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# Vale of York 3-D Borehole Interpretation and Cross-sections Study

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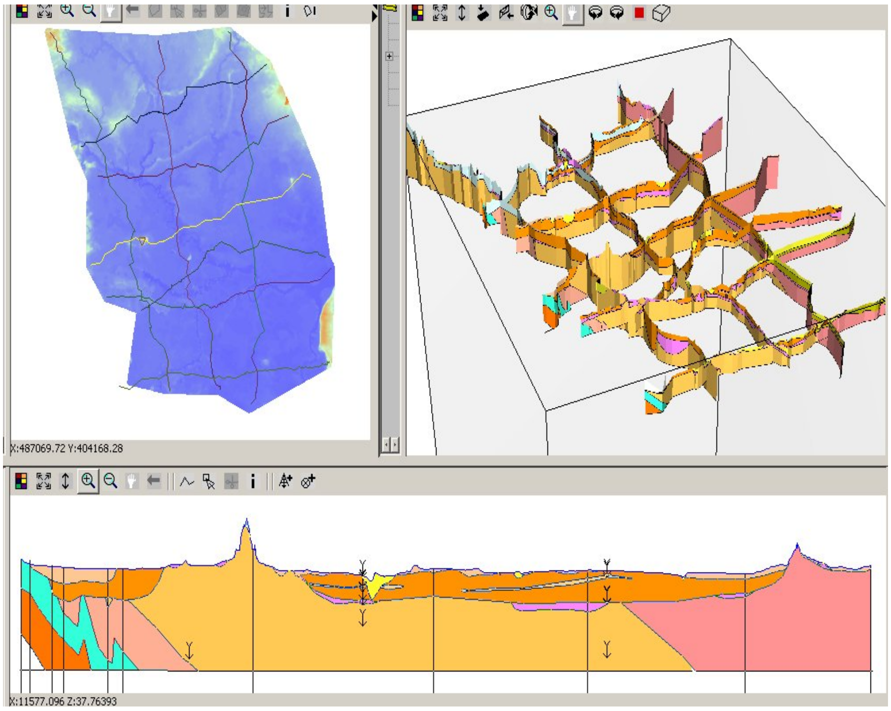
Commercial Report CR/03/251 N



BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT CR/03/251N

# Vale of York 3-D Borehole Interpretation and Cross-sections Study

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British Geological Survey



*Key words*

Report; Vale of York; boreholes; 3-D modelling; GSi3D; Quaternary; hydrogeology; faults; rockhead .

*Front cover*

Vale of York, Gsi3D map window with DTM and section lines, section and 3-D model.

*Bibliographical reference*

FORD,J.R.., KESSLER, H., PRICE, S.J., LAWLEY, R.S., COOPER, A.H., HALL, M., PHARAOH, T. C.DORAN, S.K., RICHARDSON, A.E. AND BURKE, H.F. 2003 Vale of York 3-D borehole and cross-sections study. *British Geological Survey Internal Report*, CR/03/251 26pp.



Keyworth, Nottingham British Geological Survey 2003

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# Foreword

This report is the published product of a study by the British Geological Survey (BGS) for the Environment Agency (EA) and Environmental Simulations Limited (ESI).


# Acknowledgements

Many BGS staff were involved in the lithological coding of boreholes, construction and correlation of cross sections and derivation of thematic maps. Their work is gratefully acknowledged.

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# 4 Executive Summary

The Vale of York between Doncaster and Scunthorpe in the south and York and Bugthorpe in the north is largely underlain by bedrock of the Sherwood Sandstone Group – one of the regions principal aquifers. Significant superficial deposits of Quaternary age overlie the Sherwood Sandstone. This study aims to investigate the nature of these superficial deposits with respect to their relationship with the underlying aquifer.

The Vale of York project area represents a varied glaciated terrain, consisting of pro-glacial fine-grained sediments, coarser glaciofluvilal sediments and extensive glacial tills. These diverse superficial units vary in thickness throughout the project area. The hydrogeological nature of the natural superficial sequence is consequently highly variable. Units may be considered as aquitards, while others may act as aquifers, providing a potential pathway to the underlying sandstone. The classification of lithologies as aquifer or aquitard is described in detail in this report.

To investigate the hydrogeological nature of the superficial sequence, six east-west and three north-south lithostratigraphical cross-sections were constructed. A range of geoscientific information was considered, including existing geological mapping and over 3000 fully attributed and coded boreholes. The cross-sections show a subdivision of the superficial sequence into lithostratigraphical units. Each unit is described in detail in this report.

In addition, a series of thematic maps were generated from the lithological component of the digital borehole data. Total superficial aquifer and superficial aquitard maps show how the lithological nature of the superficial sequence varies across the area. Rockhead elevation and superficial thickness maps indicate where the sandstone aquifer outcrops at the ground surface.

In summary, four main lithostratigraphical units overlie the Sherwood Sandstone Group aquifer in the project area: a basal sequence of glaciofluvial sand and gravel (interpreted as a superficial aquifer), glaciolacustrine laminated silt & clay (aquitard), glacial till comprising sandy gravelly clay (aquitard), and a cover sequence of fluvial and aeolian sand, clay and peat (aquifer / aquitard). The correlations illustrate that in certain areas, superficial deposits are thin or absent and that in these areas the Sherwood Sandstone aquifer comes directly to ground surface.

# 5 Introduction and Scope of Study

This report has been produced in response to a request made by the Environment Agency (EA) and Environmental Simulations Limited (ESI) to investigate the potential hydrogeological impact caused by the variability in thickness and composition of the natural superficial deposits of the Vale of York. The study area incorporates an area between Doncaster and Scunthorpe in the south to Green Hammerton, York and Bugthorpe in the north. The area is underlain in the central and western parts by one of the United Kingdom's major aquifers, the Sherwood Sandstone.

By constructing digital regional scale cross sections, the study aims to characterise the lithological properties of the superficial deposits, their spatial distribution, geometry and thickness including the delineation of areas where these deposits are thin or absent. The fault structure in the Sherwood Sandstone Group is also presented.

The construction of the cross sections was enabled by the interpretation, lithological coding and databasing of borehole data held within the National Geoscience Data Centre at BGS. It was agreed that the cross section construction and geological correlation would be performed digitally within GSI3D, a proprietary 3D modelling package developed by Dr Hans Sobisch at the University of Cologne.

# 6 Geology

The regional lithostratigraphical units that have been correlated in the Vale of York cross sections have been defined on the basis of their lithology and mode of origin. The bedrock ranges from late Permian to Triassic and includes the regionally important Sherwood Sandstone Group aquifer. The superficial units are made up of a series of glacial sediments typically comprising: till (boulder clay and morainic deposits), laminated clay & silt, sand & gravel, and gravelly sand. The glacial units are variably overlain by a series of younger, Holocene sediments that are associated with modern river systems and comprise sand and rare gravel with common silt and clay.

An outline of the main geological superficial units and their relative age is given in Table 1 and a more detailed description of the geological units is given below.

## 6.1 DESCRIPTION OF MAIN BEDROCK GEOLOGICAL UNITS

### 6.1.1 Roxby Formation

The Roxby Formation comprises the topmost formation of the Permian sequence. In the project area, it is dominantly composed of calcareous mudstone and gypsiferous mudstone with substantial units of gypsum and anhydrite towards the base of the formation. The formation underlies the Sherwood Sandstone Group aquifer and dips gently to the east. The formation is commonly thin at outcrop (approximately 20m) where the gypsum is dissolved away, thickening to approximately 50m in the east of the district.

### 6.1.2 Sherwood Sandstone Group

The Sherwood Sandstone Group is the main aquifer in the Vale of York. It comprises mainly fine to medium-grained red-brown sandstone with occasional mudstone beds and very sporadic pebble horizons, mainly in the south of the area. The group is approximately 380m in thickness, dipping gently to the east. In boreholes and at outcrop, the upper part of the sequence is commonly heavily weathered producing sand that is difficult to differentiate from the overlying superficial deposits.

### 6.1.3 Mercia Mudstone Group

The Mercia Mudstone Group overlies the Sherwood Sandstone Group in the eastern part of the area. This unit is the main bedrock aquitard above the sandstone. The Mercia Mudstone Group comprises mainly calcareous mudstone with sequences of gypsum near its base and top.

## 6.2 DESCRIPTION OF MAIN SUPERFICIAL GEOLOGICAL UNITS

### 6.2.1 Older Glaciofluvial Deposits

Older Glaciofluvial Deposits have been identified in the south of the project area, to the east of Doncaster. This lithostratigraphical unit comprises mainly sand and gravel with minor beds of silt and clay, including rare organic material. This unit is interpreted as a superficial aquifer, reaching a maximum thickness of approximately 27m, however more commonly between 4 and 10m in thickness.

The material was probably deposited by fluvial processes from meltwater associated with earliest onset of glaciation and southward ice advance in the Vale of York.

### 6.2.2 Glaciofluvial Deposits (Undifferentiated)

Undifferentiated Glaciofluvial Deposits have been correlated throughout the project area to directly overly sandstone of the Sherwood Sandstone Group. In places the deposit is laterally persistent but in other areas forms discreet lenses. This unit is considered to be the lateral equivalent of the Older Glaciofluvial Deposits (see above for thickness ranges), and is generally absent over Mercia Mudstone Group rocks to the east, and the Permian rocks to the west.

The Glaciofluvial Deposits comprise: sand & gravel, gravelly sand, and sandy gravel. These sediments were deposited by fluvial processes associated with an early phase of southward ice advance in the Vale of York. This lithostratigraphical unit is interpreted as a superficial aquifer.

The unit is interpreted to include sand derived directly from local weathering of the Sherwood Sandstone Group.

### 6.2.3 Hemingbrough Glaciolacustrine Formation

The Hemingbrough Glaciolacustrine Formation forms a laterally and vertically persistent unit that is interpreted to underlie over 90% of the project area, gradually thinning towards the south. The Hemingbrough Glaciolacustrine Formation commonly overlies the Undifferentiated Glaciofluvial Deposits or lies directly on bedrock. This unit is considered to be the principal superficial aquitard in the area, reaching a maximum thickness of approximately 50m, however more commonly between 9 and 24m in thickness.

The Hemingbrough Glaciolacustrine Formation generally comprises a sequence of thinly to thickly laminated, stiff clay and silt with occasional to common sand beds. The enclosed sand beds in the upper part of the sequence are commonly completely saturated and tend to form “running sand” horizons. The elevation of the top of the unit is between 4 and 6m above OD.

The unit was probably deposited in a low energy, pro-glacial lake environment that developed ahead of the southward advancing Vale of York ice. This interpretation is confirmed by the occurrence of gravel to boulder-size “dropstones” between Escrick and Newton-upon-Derwent.

### 6.2.4 Vale of York Till Formation

The Vale of York Till Formation is present to the north and east of a line running between Escrick and Stamford Bridge in the north east of the area. The till commonly overlies silt and clay of the Hemingbrough Glaciolacustrine Formation or directly overlies bedrock.

The Vale of York Till Formation was deposited directly by ice. Consequently this unit displays a variable lithology ranging from sandy gravelly clay with common cobbles and boulders to slightly clayey sand and gravel. Clast composition, including Carboniferous lithologies and rare volcanic material supports a northern-England provenance for the till. This lithostratigraphical unit is interpreted as a superficial aquitard reaching a maximum thickness of approximately 38m, however more commonly around 14m in thickness.

It is inferred from the cross sections that the Vale of York till does not extend further south than Escrick.

### 6.2.5 Poppleton Glaciofluvial Formation

The Poppleton Glaciofluvial Formation is present in the York City area and to the north west of this location. This unit commonly overlies sandy gravelly clay of the Vale of York Till Formation, or directly overlies bedrock.

The material comprises: bedded sand & gravel, gravelly sand, or sandy gravel with rare clay horizons. This lithostratigraphical unit is interpreted as a superficial aquifer, reaching approximately 15m in thickness.

The sand and gravel was probably deposited by fluvial systems under, within and on top of the southward advancing ice (i.e. esker systems). During melting and the "northward retreat" of the ice, the material previously trapped within the ice would have been exposed to form the observed linear tracts of sand and gravel.

