE [OBSOLETE NAME AND CODE]
HA	HALESOWEN FORMATION
HEY	HELSBY SANDSTONE FORMATION
KM	KEUPER MARL (OBSOLETE NAME AND CODE: SEE MMG)

DOMAINVALUE	DOMAINDESC
KS	KEUPER SANDSTONE [OBSOLETE NAME AND CODE]
KW	KEUPER WATERSTONES [OBSOLETE NAME AND CODE]
LCM	LOWER COAL MEASURES FORMATION
LKM	KEUPER MARL, LOWER (OBSOLETE NAME AND CODE: USE MMG)
LKS	LOWER KEUPER SANDSTONE [OBSOLETE NAME AND CODE]
MCM	MIDDLE COAL MEASURES FORMATION
MEAS	MARINE AND ESTUARINE ALLUVIUM, MAINLY SAND AND GRAVEL
MENO	MENEAGE OLISTOSTROME
MG	MILLSTONE GRIT GROUP [SEE ALSO MIGR]
MGR	MADE GROUND
MM	MANCHESTER MARLS FORMATION
MMG	MERCIA MUDSTONE GROUP
MMGD	MELTON MOWBRAY GRANODIORITE
MMPN	MERCIA MUDSTONE GROUP AND PENARTH GROUP [UNDIFFERENTIATED]
MMSL	MAESGWM SLATES
MRG	MOOR GRIT MEMBER
MRGF	BLUE LIAS FORMATION [MARGINAL FACIES]
MSG	MAGILLIGAN SANDSTONE GROUP [OBSOLETE NAME AND CODE]
NGRC	NORTH GRIMSTON CEMENTSTONE MEMBER
OPSC	OPENSHAW COAL [SOUTH LANCASHIRE]
PEAT	PEAT
RTD2	RIVER TERRACE DEPOSITS, 2
RTDU	RIVER TERRACE DEPOSITS [UNDIFFERENTIATED]
SDSG	SLEAFORD SAND AND GRAVEL
SGQ	SALTERELLA GRIT MEMBER
SGS	SHOTOVER GRIT SAND [OBSOLETE NAME AND CODE]
SLVC	SILVER COAL [NORTH STAFFORDSHIRE]
SOIL	SOIL
SSA	SHIRDLEY HILL SAND
SSDPC	CLYDE PLATEAU SUBSUITE [OF SSDPV]
SSG	SHERWOOD SANDSTONE GROUP
STPC	STOCKPORT CONGLOMERATE
SUMB	SUTTON MANOR MARINE BAND [LOCAL NAME: USE VDMB]
TILL	TILL
TILS	TIBBIE PAGAN'S LIMESTONE

DOMAINVALUE	DOMAINDESC
TPSF	TARPORLEY SILTSTONE FORMATION
UCM	UPPER COAL MEASURES FORMATION
UCMS	UPPER COAL MEASURES (SCOTLAND)
UMS	UPPER MOTTLED SANDSTONE [OBSOLETE NAME AND CODE]
UNKN	UNKNOWN STRATIGRAPHY OF ANY AGE [FOR USE IN BOREHOLE LOGS ONLY]
UNKND	DRIFT GEOLOGY NOT MAPPED [FOR DIGITAL MAP USE ONLY]
W4FT	WORSLEY FOUR FOOT COAL [SOUTH LANCASHIRE]
WARP	WARP
WAWK	WARWICKSHIRE GROUP
WH	WOODHEAD HILL ROCK
WLSF	WILMSLOW SANDSTONE FORMATION
YCSL	YARD COAL [SOUTH LANCASHIRE]

Appendix 4 Dictionary of Rock Classification Codes

CODE	DESCRIPTION
AEOLTE	AEOLIANITE (WHERE CEMENTED)
ARTDP	ARTIFICIAL DEPOSIT (UNDIFFERENTIATED)
BREC	BRECCIA
CALSST	SANDSTONE, CALCAREOUS
CAMDST	MUDSTONE, CALCAREOUS
CASST	SANDSTONE, CARBONACEOUS, ARGILLACEOUS
CLAY	CLAY (UNDIFFERENTIATED)
CLGV	GRAVEL, CLAYEY
CLMST	CALCITE-MUDSTONE
CLSA	SAND, CLAYEY
CLSGV	GRAVEL, SANDY, CLAYEY
COAL	COAL
COBLE	COBBLE (GRAVEL)
CSSST	SILCATE-SANDSTONE, COARSE
CSST	SANDSTONE, CARBONACEOUS
DMTN	DIAMICTON
DRFT	COMPOSITE OF SEVERAL DRIFT LITHOLOGIES (OBSOLETE CODE)
DRFTU	UNDIFFERENTIATED SUPERFICIAL DEPOSITS (NATURAL AND/OR ARTIFICIAL)
FCMST	MUDSTONE, FRIABLE, CALCAREOUS
FILLU	FILL (UNDIFFERENTIATED)
GRAV	GRAVEL (UNDIFFERENTIATED)
GSST	SANDSTONE, GRITTY
GVSNDU	SAND, GRAVELLY (UNDIFFERENTIATED)
LMST	LIMESTONE
MCASST	SANDSTONE, MICACEOUS
MDAT	METADACITE (TAS)
MDSST	SANDSTONE,MUDDY
MDST	MUDSTONE (UNDIFFERENTIATED)
MIMDST	MUDSTONE, MICACEOUS
NCSLTR	NON-CARBONATE SALT-ROCK
NOCO	NO CORE RECOVERED
PEAT	PEAT