### 6.2.6 Elvington Glaciolacustrine Formation

The Elvington Glaciolacustrine Formation is present between Escrick and York and commonly overlies sandy gravelly clay of the Vale of York Till Formation. The elevation of the upper surface of this unit is between 10 and 12m above OD.

The material comprises mainly thinly to thickly laminated silt and clay with common sand beds. Gravel sized calcareous nodules are also common at approximately 1.5m below ground level and gypsum crystals have been observed at approximately 5m below ground level. This lithostratigraphical unit is interpreted as a superficial aquitard, reaching approximately 2.5m in thickness.

The sediments of the Elvington Glaciolacustrine Formation were probably deposited in a low energy pro-glacial lake that developed as the Vale of York ice retreated northward to York. The till forming the moraines at York and Escrick may have acted to dam in the waters of this lake.

Please note that due to close lithological association, this unit is included with the Hemingbrough Glaciolacustrine Formation on the cross-sections.

### 6.2.7 Alne Glaciolacustrine Formation

The Alne Glaciolacustrine Formation is present to the northeast of York and overlies the Vale of York Till Formation. The elevation of the base of this unit is between 14 and 17m above OD.

The material comprises mainly laminated silt and clay with occasional sand beds. This lithostratigraphical unit is interpreted as a superficial aquitard, reaching approximately 2.5m in thickness.

The sediments of the Alne Glaciolacustrine Formation were probably deposited following further retreat of the Vale of York ice to the north of York.

Please note that due to close lithological association, this unit is included with the Hemingbrough Glaciolacustrine Formation on the cross-sections.

### 6.2.8 Pocklington Gravel Formation

Sediments of the Pocklington Gravel Formation are present to the extreme east of the area, near Pocklington. These sediments directly overlie bedrock.

The Pocklington Gravel Formation is represented by a clast or matrix supported, clayey gravel. The gravel clasts are dominated by well-rounded chalk and flint with subordinate ironstone. This lithostratigraphical unit is interpreted as a superficial aquifer, reaching approximately 5m in thickness.

The Pocklington Gravel Formation forms a fan deposit derived from the high ground to the east of the Vale of York by glaciofluvial processes.

### 6.2.9 Breighton Sand Formation

The Breighton Sand Formation forms a blanket of sediment that variably overlies the Vale of York Till Formation, Hemingbrough Glaciolacustrine Formation, Elvington Glaciolacustrine Formation, Alne Glaciolacustrine Formation and the Pocklington Gravel Formation. The Breighton Sand Formation has an erosional base, which is known to incise into the underlying sequence to a variable extent.

The Breighton Sand Formation is dominated by silty coarse to fine sand that commonly has a coarse base and fines upwards. Low angle or parallel cross bedding has been observed. Thin clay beds or laminae and discontinuous peat horizons of up to 0.3m have also been observed. This lithostratigraphical unit is interpreted as a superficial aquifer, reaching approximately 4m in thickness.

The Breighton Sand Formation may have formed by a complex interaction of fluvial and aeolian processes. The sand may have initially been deposited by the southward flowing fluvial systems that were initiated at the end of the Vale of York glacial period. Subsequently, the sediments were probably modified and partially redistributed by aeolian processes.

In places the Breighton Sand Formation has been removed by subsequent erosive processes to leave older sediments exposed.

### 6.2.10 Peat

Peat in the area is commonly associated with alluvium and modern river drainage systems (i.e. Holocene sedimentation). The peat is variably preserved but often forms persistent beds of less than 1m in thickness. This lithostratigraphical unit is interpreted as a superficial aquitard, reaching approximately 3m in thickness.

### 6.2.11 Blown Sand

Late Devensian to Holcene (i.e. Recent) blown sand formed by modern aeolian processes has been correlated east of Doncaster in the Isle of Axholme area. The blown sand commonly forms dunes and variably overlies alluvium, Hemingbrough Glaciolacustrine Formation, and bedrock units. This lithostratigraphical unit is interpreted as a superficial aquifer, reaching approximately 2m in thickness.

| Relative Age | Geological Unit (Lithostratigraphy) | Correlation Code | Summary Lithology | Superficial Aquifer / Aquitard |
|---|---|---|---|---|
| YOUNG | Alluvium | alv | Common gravel base, fining upwards into SILT and CLAY. Interbedded peat horizons common throughout | Aquitard |
| | Blown Sand | bsa | SAND | Aquifer |
| | Peat | Peat | PEAT | Aquitard |
| | Breighton Sand Formation | brei | Fine to coarse, commonly silty SAND with occasional clay beds | Aquifer |
| | Pocklington Gravel Formation | pockg | Clayey, sandy medium to coarse GRAVEL | Aquifer |
| | Alne Glaciolacustrine Formation | alne | Thinly to thickly laminated SILT and CLAY with common sand beds or laminae (saturated "running sand") | Aquitard |
| | Elvington Glaciolacustrine Formation | elv | Thinly to thickly laminated SILT and CLAY with occasional sand beds or laminae (saturated "running sand") | Aquitard |
| | Poppleton Glaciofluvial Formation | popp | Gravelly SAND and sandy GRAVEL | Aquifer |
| | Vale of York Till Formation | vyork | Variable gravelly, sandy CLAY with common cobbles and boulders | Aquitard |
| | Hemingbrough Glaciolacustrine Formation | hem | Thinly to thickly laminated SILT and CLAY with occasional sand beds or laminae (saturated "running sand") | Aquitard |
| | Glaciofluvial Deposits (Undifferentiated) | gfdu | SAND and GRAVEL, gravelly SAND, sandy GRAVEL | Aquifer |
| OLD | Older Glaciofluvial Deposits | ogfd | SAND and GRAVEL | Aquifer |

Table 1 Principal superficial geological units correlated along Vale of York cross sections

# 7 Borehole Coding

Lithological interpretation of boreholes were derived from paper records held within the National Geoscience Data Centre at the British Geological survey and additional digital records provided by the Environment Agency. Boreholes for use in the project were selected based on their position within a 500m buffer zone around the previously agreed fence of sections.

## 7.1 CODING METHODOLOGY

Boreholes were coded according to the description of the downhole lithology recorded on the paper records of the borehole. The quality of the original description varied according to the age of the record and the purpose for which the borehole was drilled (e.g. site investigation, water abstraction or coal exploration). In addition to lithological interpretation, the appropriate stratigraphic code was applied where the coder was confident of the interpretation. The stratigraphic codes used for the project were derived from the BGS Stratigraphic Lexicon (http://www.bgs.ac.uk/lexicon/lexicon.html).

The lithological codes were derived from the BGS Superficial Deposits Coding Scheme. The scheme uses six letters to denote the primary lithology of a deposit and is shown in Table 2.

| **Lithological Units** | **Code** |
|---|---|
| Peat | P |
| Sand | S |
| Silt | Z |
| Clay | C |
| Gravel | V |
| Cobbles | L |
| Boulders | B |
| For Made Ground | FILLU |

Table 2 Superficial deposit coding scheme component codes

Where more than one lithological unit is present (for example a sandy clay) the letters can be combined to reflect the full lithology of the material. The coded lithological and stratigraphic information was added to the BGS Borehole Geology database to be retrieved subsequently for correlation. Each of the combinations of lithological units used in the borehole coding and modelling exercise is listed in the Appendix.

## 7.2 BOREHOLE ELEVATION

Each borehole was referenced to an elevation with respect to Ordnance Datum. The presence of this information on a borehole log was variable. If the elevation was recorded on the borehole log it was added to the database. If the elevation was missing it was derived from Ordnance Survey contours and spot heights.

# 8 Cross Section Construction and Correlation

Final cross section locations were confined within the mutually agreed 500m corridors running from Doncaster and Scunthorpe in the south to Green Hammerton, York and Bugthorpe in the north. Proprietary 2D and 3D modelling software (“GSI3D”) was used to construct three north-south sections and six east-west sections.

## 8.1 CROSS SECTION CONSTRUCTION METHODOLOGY

BGS coded boreholes were imported into GSI3D from the BGS Borehole Geology database in their correct spatial positions. In addition, the locations of the Environment Agency monitoring boreholes were imported to ensure that the lines of section passed through these key locations.

From the complete database of coded boreholes, the highest quality logs were selected for inclusion along the cross section. The selection process was based a number of key criteria including depth (preferably boreholes reaching bedrock), quality of description and coincidence with Environment Agency monitoring boreholes.

Each borehole added to the line of section defined a control point for subsequent geological correlation. In total, approximately 600 fully coded and attributed boreholes were used.

## 8.2 CORRELATION

The full lithological coding and partial stratigraphic coding was displayed on screen in GSI3D. These descriptions were used as data-rich anchor points to begin to build the correlation. The geological units correlated along the regional sections were those shown in Table 1. Correlation lines and the nodes that make up the lines were constructed manually on screen. Each line was then attributed with the corresponding correlation code (see Table 1).

Existing 1:50,000 scale 2D digital geological map data (DigMap50) was used to aid correlation and define the limits and relationships of different geological units. However, the information proved within a borehole was given a higher priority over the map data where conflicting information existed. For example, where the geological map suggested the absence of superficial material but a borehole proved a significant thickness of till, then till would be correlated. Consequently, the cross-sections provided by this study may be considered as more accurate representation of the local geology than the published linework.

The cross sections included data poor and data rich areas. Data rich areas, where the borehole density was high, resulted in increased confidence in the correlation. In data poor areas, lines of correlation were projected from data rich areas.

# 9 Derived Data and Thematic Maps

## 9.1 COMMON DATA

All of the maps presented with this study show the following reference data:

SSG_SUBCROP – The approximate subcrop of the upper and lower bounding surfaces of the Sherwood Sandstone Group. Two lines are shown, representing the lower contact with Permian strata to the west, and the upper contact with the Mercia Mudstone Group to the east. These lines are principally derived from the published digital map data.

PLACE_NAMES – Location of principal towns and cities within the project area.

LINES_OF_SECTION – Position of bespoke geological cross-sections. Three cross-sections run approximately north-south along the Vale of York, and six cross-sections run east-west across the project area. The position of these cross-sections follows closely the pattern defined in agreement with the client prior to commencing this study. Minor adjustments have been made to maximise the available borehole information, including where possible those boreholes specifically identified by the client (EA monitoring wells).

## 9.2 THEMATIC MAPS

### 9.2.1 Bedrock geology (digmap_bedrock_clip)

This map shows a mosaic of bedrock geology data derived from the 1:50,000 scale digital geological map of the British Isles (DigMap50). The main units described by the codes shown in Table 3.

| LEX-ROCK CODE | DESCRIPTION |
|---|---|
| FI-IRST | Frodingham Ironstone Member - Ironstone |
| SMD-LMST | Scunthorpe Mudstone Formation - Limestone |
| SMD-MDLM | Scunthorpe Mudstone Formation – Mudstone and limestone |
| PNG-MDST | Penarth Group - Mudstone |
| MMG-SLST | Mercia Mudstone Group - Siltstone |
| MMG-MDST | Mercia Mudstone Group - Mudstone |
| SSG-SDST | Sherwood Sandstone Group - Sandstone |
| ROX-MARL | Roxby Formation – Calcareous Mudstone |
| BTH-DOLO | Brotherton Formation - Dolostone |
| BTH-DOLM | Brotherton Formation – Dolomitic Limestone |
| EDT-MARL | Edlington Formation – Calcareous Mudstone |
| CDF-DOLM | Cadeby Formation – Dolomitic Limestone |

Table 3 Principal bedrock units and corresponding codes

The "Lex" and "Rock" codes indicate the stratigraphy and primary lithology respectively. For example, the Sherwood Sandstone Group is predominantly composed of sandstone; the corresponding Lex-Rock code is SSG-SDST. Distinct lithological variants exist for several of the units considered here.

The full description shown above provides a reference to the attribution provided by the digital file. For presentation purposes, the printed version of this map is generally coloured by stratigraphy (“Lex” code”). Consequently, single colours may be used to represent more than one lithological variant of the same stratigraphy.

Please note that the bedrock interpretation for the Selby area is based on the existing geological map. An updated interpretation is in press, including a more comprehensive understanding of the fault geometry (see below) and it’s effect on the distribution of aquifer lithologies.

### 9.2.2 Fault pattern and boundaries map

The fault pattern map represents a combination of information from published and unpublished sources. Data from seven 1:50,000 scale geological map datasets have been combined. These datasets are of variable age and quality. From the north-west corner the following have been combined.

- Harrogate (62) sheet; in the south of the area, a fault from the digital map data has been included. To the north of this, two faults have been inferred from the structural geology map published in the memoir (Figure 20) (Cooper and Burgess, 1993). This was derived from seismic interpretations completed after the publication of the map, but still now about 20 years old.
- York (63) sheet: no faults are published on the southern part of the York sheet and the information here is derived from Hawkins and Aldrick (1994) figure 2 with slight modifications based on borehole information.
- Leeds (70) sheet: the information on faults is taken from the recently published (2003) BGS digital geological map information. The faults have been extracted from the digital dataset and annotated with throw direction and approximate throw amounts.
- Selby (71) sheet (In Press): this information is all unpublished and derived from a combination of recent seismic interpretation, borehole logs (and downhole information in database / spreadsheet format) plus seismic interpretations of the Selby coalfield and published work by Hawking and Aldrick (1994). The faults are annotated with estimated or inferred (from seismic) throw amounts and directions. The BGS interpretation used seismic reflection data owned by the Coal Authority in the western part of the Selby sheet. This was augmented by a study of selected hydrocarbon exploration lines in analogue format in the eastern part of the area. The interpretations produced fault positions at the Variscan Unconformity, Billingham Anhydrite Formation / Brotherton Formation, and top Sherwood Sandstone Group. In addition, grids of the surfaces were constructed to constrain the modelling of the fault and outcrop patterns.
- Wakefield (78) sheet: the data for this sheet was extracted from the digital fault pattern data and annotated with directions of throw and approximate throw amounts derived from the published map.
- Goole (79) sheet: some information on this area has been derived from the published digital fault linework. However, the memoir for the area indicated considerably more faulting at the contact of the Sherwood Sandstone Group and the overlying Mercia Mudstone Group. Data from the published memoir (Gaunt 1993) (Figure 34) postdates the map (surveyed in the mid 1960’s and published in 1971) by many years. Information about the faults has been derived from the memoir, but it must be stressed that using data from a small diagram has many inaccuracies. There are differences between the fault positions in the memoir and the map, especially for the Bowers House Fault which is straight on the map, but which curves to the north on the memoir diagram.

In addition to the fault pattern, new information about the position of the contact between the Sherwood Sandstone Group and the overlying Mercia Mudstone Group has been derived for the Selby and York map areas. That for Selby is well–constrained by boreholes and seismic information, that for the York area is provisional.

### 9.2.3 Superficial geology (digmap_superficial_clip)

This map shows a mosaic of superficial geology data derived from the 1:50,000 scale digital geological map of the British Isles (DigMap50). The main units described by the codes shown in Table 4.

| LEX-ROCK CODE | DESCRIPTION |
|---|---|
| ALV-CLSI | Alluvium – Clay and Silt |
| ALV-CSGR | Alluvium – Clay, Sand and Gravel |
| ALV-SACL | Alluvium – Sand and Clay |
| ALV-SICL | Alluvium – Silt and Clay |
| ALV-SILT | Alluvium - Silt |
| BSA-SAND | Blown Sand - Sand |
| CDVY-CLSI | Clays and Silts of the Vale of York – Clay and Silt |
| GFDU-SAGR | Glaciofluvial Deposits Undivided – Sand and Gravel |
| GFDU1-SAGR | Glaciofluvial Deposits Undivided – Sand and Gravel |
| GFSD-SAGR | Glaciofluvial sheet deposits – Sand and Gravel |
| GFSG-SAGR | Glaciofluvial Sand and Gravel – Sand and Gravel |
| GFTD-SAGR | Glaciofluvial Terrace Deposit – Sand and Gravel |
| GLLD-CLSI | Glaciolacustrine Deposits [Undifferentiated] – Clay and Silt |
| GLLD-SAGR | Glaciolacustrine Deposits [Undifferentiated] – Sand and Gravel |
| GLLD-SAND | Glaciolacustrine Deposits [Undifferentiated] – Sand |
| GLLD-SICL | Glaciolacustrine Deposits [Undifferentiated] – Silt and Clay |
| GLLD1-CLSI | Glaciolacustrine Deposits [Undifferentiated] – Clay and Silt |
| HEAD-CSGR | Head - Clay, Sand and Gravel |
| HEAD-DMTN | Head - Diamicton |
| HMGD-DMTN | Hummocky [Moundy] Glacial Deposits - Diamicton |
| LABD-SAGR | Lacustrine Beach Deposits – Sand and Gravel |
| LDE-SAGR | Lacustrine Deposits [Undifferentiated] – Sand and Gravel |
| OGFD-SAGR | Older Glaciofluvial Deposits – Sand and Gravel |
| ORG-SAGR | Older River Gravel – Sand and Gravel |
| PEAT-PEAT | Peat - Peat |
| RTD1-SAGR | River Terrace Deposits – Sand and Gravel |
| RTDU-SAGR | River Terrace Deposits – Sand and Gravel |
| SDVY-SAND | Sands of the Vale of York - Sand |
| TFD-CLSI | Tidal Flat Deposits – Clay and Silt |
| TILL-DMTN | Till - Diamicton |

Table 4 Principal superficial deposits and corresponding codes

The “Lex” and “Rock” codes indicate the stratigraphy and primary lithology respectively. For example, Glaciofluvial Deposits Undivided is predominantly composed of sand and gravel; the corresponding Lex-Rock code is GFDU-SAGR. Distinct lithological variants exist for several of the units considered here.

The full description shown above provides a reference to the attribution provided by the digital file. For presentation purposes, the printed version of this map is generally coloured by stratigraphy ("Lex" code"). Consequently, single colours may be used to represent more than one lithological variant of the same stratigraphy.

Please note that the superficial interpretation for the Selby area is based on the existing geological map. An updated interpretation is in press.

### 9.2.4 Rockhead elevation

This map shows a gridded surface representing the elevation of rockhead in the project area. The elevation data is shown as metres above or below OD.

This surface is a subset of a national dataset, and is based on a combination of digital downhole information and surface geological information. Rockhead is interpreted as the base of superficial deposits (i.e. base of Quaternary).

### 9.2.5 Superficial thickness

This map shows a grid of the total thickness in metres of superficial deposits in the project area. The thickness is independent of the lithological nature of the deposits, and includes all material (including Artificial Ground) above rockhead.

The thickness is calculated by subtracting the rockhead elevation surface from a digital elevation model of the land surface. The digital elevation model used in this study is based on the OS Landform Profile elevation data (contours and spot-heights), interpolated to a gridded surface with a 25m cell-size.

Both the rockhead elevation and drift thickness surfaces are based on an existing borehole database that includes only summary lithological data. This database is distinct to that used for the detailed lithological models described below. The distribution and density of data used in creating the rockhead elevation and drift thickness surfaces is generally greater than that used for the detailed lithological models.

### 9.2.6 Borehole locations

This map shows the distribution of boreholes for which detailed lithological information has contributed to the main gridded surfaces (i.e. not Rockhead Elevation or Superficial Thickness). This dataset includes digital logs collated from several BGS mapping projects (Leeds, Selby and York) together with logs entered specifically for this study (Goole, Doncaster and Wakefield). The dataset contains approximately 3287 borehole records.

### 9.2.7 Continuous superficial aquitard greater than 5 metres

This map shows areas where the superficial sequence includes continuous aquitard units of greater than 5 m thickness.

The classification of superficial lithologies by hydraulic character is described below.

- All sand-dominated lithologies are considered as aquifers. This class includes all clean gravel, clean sand, fine sand and clean silt. Previous studies have indicated that these lithologies may have a hydraulic conductivity in the range $10^{-2}$ to $>10^{3}$ metres/day.

- All clay-dominated lithologies are considered as aquitards. This class includes all clay, silt and mixtures of clay silt and sand. The corresponding hydraulic conductivity may be in the range 0 to <$10^{-2}$ metres/day.
- All other data (unclassified or unrelated) are excluded from this study.

The resulting classification is presented as a table in the Appendix.

The interpretation is based on an appraisal of those boreholes described above. An automated gridding process has been used to interpolate between boreholes. This process produces a best estimate of the distribution of aquitard lithologies, but is dependent on the density and distribution of data.

#### 9.2.8 Superficial aquitard maximum thickness

This map shows a grid of the thickness of the greatest continuous aquitard unit recorded in each borehole. Thicknesses range from 0 m (where no aquitard units are present) to >20 m (where extensive continuous aquitard units are present). The maximum-recorded aquitard thickness is 45.72 m.

The “Continuous Superficial Aquitard Greater than 5 metres” is derived from this gridded data.

#### 9.2.9 Superficial aquifer maximum thickness

This map shows a grid of the thickness of the greatest continuous aquifer unit recorded in each borehole. Thicknesses range from 0 m (where no aquifer units are present) to >20 m (where extensive continuous aquifers units are present). The maximum-recorded aquifer thickness is 31.7 m.

#### 9.2.10 Superficial aquitard total thickness

This map shows a grid of the combined thickness of aquitard units recorded in each borehole. All aquitard units are included, independent of thickness. Total thicknesses range from 0 m (where no aquitard units are present) to >20 m (where many isolated or continuous aquitard units are present). The maximum-recorded total aquitard thickness is 45.72 m (i.e. corresponding to the greatest continuous aquitard).

#### 9.2.11 Superficial aquifer total thickness

This map shows a grid of the combined thickness of aquifer units recorded in each borehole. All aquifer units are included, independent of thickness. Total thicknesses range from 0 m (where no aquifer units are present) to >20 m (where many isolated or continuous aquifer units are present). The maximum-recorded total aquifer thickness is 31.7 m (i.e. corresponding to the greatest continuous aquifer).

#### 9.2.12 Ratio of superficial total aquifer to total aquitard

This map shows a grid of the ratio of the total aquifer thickness to total aquitard thickness recorded in each borehole. Values in the range 0 to 0.5 represent areas where the superficial sequence is dominantly composed of aquitard units (isolated or continuous). Values in the range 0.5 to 1 represent areas where the superficial sequence is dominantly composed of aquifer units (isolated or continuous).

# 10 Conclusions and Recommendations

The results of this 3 dimensional appraisal show how the diverse sequence of superficial lithologies in the Vale of York can be resolved into a correlatable sequence of lithostratigraphical units. By considering the hydrogeological character of each unit, subsequent interpretation is possible regarding the potential impact of this sequence on the underlying Sherwood Sandstone aquifer.

Thematic maps show clearly the regional variability of the superficial sequence, and indicate areas where the superficial sequence is likely to consist of non-aquitard lithologies. The corresponding superficial thickness map provides an immediate impression of areas that are free from superficial cover.

Detailed information concerning the structure and distribution of bedrock lithologies is also provided, and is intended to contribute to any subsequent hydrogeological appraisal of the Sherwood Sandstone aquifer.

This results of this project are based a subset of the actual data inventory for the project area. All available data was considered for the Leeds, Selby and York areas, but only data within 500m of the lines of section were considered elsewhere. Consequently, the relatively widely spaced cross sections may not be representative of the intervening ground. Similarly, the gridding method used to interpret the thematic maps is also dependent on the relative availability of data.

# 11 References

COOPER, A H and BURGESS, I C. 1993 Geology of the country around Harrogate. *Memoir of the British Geological Survey,* Sheet 62 (England and Wales).

GAUNT, G.D. 1993 Geology of the country around Doncaster and the Isle of Axholme. COOPER, A H and BURGESS, I C. 1993 Geology of the country around Harrogate. *Memoir of the British Geological Survey*, Sheets 79 and 88 (England and Wales).

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# 12 Appendix

Table summarising the hydraulic classification of superficial lithologies applied to this study.