CODE	DESCRIPTION
PECL	CLAY, PEBBLY
PEL	PELITE
PESST	SANDSTONE, PEBBLY
ROCK	ROCK (UNDIFFERENTIATED)
SACL	CLAY, SANDY
SAGR	SAND AND GRAVEL
SAMDST	MUDSTONE, SANDY
SANDU	SAND(UNDIFFERENTIATED)
SDST	SANDSTONE (UNDIFFERENTIATED)
SICL	CLAY, SILTY
SICLY	SILICATE-CLAY
SICOG	SILICATE-CONGLOMERATE
SIGV	SILICATE-GRAVEL
SILT	SILT (UNDIFFERENTIATED)
SIMST	SILICATE-MUDSTONE
SISND	SAND, SILTY
SISST	SILICATE-SANDSTONE
SIST	SILICATE-SAND
SLMDST	MUDSTONE, SILTY (UNDIFFERENTIATED)
SLSST	SANDSTONE, SILTY (UNDIFFERENTIATED)
SLST	SILTSTONE (UNDIFFERENTIATED)
SND	SAND (MARINE SEDIMENT)
SOIL	SOIL
SR	SEDIMENTARY ROCK (UNDIFFERENTIATED)
UKNOWN	UNKNOWN/UNCLASSIFIED ENTRY
VOID	VOID
WOODU	WOOD (UNDIFFERENTIATED)
B	BOULDERS (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
BVL	GRAVELLY COBBLY BOULDERS (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
C	CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CB	BOULDERY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CP	PEATY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CS	SANDY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CSB	SANDY BOULDERY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)

CODE	DESCRIPTION
CSL	SANDY COBBLY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CSV	SANDY GRAVELLY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CSVB	SANDY GRAVELLY BOULDERY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CV	GRAVELLY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CZ	SILTY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CZB	SILTY BOULDERY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CZL	SILTY COBBLY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CZP	SILTY PEATY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CZS	SILTY SANDY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CZSB	SILTY SANDY BOULDERY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CZSL	SILTY SANDY COBBLY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CZSP	SILTY SANDY PEATY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CZSV	SILTY SANDY GRAVELLY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CZSVLB	SILTY SANDY GRAVELLY COBBLY BOULDERY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
CZV	SILTY GRAVELLY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
L	COBBLES (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
LB	COBBLES AND BOULDERS (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
LS	SANDY COBBLES (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
P	PEAT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
PC	CLAYEY PEAT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
PCS	CLAYEY SANDY PEAT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
PCZ	CLAYEY SILTY PEAT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
PS	SANDY PEAT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
PZ	SILTY PEAT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
S	SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
SB	BOULDERY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
SBP	BOULDERY PEATY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
SC	CLAYEY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
SCP	CLAYEY PEATY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
SCV	CLAYEY GRAVELLY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
SCVL	CLAYEY GRAVELLY COBBLY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)

CODE	DESCRIPTION
SCZ	CLAYEY SILTY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
SCZV	CLAYEY SILTY GRAVELLY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
SL	COBBLY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
SP	PEATY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
SV	GRAVELLY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
SVB	GRAVELLY BOULDERY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
SVL	GRAVELLY COBBLY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
SZ	SILTY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
SZP	SILTY PEATY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
SZV	SILTY GRAVELLY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
V	GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
VB	BOULDERY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
VC	CLAYEY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
VCL	CLAYEY COBBLY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
VCS	CLAYEY SANDY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
VCZ	CLAYEY SILTY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
VCZS	CLAYEY SILTY SANDY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
VCZSB	CLAYEY SILTY SANDY BOULDERY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
VL	COBBLY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
VS	SANDY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
VSB	SANDY BOULDERY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
VSL	SANDY COBBLY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
VZ	SILTY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
VZS	SILTY SANDY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
Z	SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
ZC	CLAYEY SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
ZCB	CLAYEY BOULDERY SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
ZCS	CLAYEY SANDY SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
ZCSV	CLAYEY SANDY GRAVELLY SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
ZP	PEATY SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
ZS	SANDY SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)

CODE	DESCRIPTION
ZSV	SANDY GRAVELLY SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)
ZV	GRAVELLY SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)

Appendix 5 Coding guidance notes

To assist data entry staff a set of coding guidance was formulated for the project. An edited version of this guidance is reproduced below.

LITHOLOGY CODE – DRIFT GEOLOGY

The BGS Rock Classification Scheme (RCS) code is limited to 6 characters, but fortunately there are 6 end members to the lithologies of the majority of "granular" deposits as described in geology and engineering geology. These are clay, silt, sand, gravel, cobbles and boulders (using BS5930, not the Wentworth sedimentology scheme). Z is commonly used to signify silt. We can designate each of these lithologies with one character and use combinations of characters to describe more complex mixed lithologies. The abbreviations used are:

CLAY: C, SILT: Z, SAND: S, GRAVEL: V*, COBBLE: L, BOULDER: B

(* V is suggested for gravel because G is extensively used in the RCS for other rocks, including Gabbro, and many of the code combinations generated by the proposed scheme would clash. V has no conflicts)

For ease of use in databases and for searching in is recommended that the dominant lithology (the one that is in capitals in engineering logs) is listed *first* in the code. This practice follows that used for the BGS engineering geology database. The subordinate lithologies are then listed in decreasing order, i.e.:

UNIT	CODE
SAND	S
Clayey SAND	SC
Silty SAND	SZ
Gravely SAND	SV
Cobbly SAND	SL
Bouldery SAND	SB
Clayey silty SAND	SCZ
Clayey gravely SAND	SCV
Silty gravely SAND	SZG
Clayey, silty, gravely, cobbly, bouldery, SAND	SCZVLB
And so on	

This scheme allows all the combinations of lithology currently used in the AGS listings of Howland Associates, plus the BS5930 attributes to be coded. However, it does not separate the very sandy from the slightly sandy or the very clayey from the slightly clayey as used in BS5930

Note: peat is covered by this scheme, as although it is not a grainsize, it is an important lithology within many British drift deposits.