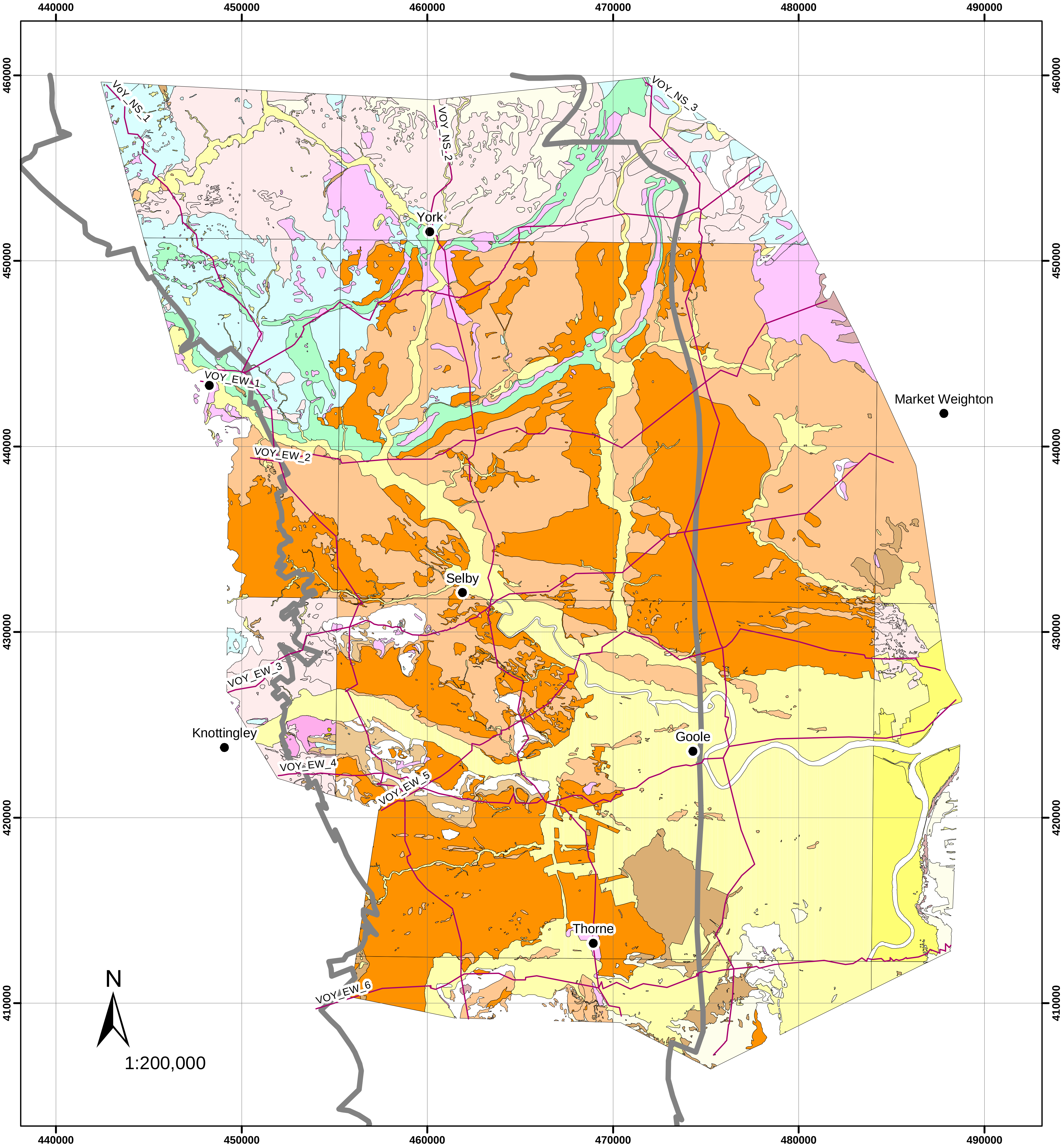
| CODE | AQUIFER TYPE | DESCRIPTION |
|---|---|---|
| ARTDP | aquifer | ARTIFICIAL DEPOSIT |
| B | aquifer | BOULDERS |
| BVL | aquifer | Gravelly cobbly BOULDERS |
| CSVLB | aquifer | Sandy gravelly cobbly bouldery CLAY |
| CZSVB | aquifer | Silty sandy gravelly bouldery CLAY |
| CZSVL | aquifer | Silty sandy gravelly cobbly CLAY |
| CZSVLB | aquifer | Silty sandy gravelly cobbly bouldery CLAY |
| FILLU | aquifer | FILL (UNDIFFERENTIATED) |
| GRAV | aquifer | GRAVEL (UNDIFFERENTIATED) |
| GV | aquifer | GRAVEL (MARINE SEDIMENTS) |
| L | aquifer | COBBLES |
| LB | aquifer | COBBLES and BOULDERS |
| LV | aquifer | Gravelly COBBLES |
| LZ | aquifer | Silty COBBLES |
| PESA | aquifer | PEBBLY (GRAVELLY)SAND |
| PL | aquifer | Cobbly PEAT |
| PS | aquifer | Sandy PEAT |
| PSZ | aquifer | sandy silty PEAT |
| PZ | aquifer | Silty PEAT |
| S | aquifer | SAND |
| SAGR | aquifer | SAND AND GRAVEL |
| SANDU | aquifer | SAND(UNDIFFERENTIATED) |
| SB | aquifer | Bouldery SAND |
| SBP | aquifer | Bouldery peaty SAND |
| SCZVL | aquifer | Clayey silty gravelly cobbly |
| SCZVLB | aquifer | Clayey silty gravelly cobbly bouldery SAND |
| SDYGV | aquifer | SANDY GRAVEL |
| SILT | aquifer | SILT (UNDIFFERENTIATED) |
| SL | aquifer | Cobbly SAND |
| SP | aquifer | Peaty SAND |
| SV | aquifer | Gravelly SAND |
| SVB | aquifer | Gravelly bouldery SAND |
| SVC | aquifer | gravelly clayey SAND |
| SVCZ | aquifer | gravelly clayey silty SAND |
| SVL | aquifer | Gravelly cobbly SAND |
| SVLB | aquifer | Gravelly cobbly bouldery SAND |
| SVZ | aquifer | gravelly silty SAND |
| SVZC | aquifer | gravelly silty clayey SAND |

| | | |
|---|---|---|
| SZ | aquifer | Silty SAND |
| SZC | aquifer | silty clayey SAND |
| SZCV | aquifer | silty clayey gravelly SAND |
| SZP | aquifer | Silty peaty SAND |
| SZV | aquifer | Silty gravelly SAND |
| SZVC | aquifer | Silty gravelly cobbly SAND |
| SZVLB | aquifer | Silty gravelly cobbly bouldery SAND |
| V | aquifer | GRAVEL |
| VB | aquifer | Bouldery GRAVEL |
| VL | aquifer | Cobbly GRAVEL |
| VOID | aquifer | VOID |
| VS | aquifer | Sandy GRAVEL |
| VSB | aquifer | Sandy bouldery GRAVEL |
| VSC | aquifer | sandy clayey GRAVEL |
| VSL | aquifer | Sandy cobbly GRAVEL |
| VSZ | aquifer | sandy silty GRAVEL |
| VSZC | aquifer | sandy silty clayey GRAVEL |
| VZ | aquifer | Silty GRAVEL |
| VZS | aquifer | Silty sandy GRAVEL |
| VZSL | aquifer | Silty sandy cobbly GRAVEL |
| Z | aquifer | SILT |
| ZB | aquifer | Bouldery SILT |
| ZCB | aquifer | Clayey bouldery SILT |
| ZCL | aquifer | Clayey cobbly SILT |
| ZP | aquifer | Peaty SILT |
| ZS | aquifer | Sandy SILT |
| ZSC | aquifer | sandy clayey SILT |
| ZSCV | aquifer | sandy clayey gravelly SILT |
| ZSP | aquifer | Sandy peaty SILT |
| ZSV | aquifer | Sandy gravelly SILT |
| ZSVC | aquifer | Sandy gravelly clayey SILT |
| ZV | aquifer | Gravelly SILT |
| ZVC | aquifer | Gravelly clayey SILT |
| ZVL | aquifer | Gravelly cobbly SILT |
| C | aquitard | CLAY |
| CB | aquitard | Bouldery CLAY |
| CL | aquitard | Cobbly CLAY |
| CLAY | aquitard | CLAY (UNDIFFERENTIATED) |
| CLSA | aquitard | CLAYEY SAND |
| CLSGV | aquitard | SANDY, CLAYEY GRAVEL |
| CP | aquitard | Peaty CLAY |
| CPS | aquitard | peaty sandy CLAY |
| CS | aquitard | Sandy CLAY |
| CSB | aquitard | Sandy bouldery CLAY |
| CSL | aquitard | Sandy cobbly CLAY |
| CSP | aquitard | sandy peaty CLAY |

| | | |
|---|---|---|
| CSPZ | aquitard | sandy peaty silty CLAY |
| CSV | aquitard | Sandy gravelly CLAY |
| CSVB | aquitard | Sandy gravelly bouldery CLAY |
| CSVL | aquitard | Sandy gravelly cobbly CLAY |
| CSZ | aquitard | Sandy silty CLAY |
| CSZV | aquitard | sandy silty gravelly CLAY |
| CV | aquitard | Gravelly CLAY |
| CVB | aquitard | gravelly bouldery CLAY |
| CVS | aquitard | gravelly sandy CLAY |
| CVSZ | aquitard | gravelly sandy silty CLAY |
| CVZ | aquitard | gravelly silty CLAY |
| CVZS | aquitard | gravelly silty sandy CLAY |
| CZ | aquitard | Silty CLAY |
| CZB | aquitard | Silty bouldery CLAY |
| CZL | aquitard | Silty cobbly CLAY |
| CZP | aquitard | Silty peaty CLAY |
| CZPV | aquitard | silty peaty gravelly CLAY |
| CZS | aquitard | Silty sandy CLAY |
| CZSB | aquitard | Silty sandy bouldery CLAY |
| CZSL | aquitard | Silty sandy cobbly CLAY |
| CZSP | aquitard | Silty sandy peaty CLAY |
| CZSV | aquitard | Silty sandy gravelly CLAY |
| CZSVP | aquitard | Silty sandy gravelly peaty CLAY |
| CZV | aquitard | Silty gravelly CLAY |
| CZVS | aquitard | silty gravelly sandy CLAY |
| DMTN | aquitard | DIAMICTON |
| LOAM | aquitard | LOAM |
| MUD | aquitard | MUD (UNDIFFERENTIATED) |
| P | aquitard | PEAT |
| PC | aquitard | Clayey PEAT |
| PCS | aquitard | Clayey sandy PEAT |
| PCV | aquitard | Clayey gravelly PEAT |
| PCZ | aquitard | Clayey silty PEAT |
| PEAT | aquitard | PEAT |
| PECL | aquitard | PEBBLY CLAY |
| SACL | aquitard | SANDY CLAY |
| SC | aquitard | Clayey SAND |
| SCP | aquitard | Clayey peaty SAND |
| SCV | aquitard | Clayey gravelly SAND |
| SCVL | aquitard | Clayey gravelly cobbly SAND |
| SCZ | aquitard | Clayey silty SAND |
| SCZP | aquitard | Clayey silty peaty SAND |
| SCZV | aquitard | Clayey silty gravelly SAND |
| SICL | aquitard | SILTY CLAY |
| VC | aquitard | Clayey GRAVEL |
| VCL | aquitard | Clayey cobbly GRAVEL |