The codes to be used are tabulated in Appendix 3 above.

NOTE ON MADE GROUND

Made Ground can be defined as 'ground that has been deposited under the influence of man'. It includes embankments, backfilled quarries, landfill, coastal reclamation zones, and areas levelled prior to development. Made Ground has an extremely variable composition. As there is currently no BGS classification scheme set up for the classification of Made Ground, all artificial ground is coded 'FILLU' (undifferentiated fill').

MINIMUM BED THICKNESS

The minimum bed thickness coded for the pilot project is 0.3 m, or 1 foot. For beds thinner than this, the thickness should be added to the next bed down the borehole. Soil, no matter what its thickness is not coded. The bed beneath is extended upwards to cover the volume taken up by the soil. If the bed beneath is less than 0.3m thick, but the combined thickness of soil and first bed is 0.3m or more, this bed is coded.

OUT OF DATE TERMINOLOGIES

Much of the original archive borehole data held by BGS uses terms that are now out-of-date. Although the term is out-of-date, the information described by the record is still valuable, and was translated into modern terms. Some of the most common out-of-date terms and their translations are given:

Old term	New term	Lithology code
Marl	Calcareous mudstone	CAMDST
Pebbly	Gravelly	V (Gravel)
Conglomerate	Sandy gravel	VS
Loam	Silty Clay	CZ
Ballast	Gravel	V
Earth	Variety of meanings- can mean Soil General rock/strata	 Include with first deposit beneath 'Earth' if less than 0.3 m/1 ft thick Code as 'UNKN'
Drift described in terms such as 'sandstone'; 'shale'	Translate into grainsize, e.g., sand; clay	

DIFFICULT TERMINOLOGIES

Term	Note	Lithology Code
Drift deposits are undivided on log		DRIFTU (Undifferentiated drift)
Alluvium		DRFTU_ALV (lithology_lithostrat)
Boulder Clay; Till		DMTN (Diamicton)
Glacial Deposits		GDU (Glacial Deposits undifferentiated)
Sandy and clayey gravel	Add subordinate lithology in PROPERTY TYPE: LITH2 field	
Clayey sand and gravel	"	
Sand, gravel and clay	(use LITH3 field as needed)	
Sand with clay	"	
Veins	"	
Pockets	"	
Traces	"	
Patches	"	
Inclusions	"	
Layers	"	
Fragments	"	
Boulders at 39 feet	Add as free text in UNIT DESCRIPTION	
No record (within drift)		UKNOWN_UNKND
Void, e.g., sewer, tunnel (within drift)		VOID_UNKND
Slightly; very; mostly; rare; occasional	These terms are not handled well in the current classification system	Try to translate as best as possible

Note: where no drift is present in the borehole,

0.0 in depth top

0.0 in depth base

UKNOWN in lithology code

RH in BaseBed

LITHOLOGY CODE: SOLID GEOLOGY

The first solid geology beneath rockhead was recorded, e.g., 'SDST' (Sandstone), with the stratigraphy where known, e.g., 'SSG' (Sherwood Sandstone Group). Lithology of 'MEAS' is useful in Coal Measures areas.

Name	Old Name(s)	Abbreviations on records	Lithostrat code used
Collyhurst Sandstone Formation	Lower Mottled Sandstone; soft sandstone	CS; LMS; SSG	CS
Chester Pebble Beds Formation	Bunter Pebble Beds; Bunter Sandstone	BS; CPB; SSG	CPB
Wilmslow Sandstone Formation	Upper Mottled Sandstone	UMS; WLS; SSG	WLSF
Helsby Sandstone Formation	Lower Keuper Sandstone	LKS; HEY; SSG	HEY
Sherwood Sandstone Group	Bunter		SSG
Tarporley Siltstone Formation	Waterstones; Passage Beds		TPS
Mercia Mudstone Group	Keuper Marl; Mudstone Division	KM	MM
Coal Measures	Measures; Lower, Middle or Upper Coal Measures	LCM; MCM; UCM	CM

LITHOSTRATIGRAPHY CODE

This field is populated where the data entry officer is confident about the lithostratigraphy of the deposit described in the log (note: this has sometimes already been interpreted by a geologist, or is on the log already). These codes cover >90% of the deposits encountered in the pilot area:

Deposit	Code
Till	TILL
River Terrace Deposits, undifferentiated	RTDU
First River Terrace Deposits	RTD1
Second River Terrace Deposits	RTD2
Alluvium	ALV
Glacial Sand and Gravel Undifferentiated	GSG
Glacial Sand and Gravel with a sheet like form (eg, outwash, sandir)	GFSD
Glaciolacustrine clay (includes laminated clay)	GLLD
Glacial Deposits (Undifferentiated)	GDU
Drift Deposite (Undifferentiated)- includes glacial and post-glacial deposits)	DRFT

OTHER CODES

Unit Description: Used for comments that do not fit in other fields- kept to a minimum.

BBED field: record rockheads for all boreholes, where present (‘**RH**’ in **BBED** field).

If the final record entered is the base of the borehole, add **BBED** as **TD** (Terminal Depth)

DEPTHTOP, DEPTHBASE: all depths are entered as metric depths.

CONTCODE: records how the data input reflects the original data on the paper log.

F: Full- all data on paper log is in database

L: Limited- data is interpreted from original, or some data is missing (eg, units less than 0.3 m/1 ft, or solid units)

X: default code- unsure if data is F or L

PROPERTY_TYPE- records additional non lithological properties of the strata.