| | | |
|---|---|---|
| VCS | aquitard | Clayey sandy GRAVEL |
| VCZ | aquitard | Clayey silty GRAVEL |
| VCZS | aquitard | Clayey silty sandy GRAVEL |
| ZC | aquitard | Clayey SILT |
| ZCP | aquitard | Clayey peaty SILT |
| ZCS | aquitard | Clayey sandy SILT |
| ZCSV | aquitard | Clayey sandy gravelly SILT |
| ZCSVP | aquitard | Clayey sandy gravelly peaty SILT |
| ZCV | aquitard | clayey gravelly SILT |
| AGG | unknown | AGGLOMERATE |
| ANHY | unknown | ANHYDRITE-STONE |
| ARLMST | unknown | ARGILLACEOUS (MUDDY) LIMESTONE (CEMENTSTONE/CALCILUTITE) |
| ASHFIL | unknown | ASH FILL (INDUSTRIAL) |
| BREC | unknown | BRECCIA |
| CALSST | unknown | CALCAREOUS SANDSTONE |
| CAMDST | unknown | CALCAREOUS MUDSTONE |
| CANL | unknown | CANNEL-COAL |
| CLBST | unknown | CALCITE-BOUNDSTONE |
| CMDST | unknown | CARBONACEOUS MUDSTONE |
| COAL | unknown | COAL |
| CONG | unknown | CONGLOMERATE |
| CSST | unknown | CARBONACEOUS SANDSTONE |
| DLSD | unknown | DOLOMITE-SEDIMENTS |
| DOLMST | unknown | DOLOMITIC LIMESTONE |
| DOLO | unknown | DOLOSTONE |
| DRFT | unknown | COMPOSITE OF SEVERAL DRIFT LITHOLOGIES (OBSOLETE CODE) |
| DRFTU | unknown | UNDIFFERENTIATED SUPERFICIAL DEPOSITS (NATURAL AND/OR ARTIFICIAL) |
| FCMST | unknown | FRIABLE, CALCAREOUS MUDSTONE |
| FEST | unknown | IRONSTONE |
| GYPS | unknown | GYPSUM |
| GYPST | unknown | GYPSUM-STONE |
| HALI | unknown | HALITE |
| HALIST | unknown | HALITE-STONE |
| LMMST | unknown | LIME-MUDSTONE |
| LMST | unknown | LIMESTONE |
| LMSTN | unknown | NODULAR LIMESTONE (CORNSTONE) |
| MARSDU | unknown | MARINE SEDIMENTS (UNDIFFERENTIATED) |
| MCASST | unknown | MICACEOUS SANDSTONE |
| MDSST | unknown | MUDDY SANDSTONE |
| MDST | unknown | MUDSTONE (UNDIFFERENTIATED) |
| MINFIL | unknown | MINERAL FILL (UNDIFFERENTIATED) |
| MSDST | unknown | METASANDSTONE |
| NOCO | unknown | NO CORE RECOVERED |
| OOLMST | unknown | OOIDAL LIMESTONE |
| ORCL | unknown | ORGANIC CLAY |
| ORSA | unknown | ORGANIC SAND |

| | | |
|---|---|---|
| ORSI | unknown | ORGANIC SILT |
| PESST | unknown | PEBBLY SANDSTONE |
| ROCK | unknown | ROCK (UNDIFFERENTIATED) |
| SAMDST | unknown | SANDY MUDSTONE |
| SDST | unknown | SANDSTONE (UNDIFFERENTIATED) |
| SEAT | unknown | SEAT-EARTH (UNDIFFERENTIATED) |
| SEATC | unknown | SEAT-EARTH CLAYSTONE |
| SEATM | unknown | SEAT-EARTH MUDSTONE |
| SEATS | unknown | SEAT-EARTH SANDSTONE |
| SEATSI | unknown | SEAT-EARTH SILTSTONE |
| SHMDM | unknown | SHELLY MUDSTONE (MARINE) |
| SLMDST | unknown | SILTY MUDSTONE (UNDIFFERENTIATED) |
| SLSST | unknown | SILTY SANDSTONE (UNDIFFERENTIATED) |
| SLST | unknown | SILTSTONE (UNDIFFERENTIATED) |
| SLTE | unknown | SLATE |
| SNDGVI | unknown | SANDY-GRAVEL (UNKNOWN/INDUSTRIAL) |
| SOIL | unknown | SOIL |
| UKNOWN | unknown | UNKNOWN/UNCLASSIFIED ENTRY |




**Vale of York 3-D Borehole Interpretation and Cross-Sections Study**

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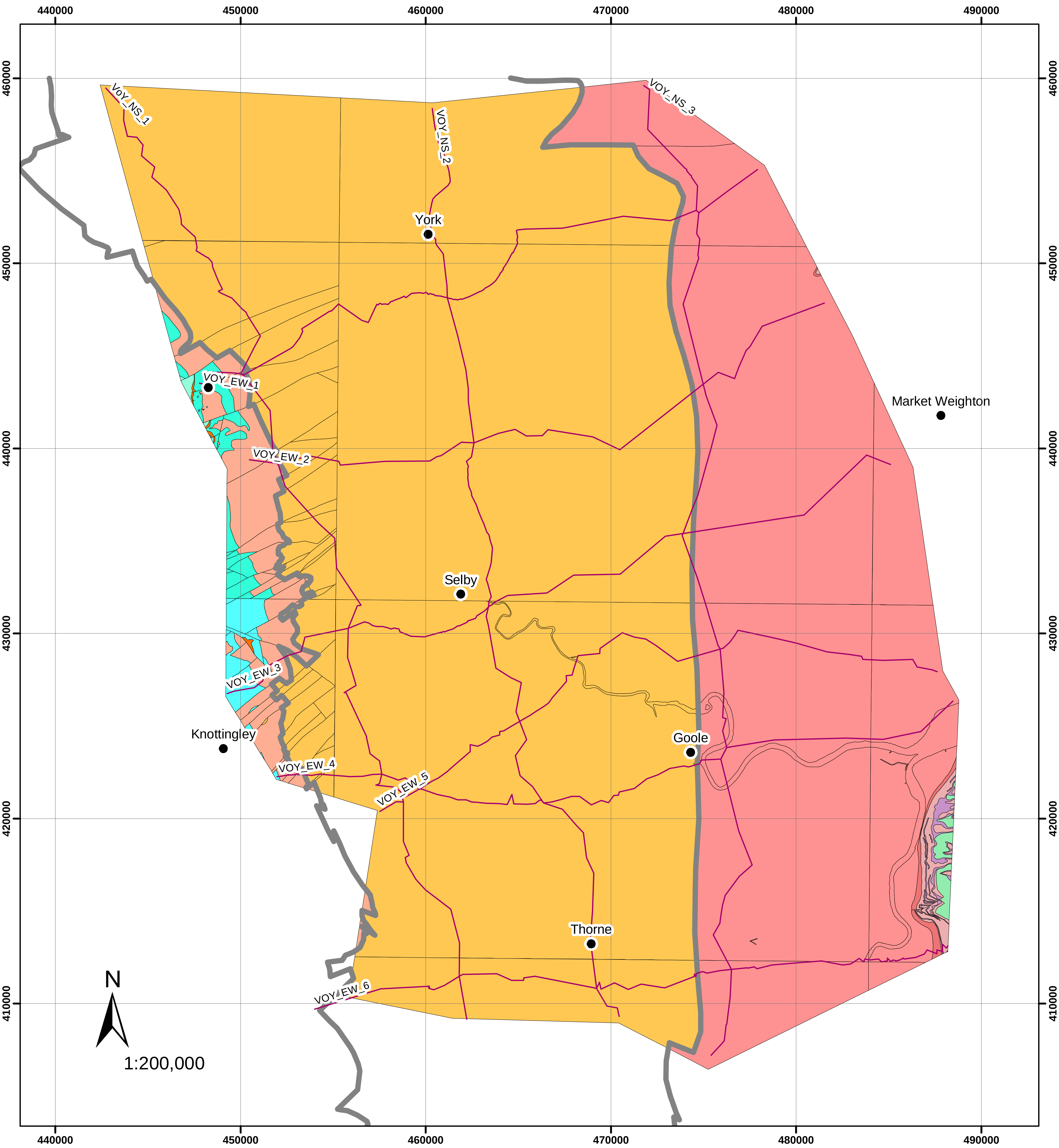
NO-SUPERFICIAL
ALV-CLSI
ALV-CSGR
ALV-SACL
ALV-SICL
ALV-SILT
BSA-SAND
CDVY-CLSI
GFDU-SAGR
GFDU1-SAGR
GFSD-SAGR
GFSG-SAGR
GFTD-SAGR
GLLD-CLSI
GLLD-SAGR
GLLD-SAND
GLLD-SICL
GLLD1-CLSI
HEAD-CSGR
HEAD-DMTN
HMGD-DMTN
LABD-SAGR
LDE-SAGR
OGFD-SAGR
ORG-SAGR
PEAT-PEAT
RTD1-SAGR
RTDU-SAGR
SDVY-SAND
TFD-CLSI
TILL-DMTN