Water strikes: If one or many water strikes are recorded, WTR_ST with a value WS. Water strikes are located to the bed in which they were encountered. If a water strike occurs below the first consolidated bed it is not recorded in the database.

Grainsize: grainsize data is generally ignored (eg, *medium* grained sandstone).

Sedimentary structures: ignored **except laminated clay**. If in Glaciolacustrine Deposits, recorded as Lithology: GLLD (Glaciolacustrine Deposits). If not in Glaciolacustrine Deposits, recorded in the UNIT DESCRIPTION field as free text.

Colour: recorded in BGSCOL; keep as simple as possible.

***Additional data**: if there appears to be additional data regarding hydrogeology, engineering properties or geochemical data, record as a tick in the ‘Extra data available’ box.

Appendix 6 Drift Characteristics Dictionary + Hydraulic Conductivity

LITHOLOGY CODE	DESCRIPTION	TRANSLATION BS5930	DESCRIPTION BS5930	Hyd. Cond.
NOCO	NO CORE RECOVERED	NOCO	NO CORE RECOVERED	
UKNOWN	UNKNOWN/UNCLASSIFIED ENTRY	UKNOWN	UNKNOWN/UNCLASSIFIED ENTRY	
VOID	VOID	VOID	VOID	VHIGH
AEOLTE	AEOLIANITE (WHERE CEMENTED)	AEOLTE	AEOLIANITE (WHERE CEMENTED)	
BREC	BRECCIA	BREC	BRECCIA	
CALSST	SANDSTONE, CALCAREOUS	CALSST	CALCAREOUS SANDSTONE	
CAMDST	MUDSTONE, CALCAREOUS	CAMDST	CALCAREOUS MUDSTONE	
CASST	SANDSTONE, CARBONACEOUS, ARGILLACEOUS	CASST	CARBONACEOUS, ARGILLACEOUS SANDSTONE	
CLMST	CALCITE-MUDSTONE	CLMST	CALCITE-MUDSTONE	
COAL	COAL	COAL	COAL	
CSSST	SILCATE-SANDSTONE, COARSE	CSSST	COARSE, SILICATE-SANDSTONE	
CSST	SANDSTONE, CARBONACEOUS	CSST	CARBONACEOUS SANDSTONE	
FCMST	MUDSTONE, FRIABLE, CALCAREOUS	FCMST	FRIABLE, CALCAREOUS MUDSTONE	
GSST	SANDSTONE, GRITTY	GSST	GRITTY SANDSTONE	
LMST	LIMESTONE	LMST	LIMESTONE	
MCASST	SANDSTONE, MICACEOUS	MCASST	MICACEOUS SANDSTONE	
MDAT	METADACITE (TAS)	MDAT	METADACITE (TAS)	
MDSST	SANDSTONE,MUDDY	MDSST	MUDDY SANDSTONE	
MDST	MUDSTONE (UNDIFFERENTIATED)	MDST	MUDSTONE (UNDIFFERENTIATED)	
MIMDST	MUDSTONE, MICACEOUS	MIMDST	MICACEOUS MUDSTONE	
NCSLTR	NON-CARBONATE SALT-ROCK	NCSLTR	NON-CARBONATE SALT-ROCK	
PEL	PELITE	PEL	PELITE	
PESST	SANDSTONE, PEBBLY	PESST	PEBBLY SANDSTONE	
ROCK	ROCK (UNDIFFERENTIATED)	ROCK	ROCK (UNDIFFERENTIATED)	
SAMDST	MUDSTONE, SANDY	SAMDST	SANDY MUDSTONE	
SDST	SANDSTONE (UNDIFFERENTIATED)	SDST	SANDSTONE (UNDIFFERENTIATED)	
SICOG	SILICATE-CONGLOMERATE	SICOG	SILICATE-CONGLOMERATE	
SIMST	SILICATE-MUDSTONE	SIMST	SILICATE-MUDSTONE	
SISST	SILICATE-SANDSTONE	SISST	SILICATE-SANDSTONE	
SLMDST	MUDSTONE, SILTY (UNDIFFERENTIATED)	SLMDST	SILTY MUDSTONE (UNDIFFERENTIATED)	
SLSST	SANDSTONE, SILTY (UNDIFFERENTIATED)	SLSST	SILTY SANDSTONE (UNDIFFERENTIATED)	
SLST	SILTSTONE (UNDIFFERENTIATED)	SLST	SILTSTONE (UNDIFFERENTIATED)	
SR	SEDIMENTARY ROCK (UNDIFFERENTIATED)	SR	SEDIMENTARY ROCK (UNDIFFERENTIATED)	

ARTDP	ARTIFICIAL DEPOSIT (UNDIFFERENTIATED)	FILLU	FILL (UNDIFFERENTIATED)	HIGH
B	BOULDERS (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	B	BOULDERS	VHIGH
BVL	GRAVELLY COBBLY BOULDERS (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	BVL	Gravelly cobbly BOULDERS	VHIGH
C	CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	C	CLAY	VLOW
CB	BOULDERY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CB	Bouldery CLAY	LOW
CLAY	CLAY (UNDIFFERENTIATED)	C	CLAY	VLOW
CLGV	GRAVEL, CLAYEY	VC	Clayey GRAVEL	LOW
CLSA	SAND, CLAYEY	SC	Clayey SAND	LOW
CLSGV	GRAVEL, SANDY, CLAYEY	VCS	Clayey sandy GRAVEL	LOW
COBLE	COBBLE (GRAVEL)	V	GRAVEL	VHIGH
CP	PEATY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CP	Peaty CLAY	LOW
CS	SANDY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CS	Sandy CLAY	LOW
CSB	SANDY BOULDERY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CSB	Sandy bouldery CLAY	LOW
CSL	SANDY COBBLY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CSL	Sandy cobbly CLAY	LOW
CSV	SANDY GRAVELLY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CSV	Sandy gravelly CLAY	LOW
CSVB	SANDY GRAVELLY BOULDERY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CSVB	Sandy gravelly bouldery CLAY	LOW
CV	GRAVELLY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CV	Gravelly CLAY	LOW
CZ	SILTY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CZ	Silty CLAY	LOW
CZB	SILTY BOULDERY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CZB	Silty bouldery CLAY	LOW