PLACE_NAMES
SSG_SUBCROP
LINES_OF_SECTION

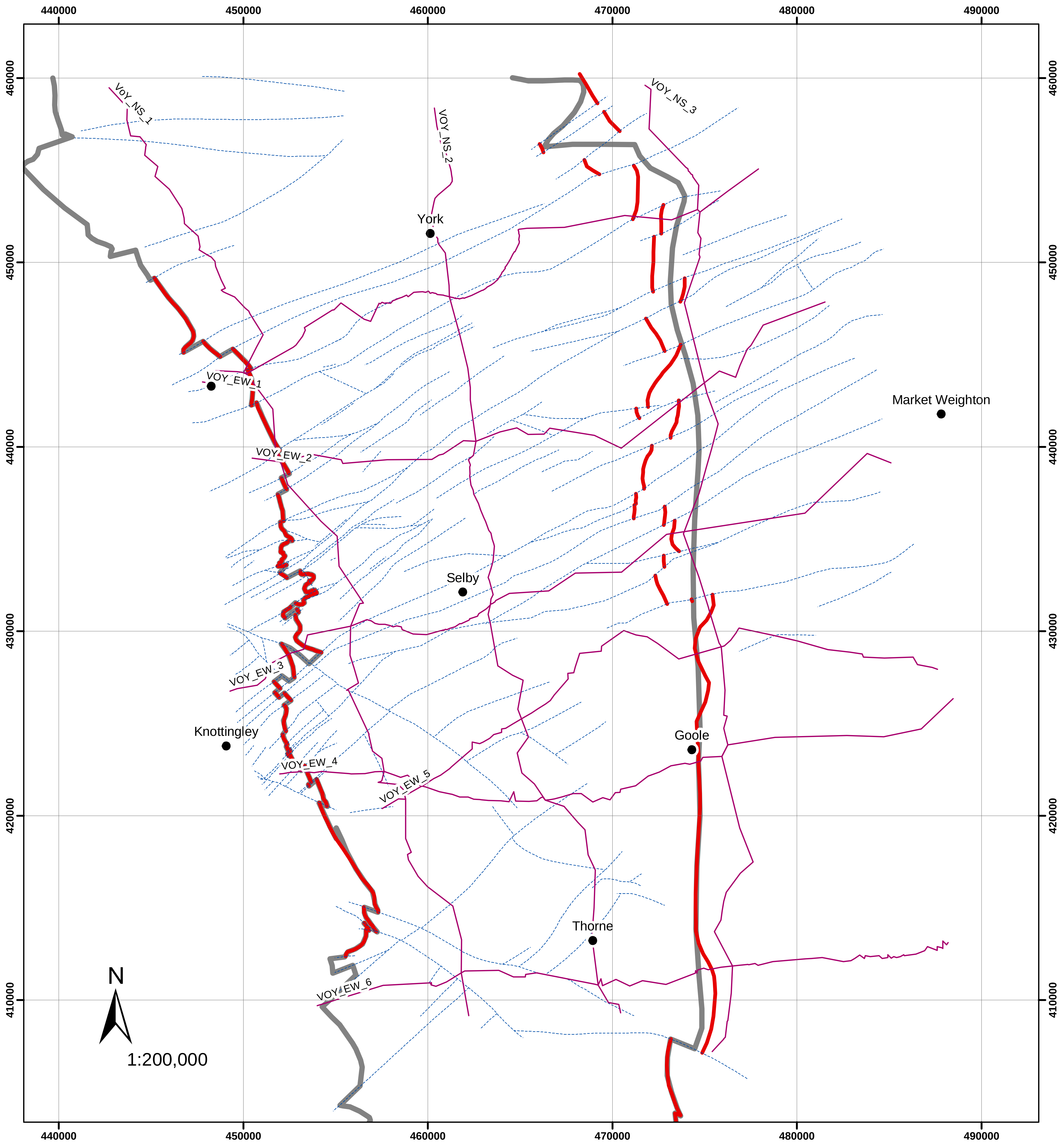



**Vale of York 3-D Borehole Interpretation and Cross-Sections Study**

**digmap_bedrock_clip**

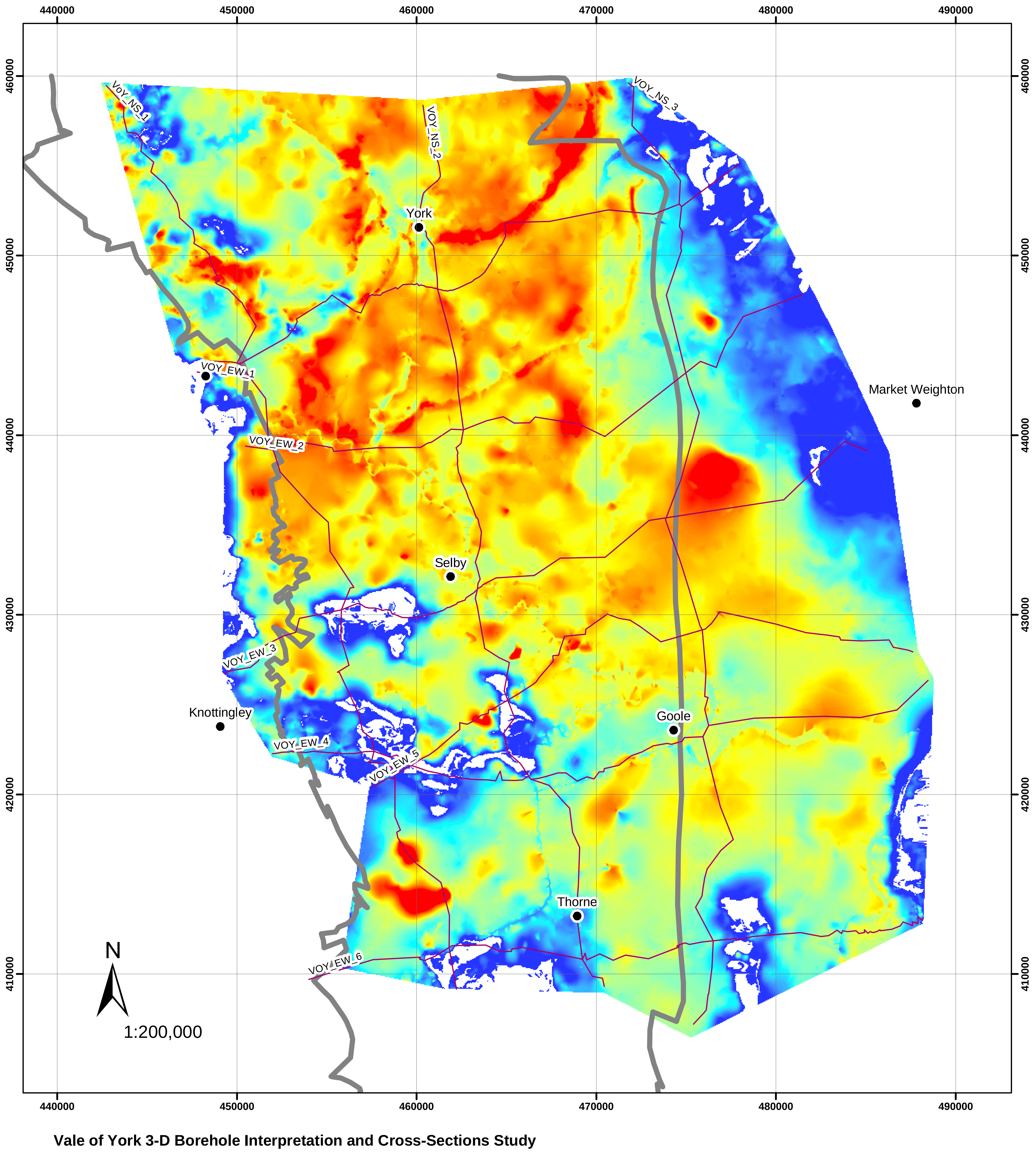
- FI-IRST
- SMD-LMST
- SMD-MDLM
- PNG-MDST
- MMG-SLST
- MMG-MDST
- SSG-SDST
- ROX-MARL
- BTH-DOLO
- BTH-DOLM
- EDT-MARL
- CDF-DOLM

- PLACE_NAMES
- SSG_SUBCROP
- LINES_OF_SECTION




**Vale of York 3-D Borehole Interpretation and Cross-Sections Study**

Provisional_SELBY_FAULTS
Provisional_SSG_SUBCROP
PLACE_NAMES
SSG_SUBCROP
LINES_OF_SECTION