CZL	SILTY COBBLY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CZL	Silty cobbly CLAY	LOW
CZP	SILTY PEATY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CZP	Silty peaty CLAY	LOW
CZS	SILTY SANDY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CZS	Silty sandy CLAY	LOW
CZSB	SILTY SANDY BOULDERY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CZSB	Silty sandy bouldery CLAY	LOW
CZSL	SILTY SANDY COBBLY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CZSL	Silty sandy cobbly CLAY	LOW
CZSP	SILTY SANDY PEATY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CZSP	Silty sandy peaty CLAY	LOW
CZSV	SILTY SANDY GRAVELLY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CZSV	Silty sandy gravelly CLAY	LOW
CZSVLB	SILTY SANDY GRAVELLY COBBLY BOULDERY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CZSVLB	Silty sandy gravelly cobbly bouldery CLAY	MODERATE
CZV	SILTY GRAVELLY CLAY (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	CZV	Silty gravelly CLAY	LOW
DRFT	COMPOSITE OF SEVERAL DRIFT LITHOLOGIES (OBSOLETE CODE)	DRFTU	UNDIFFERENTIATED SUPERFICIAL DEPOSITS (NATURAL AND/OR ARTIFICIAL)	HIGH
DRFTU	UNDIFFERENTIATED SUPERFICIAL DEPOSITS (NATURAL AND/OR ARTIFICIAL)	DRFTU	UNDIFFERENTIATED SUPERFICIAL DEPOSITS (NATURAL AND/OR ARTIFICIAL)	HIGH
FILLU	FILL (UNDIFFERENTIATED)	FILLU	FILL (UNDIFFERENTIATED)	HIGH
GRAV	GRAVEL (UNDIFFERENTIATED)	V	GRAVEL	VHIGH
GVSNDU	SAND, GRAVELLY (UNDIFFERENTIATED)	SV	Gravelly SAND	VHIGH
L	COBBLES (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	L	COBBLES	VHIGH
LB	COBBLES AND BOULDERS (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	LB	COBBLES and BOULDERS	VHIGH
LS	SANDY COBBLES (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	LS	Sandy COBBLES	VHIGH

P	PEAT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	P	PEAT	LOW
PC	CLAYEY PEAT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	PC	Clayey PEAT	LOW
PCS	CLAYEY SANDY PEAT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	PCS	Clayey sandy PEAT	LOW
PCZ	CLAYEY SILTY PEAT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	PCZ	Clayey silty PEAT	LOW
PEAT	PEAT	P	PEAT	LOW
PECL	CLAY, PEBBLY	CV	Gravelly CLAY	LOW
PS	SANDY PEAT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	PS	Sandy PEAT	MODERATE
PZ	SILTY PEAT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	PZ	Silty PEAT	MODERATE
S	SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	S	SAND	HIGH
SACL	CLAY, SANDY	CS	Sandy CLAY	LOW
SAGR	SAND AND GRAVEL	SV	Gravelly SAND	VHIGH
SANDU	SAND(UNDIFFERENTIATED)	S	SAND	HIGH
SB	BOULDERY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	SB	Bouldery SAND	VHIGH
SBP	BOULDERY PEATY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	SBP	Bouldery peaty SAND	HIGH
SC	CLAYEY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	SC	Clayey SAND	LOW
SCP	CLAYEY PEATY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	SCP	Clayey peaty SAND	LOW
SCV	CLAYEY GRAVELLY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	SCV	Clayey gravelly SAND	LOW
SCVL	CLAYEY GRAVELLY COBBLY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	SCVL	Clayey gravelly cobbly SAND	LOW
SCZ	CLAYEY SILTY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	SCZ	Clayey silty SAND	LOW

SCZV	CLAYEY SILTY GRAVELLY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	SCZV	Clayey silty gravelly SAND	LOW
SICL	CLAY, SILTY	CZ	Silty CLAY	LOW
SICLY	SILICATE-CLAY	C	CLAY	VLOW
SIGV	SILICATE-GRAVEL	V	GRAVEL	VHIGH
SILT	SILT (UNDIFFERENTIATED)	Z	SILT	MODERATE
SISND	SAND, SILTY	SZ	Silty SAND	MODERATE
SIST	SILICATE-SAND	S	SAND	HIGH
SL	COBBLY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	SL	Cobbly SAND	VHIGH
SND	SAND (MARINE SEDIMENT)	S	SAND	HIGH
SP	PEATY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	SP	Peaty SAND	HIGH
SV	GRAVELLY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	SV	Gravelly SAND	VHIGH
SVB	GRAVELLY BOULDERY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	SVB	Gravelly bouldery SAND	VHIGH
SVL	GRAVELLY COBBLY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	SVL	Gravelly cobbly SAND	VHIGH
SZ	SILTY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	SZ	Silty SAND	MODERATE
SZP	SILTY PEATY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	SZP	Silty peaty SAND	MODERATE
SZV	SILTY GRAVELLY SAND (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	SZV	Silty gravelly SAND	MODERATE
V	GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	V	GRAVEL	VHIGH
VB	BOULDERY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	VB	Bouldery GRAVEL	VHIGH
VC	CLAYEY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	VC	Clayey GRAVEL	LOW
VCL	CLAYEY COBBLY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	VCL	Clayey cobbly GRAVEL	LOW