**Vale of York 3-D Borehole Interpretation and Cross-Sections Study**

**SUPERFICIAL_THICKNESS**

**Value**

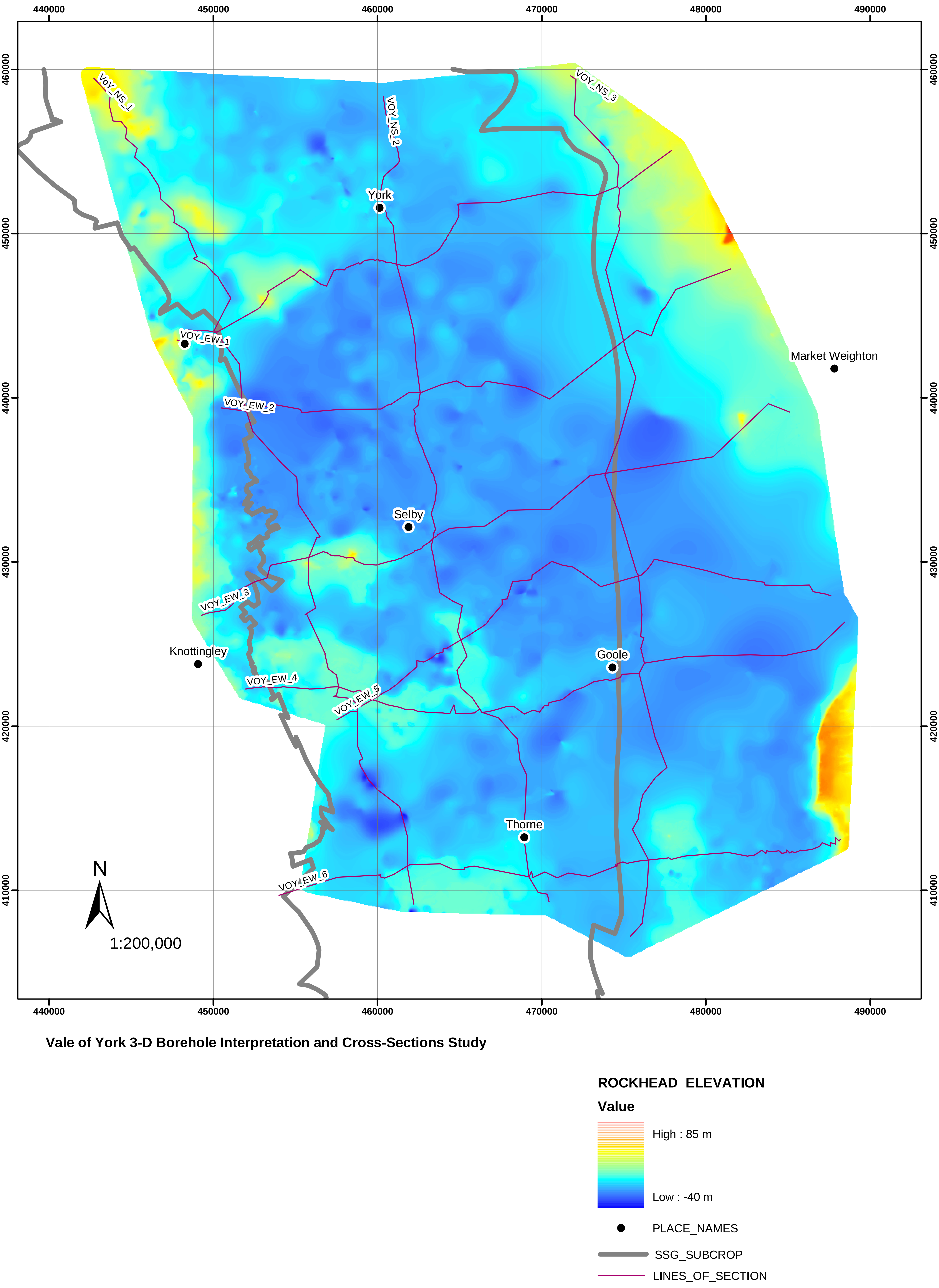
High : >30 m

Low : 0 m

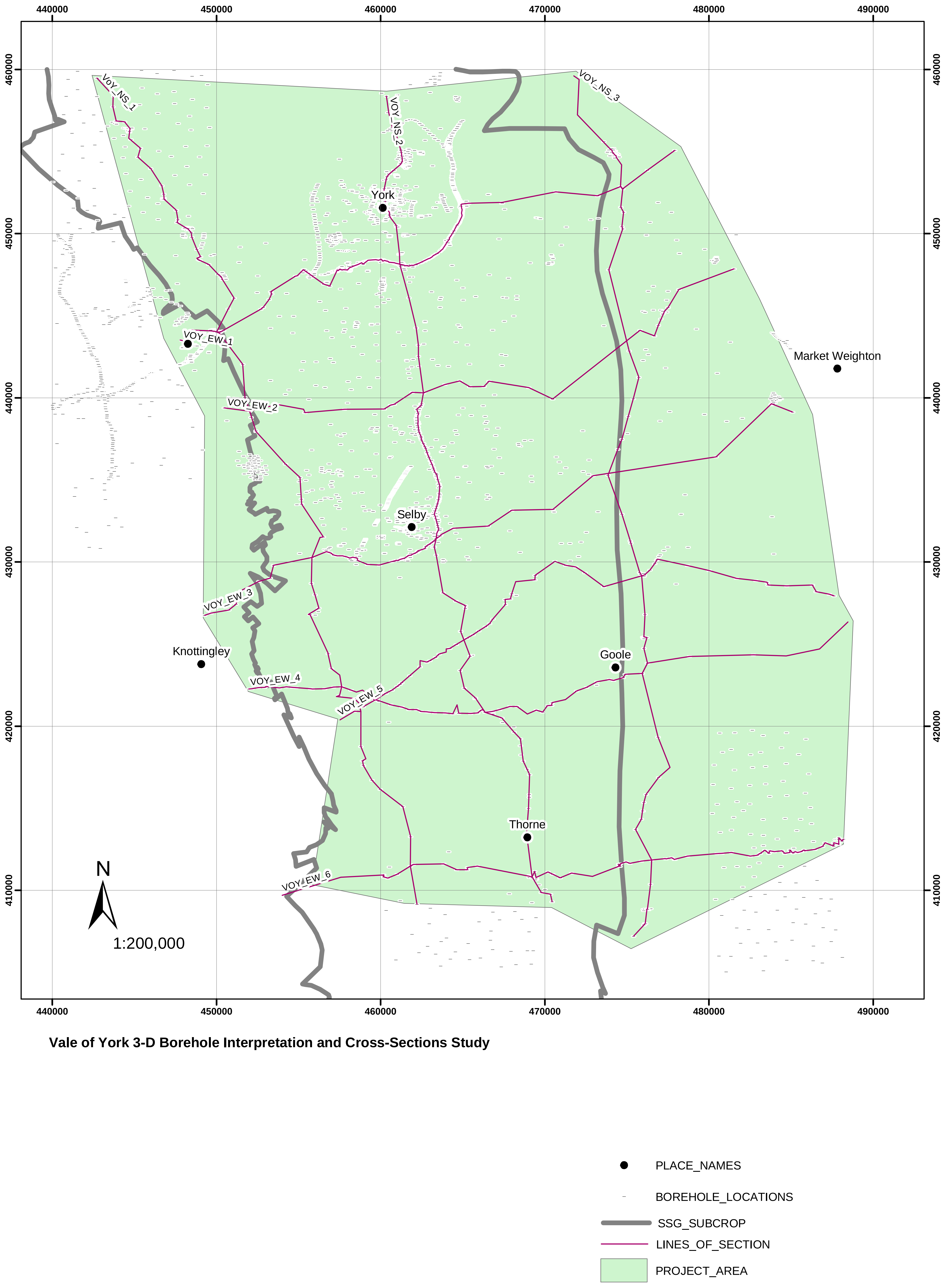
PLACE_NAMES

SSG_SUBCROP

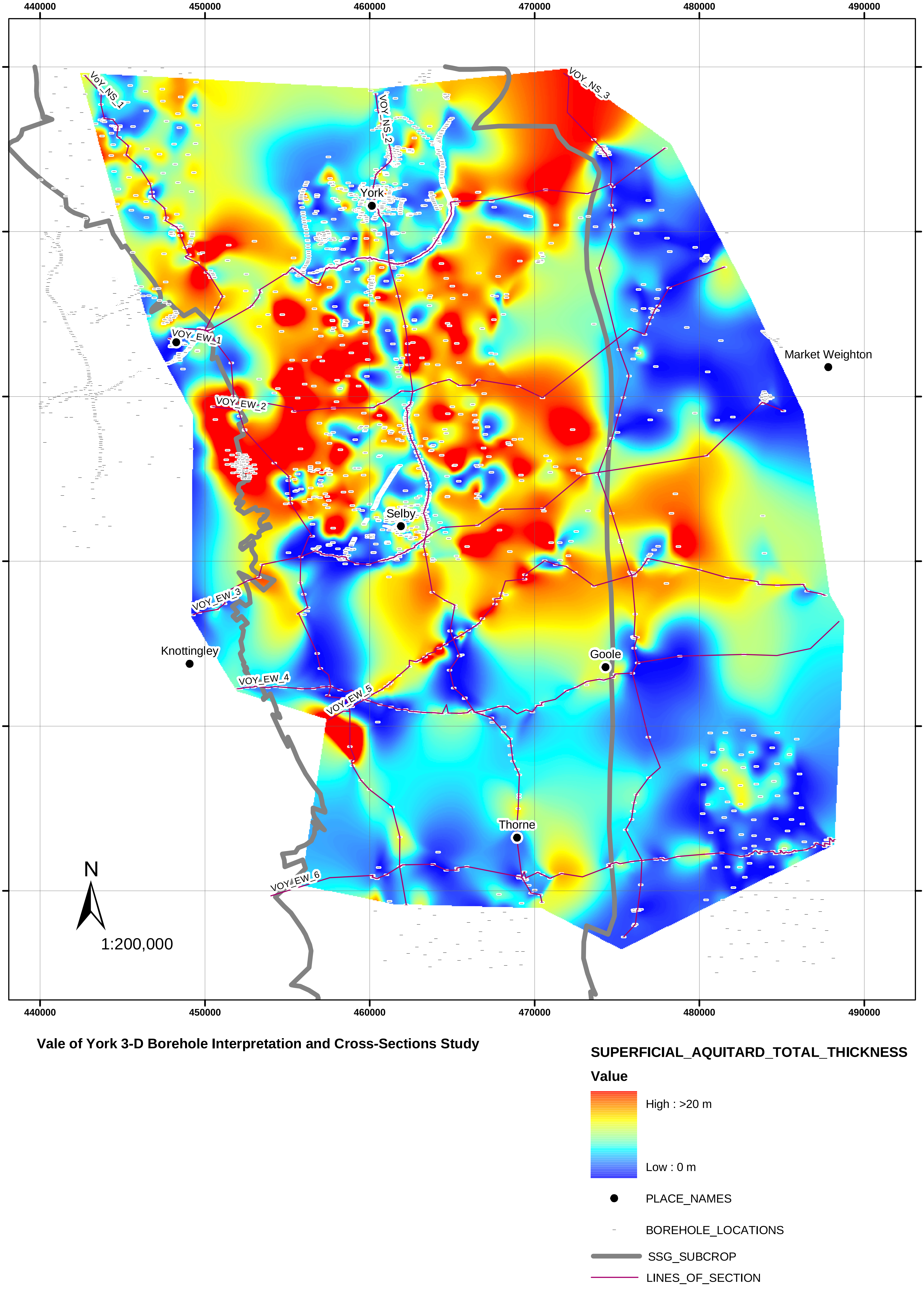
LINES_OF_SECTION



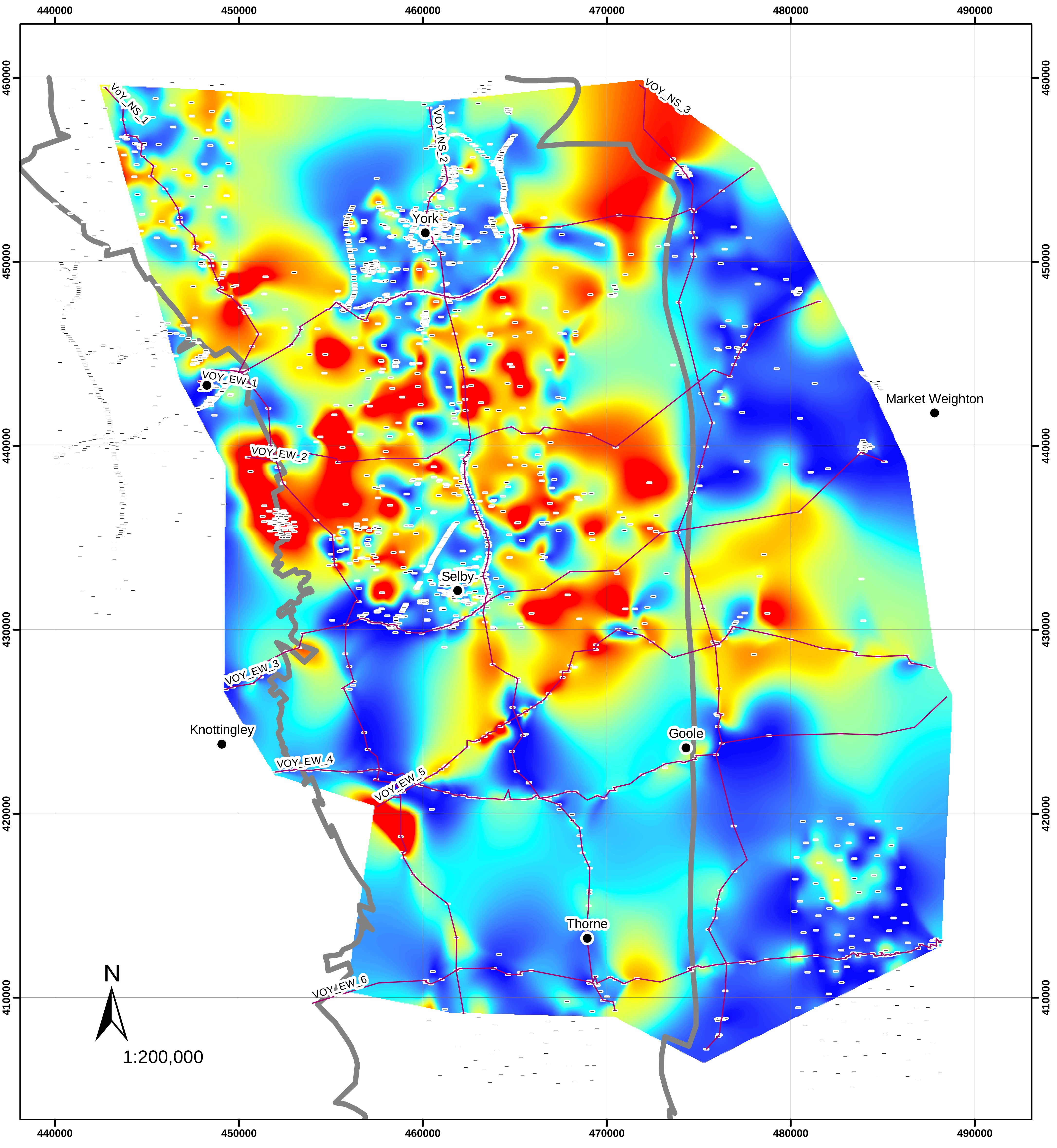

Vale of York 3-D Borehole Interpretation and Cross-Sections Study




**Vale of York 3-D Borehole Interpretation and Cross-Sections Study**




**Vale of York 3-D Borehole Interpretation and Cross-Sections Study**




**Vale of York 3-D Borehole Interpretation and Cross-Sections Study**

**SUPERFICIAL_AQUITARD_MAX_THICKNESS**

**Value**

High : >20 m

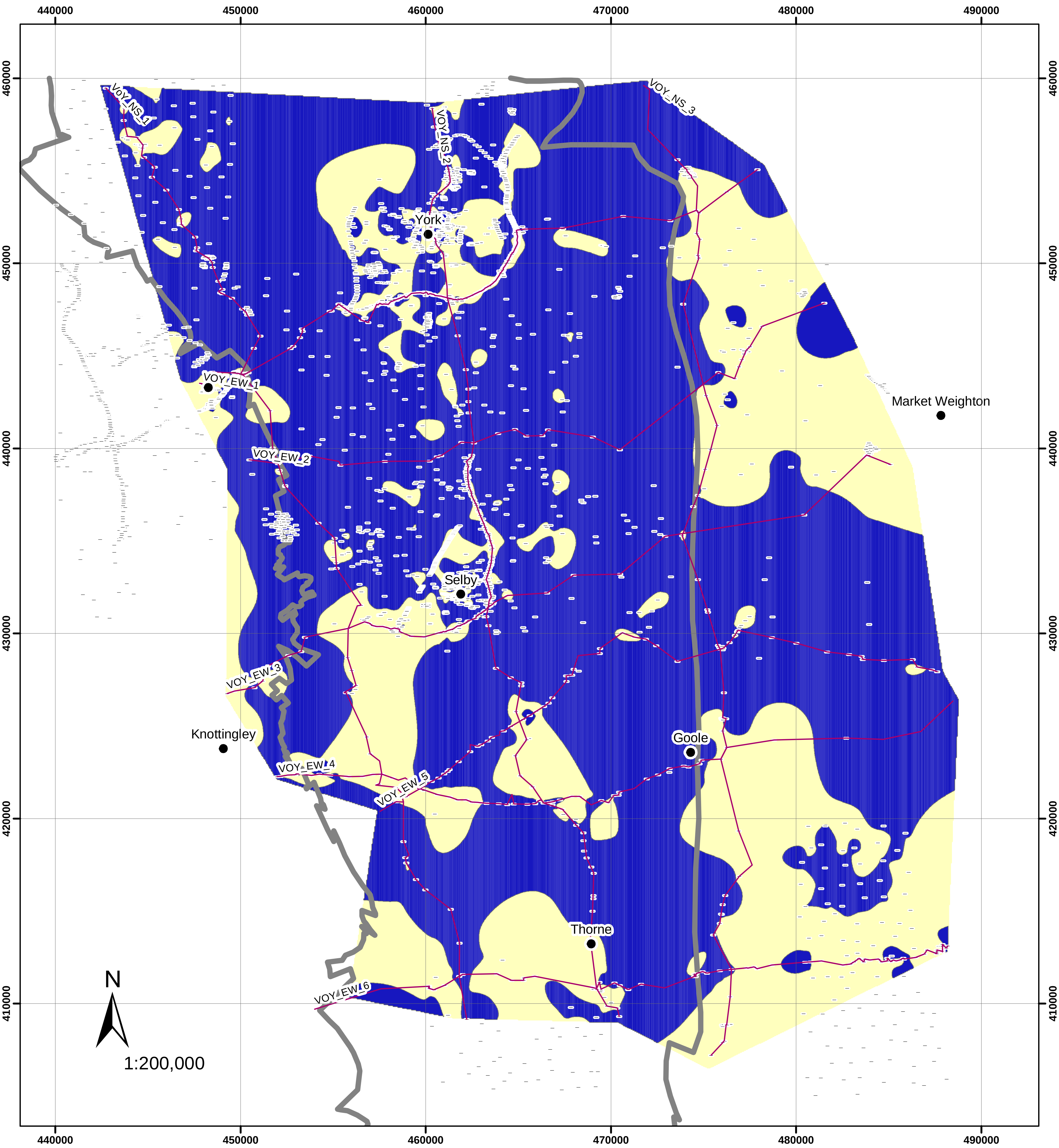
Low : 0 m

PLACE_NAMES

BOREHOLE_LOCATIONS

SSG_SUBCROP

LINES_OF_SECTION