VCS	CLAYEY SANDY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	VCS	Clayey sandy GRAVEL	LOW
VCZ	CLAYEY SILTY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	VCZ	Clayey silty GRAVEL	LOW
VCZS	CLAYEY SILTY SANDY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	VCZS	Clayey silty sandy GRAVEL	LOW
VCZSB	CLAYEY SILTY SANDY BOULDERY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	VCZSB	Clayey silty sandy bouldery GRAVEL	LOW
VL	COBBLY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	VL	Cobbly GRAVEL	VHIGH
VS	SANDY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	VS	Sandy GRAVEL	VHIGH
VSB	SANDY BOULDERY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	VSB	Sandy bouldery GRAVEL	VHIGH
VSL	SANDY COBBLY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	VSL	Sandy cobbly GRAVEL	VHIGH
VZ	SILTY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	VZ	Silty GRAVEL	MODERATE
VZS	SILTY SANDY GRAVEL (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	VZS	Silty sandy GRAVEL	MODERATE
WOODU	WOOD (UNDIFFERENTIATED)	FILLU	FILL (UNDIFFERENTIATED)	HIGH
Z	SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	Z	SILT	MODERATE
ZC	CLAYEY SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	ZC	Clayey SILT	LOW
ZCB	CLAYEY BOULDERY SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	ZCB	Clayey bouldery SILT	MODERATE
ZCS	CLAYEY SANDY SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	ZCS	Clayey sandy SILT	LOW

ZCSV	CLAYEY SANDY GRAVELLY SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	ZCSV	Clayey sandy gravelly SILT	LOW
ZP	PEATY SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	ZP	Peaty SILT	MODERATE
ZS	SANDY SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	ZS	Sandy SILT	MODERATE
ZSV	SANDY GRAVELLY SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	ZSV	Sandy gravelly SILT	MODERATE
ZV	GRAVELLY SILT (UNCONSOLIDATED DEPOSITS CLASSIFICATION SCHEME)	ZV	Gravelly SILT	MODERATE

Appendix 7 Example output

WELLMASTER INDEX REPORT

INFORMATION MANAGEMENT PROGRAMME

DRIFT CHARCTERISATION SEARCH RESULTS

Wells and boreholes between NGR 370039,396138 and 372331,397953

Sheet No. *SJ79N*

QS	BNum	BSuff	Location	Grid Reference		Depth	Rock head?	Data Available G	E	W	Ch
SJ79NW	8	.	A1/9 MANOR FARM	372121	397572	1104.42	✓	✓		×	
SJ79NW	9	.	ASTLEY STATION	370403	397228	154.23	✓	✓		×	
SJ79NW	10	.	A1/8 ASTLEY STATION	370290	397259	1054.00	✓	✓		×	
SJ79NW	73	.	CUTNOOK	371810	396285	1568.00	✓	✓		×	
SJ79NW	137	.	ASTLEY STATION	370800	397270			×		×	

Number of sites = 5
Sites digitised = 5

24 September 2002 G = Geology, E = GeoTechnical, W = Water, Ch = Chemistry Page 14 of 14

WELLMASTER ROCKHEAD SUMMARY

INFORMATION MANAGEMENT PROGRAMME

WELLMASTER ROCKHEAD SUMMARY

Wells and boreholes between NGR 388018,384737 and 390710,386756

QS	BNum	BSuff	Location	Grid Reference		Rock Head (mbgl)	Rock Head (maod)
SJ88NE	204	.	20 MANOR ROAD BRAMHALL	388250	385750	>60	<14.4
SJ88NE	262	.	BRAMHALL BRIDGE BH6	389447	386401	12.4	45.86
SJ88NE	264	.	BRAMHALL BRIDGE BH8	389400	386410	12	46.12
SJ98NW	63	.	REDDISH WOOD NURSERIES	390370	385420	25.9	58.7
SJ98NW	194	.	STOCKPORT RUFC HEADLANDS ROAD 1	390000	386000	>8	<63.3

NB Borehole starting evelations have been derived from a DEM , and may not accurately represent the ground surface at time of drilling

WELLMASTER GEOLOGICAL SUMMARY

INFORMATION MANAGEMENT PROGRAMME

WELLMASTER
GEOLOGICAL SUMMARY

Boreholes in Quarter Sheet(s)
SJ79NW

From (m)	To (m)	Rock type	Lithostratigraphy	Description
SJ79NW 1	.	ASTLEY GREEN 1 PIT	370465 399920	
0	0.91	CLAY	TILL	
0.91	2.59	Gravelly CLAY	TILL	
2.59	6.17	CLAY	TILL	
6.17	7.01	Gravelly CLAY	TILL	
7.01	10.9	CLAY	TILL	WITH SANDY BEDS
10.9	16.46	Clayey silty gravelly SAND	GLACIAL DEPOSITS [UNDIFFERENTIATED]	
16.46	24.99	Sandy gravelly CLAY	TILL	
24.99	28.65	Clayey silty gravelly SAND	TILL	
28.65	30.28	Sandy gravelly CLAY	TILL	
30.28	33.98	MUDSTONE (UNDIFFERENTIATED)	MANCHESTER MARLS FORMATION	

Borehole penetrated drift sequence

WELLMASTER HYDRAULIC PROPERTIES SUMMARY

INFORMATION MANAGEMENT PROGRAMME

WELLMASTER
HYDRAULIC PROPERTIES SUMMARY

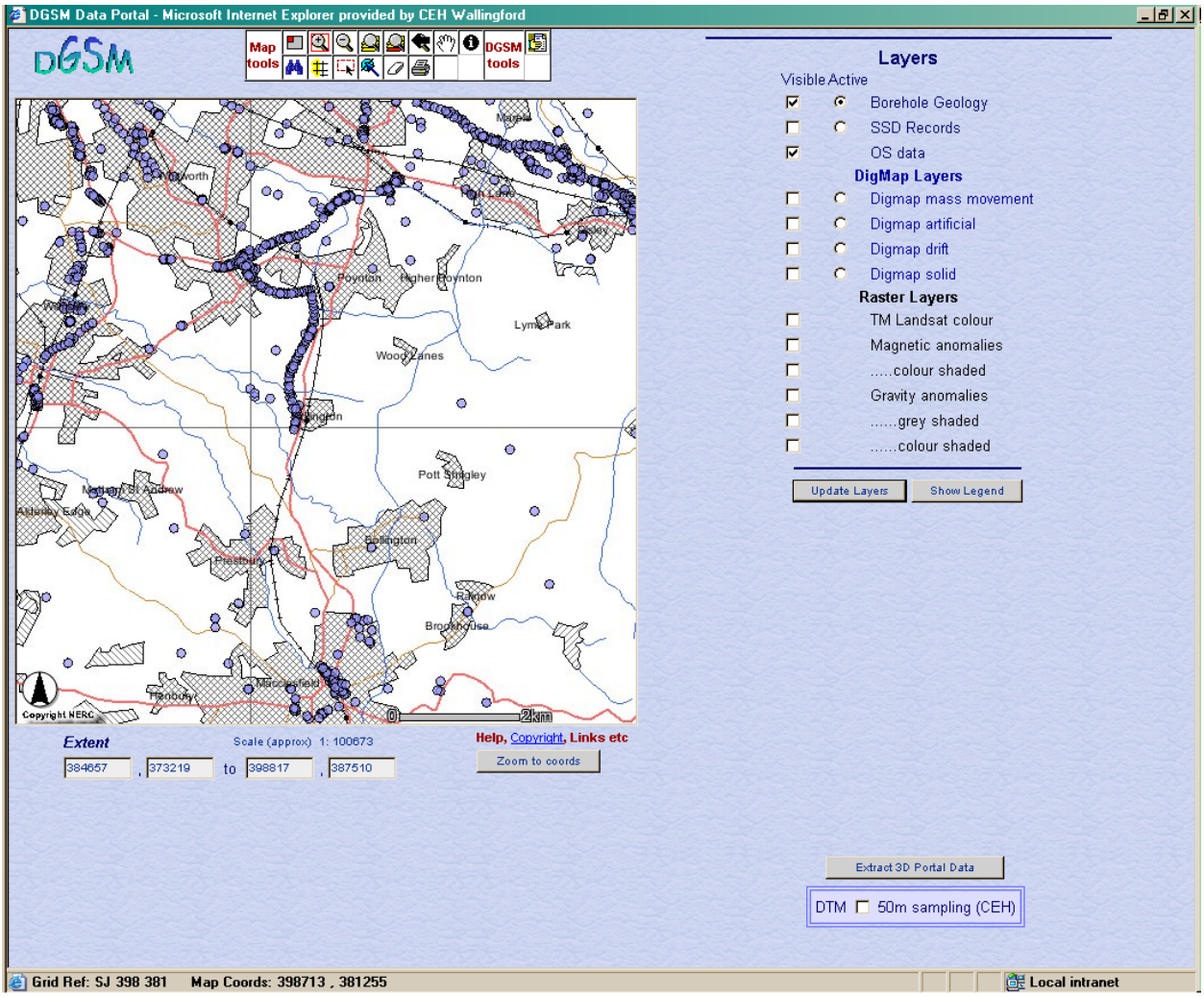
Boreholes in Quarter Sheet(s)
SJ79NW

QS	BNum	BSuff	Location	Grid Reference	
SJ79NW	1	.	ASTLEY GREEN 1 PIT	370465	399920
Interpreter		JWOODIER			
	LOW	21.9	summed thickness, metres		
	VLOW	8.38	summed thickness, metres		
Full drift thickness		30.28	metres		