**Vale of York 3-D Borehole Interpretation and Cross-Sections Study**

**CONTINUOUS_SUPERFICIAL_AQUITARD**

<5 m

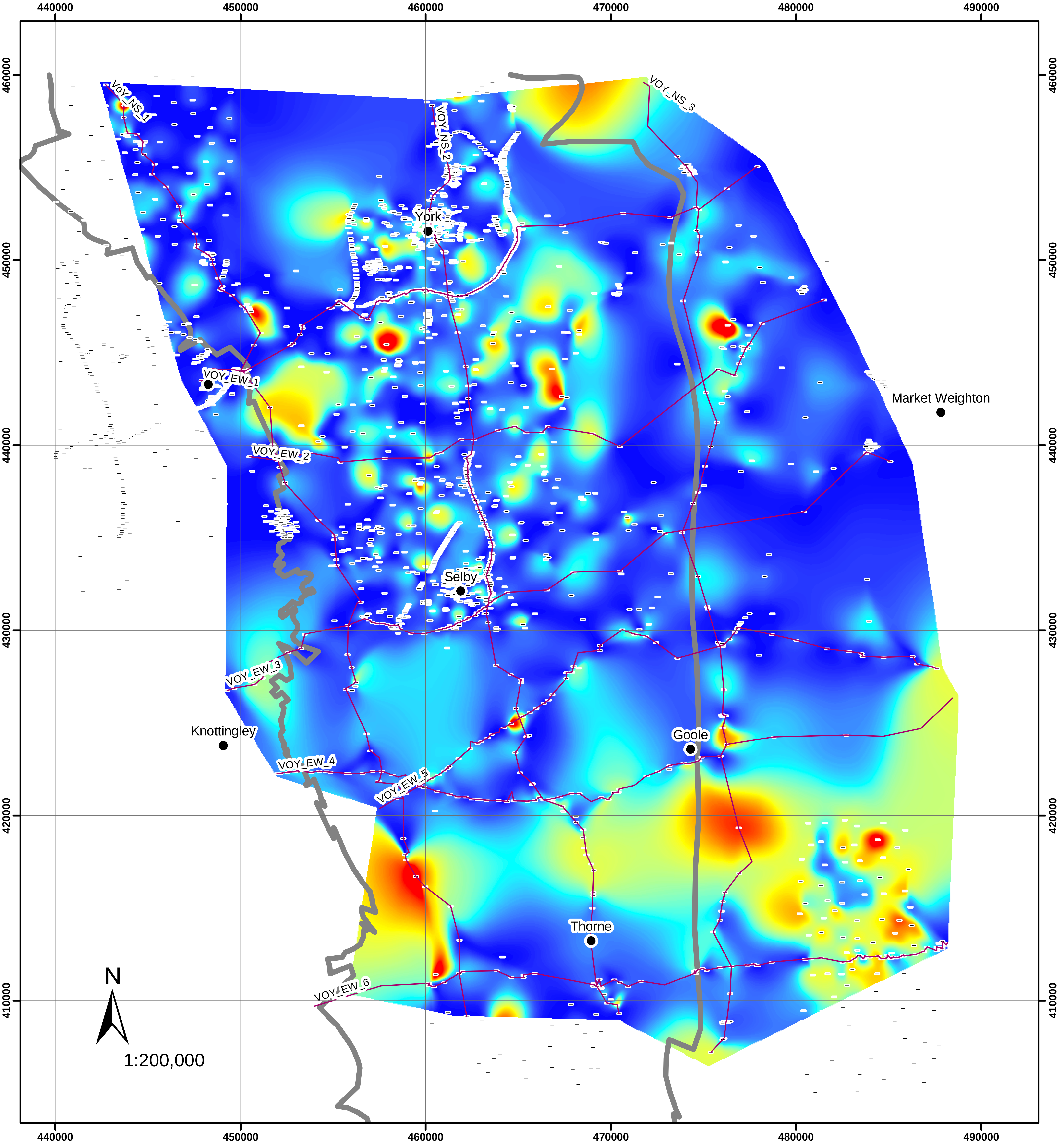
>=5 m

PLACE_NAMES

BOREHOLE_LOCATIONS

SSG_SUBCROP

LINES_OF_SECTION




**Vale of York 3-D Borehole Interpretation and Cross-Sections Study**

**SUPERFICIAL_AQUIFER_TOTAL_THICKNESS**

**Value**

High : >20 m

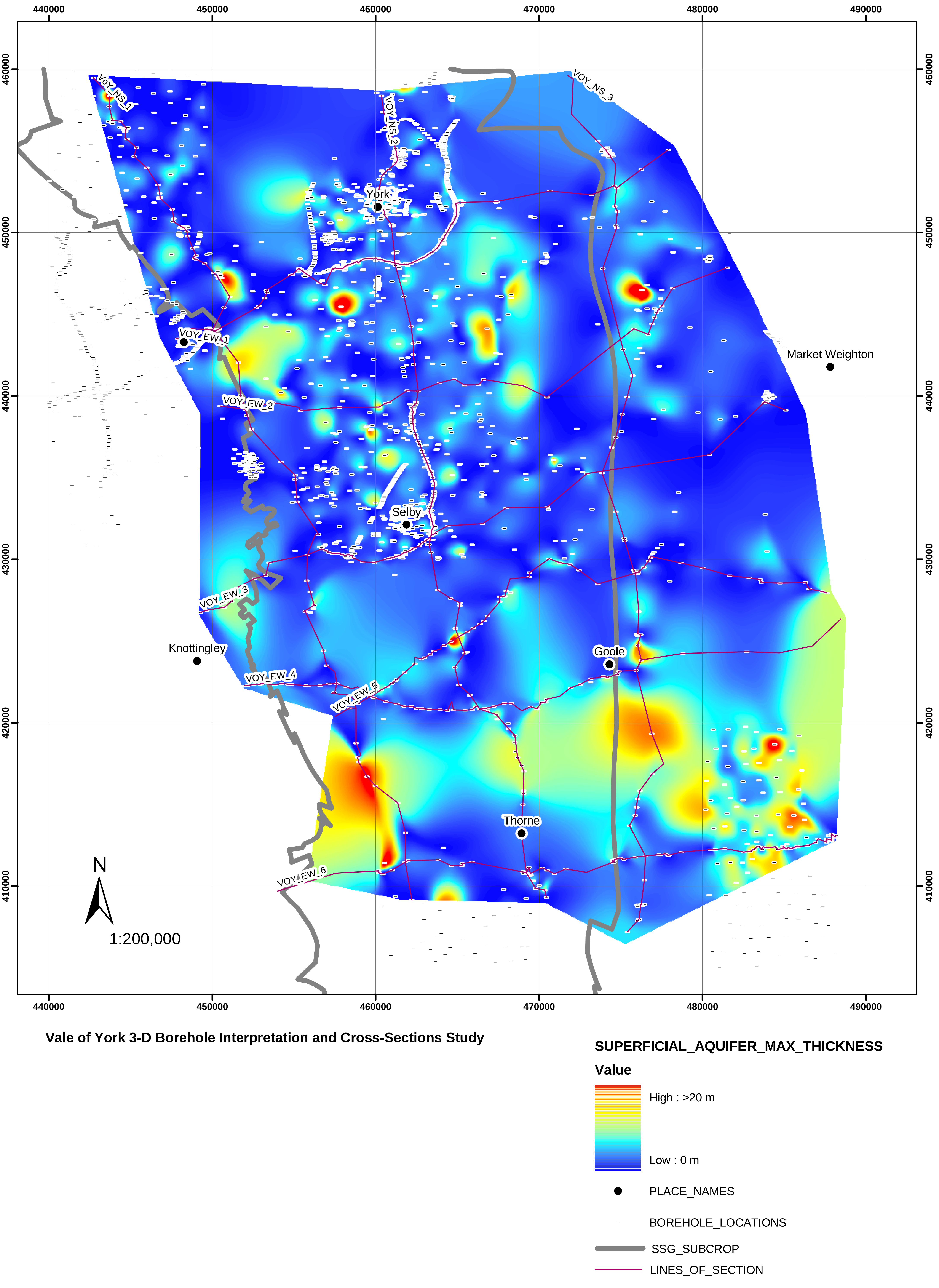
Low : 0 m

PLACE_NAMES

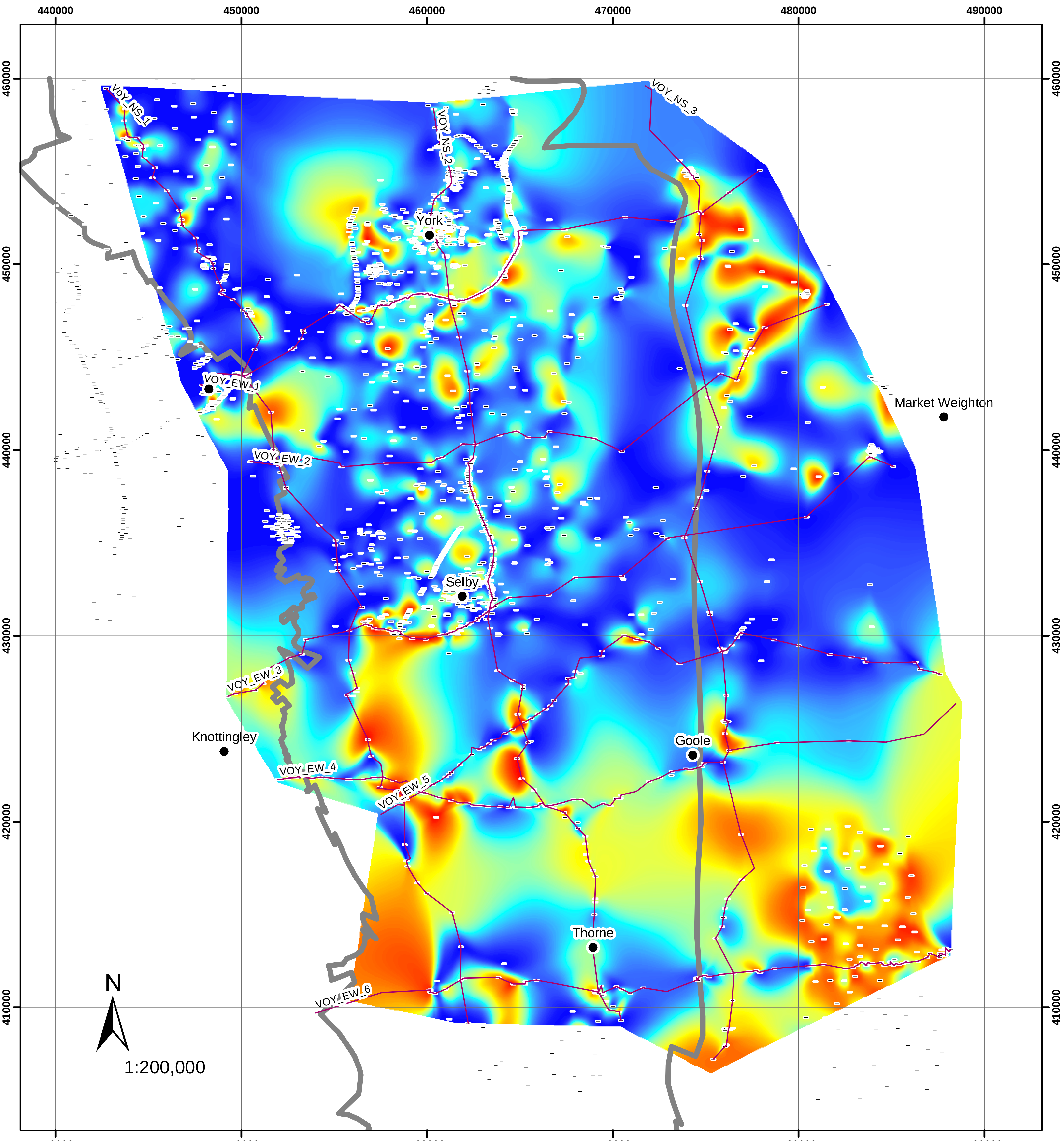
BOREHOLE_LOCATIONS

SSG_SUBCROP

LINES_OF_SECTION




**Vale of York 3-D Borehole Interpretation and Cross-Sections Study**




**Vale of York 3-D Borehole Interpretation and Cross-Sections Study**

**RATIO_SUPERFICIAL_AQUIFER:AQUITARD**

**Value**

AQUIFER DOMINANT (1)

EQUAL PROPORTIONS (0.5)

AQUITARD DOMINANT (0)

PLACE_NAMES

BOREHOLE_LOCATIONS

SSG_SUBCROP

LINES_OF_SECTION