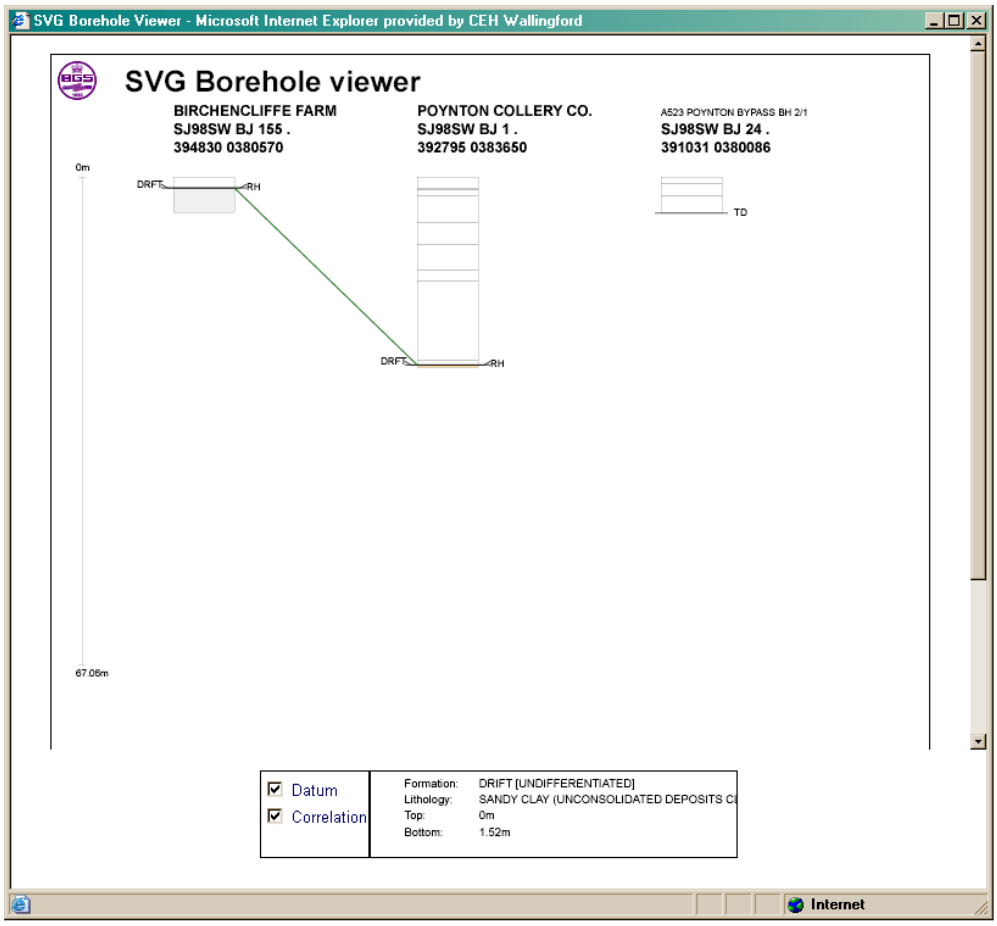
SJ79NW	3	.	ASTLEY RAYNERS	370230	398624
Interpreter		JWOODIER			
	VHIGH	4.46	summed thickness, metres		
	HIGH	1.53	summed thickness, metres		
	MODERATE	0.76	summed thickness, metres		
	LOW	16.34	summed thickness, metres		
	VLOW	12.5	summed thickness, metres		
Full drift thickness		35.59	metres		

NB: This report shows thickness of drift units classified by permeability - it does not show a drift sequence - classification is ordered by permeability, not depth.

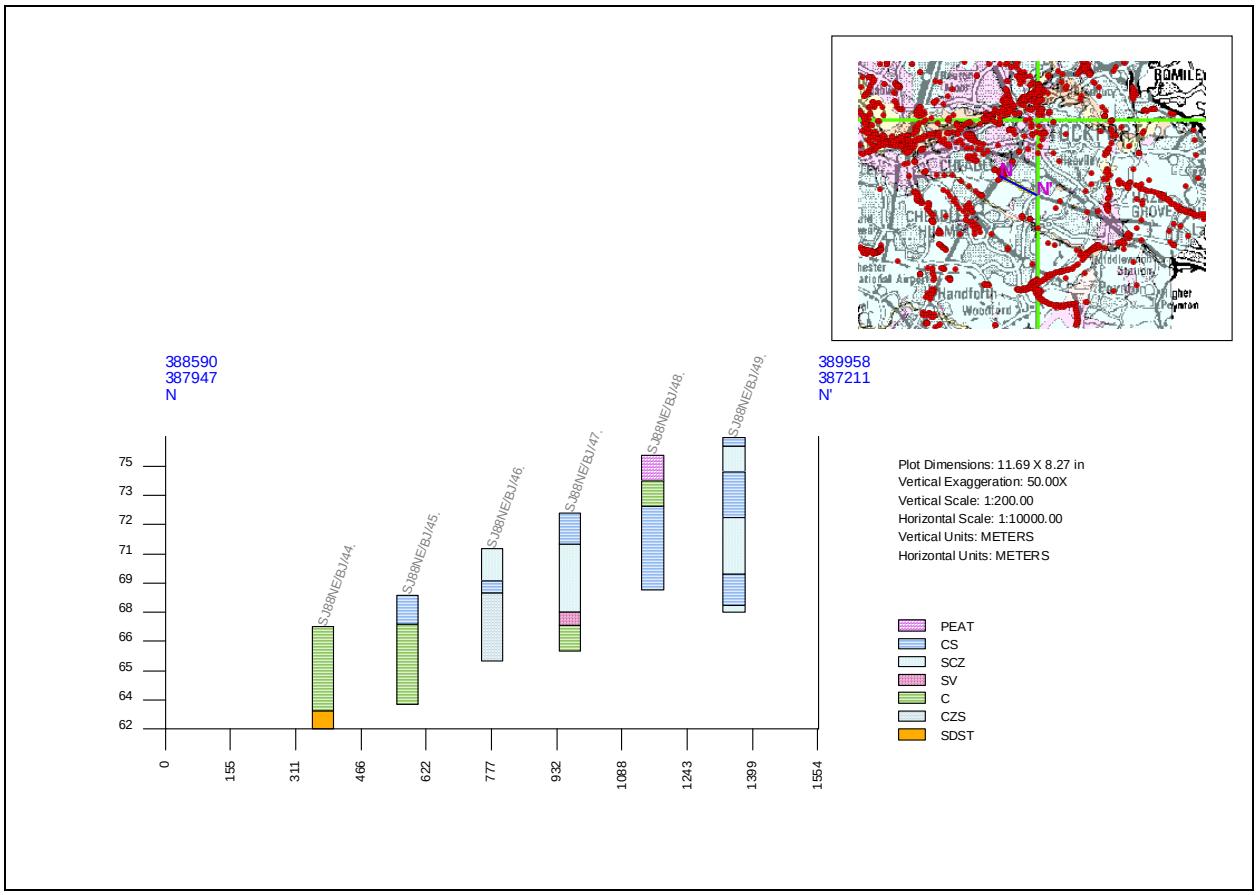
INTRANET CROSS SECTION VISUALISATION – DATA SELECTION



INTRANET CROSS SECTION VISUALISATION – CROSS SECTION



ARCVIEW BOREHOLE DATA DISPLAY



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Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

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