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# Hydrochemical characterisation of the Sherwood Sandstone Group in the vicinity of Thoresby Colliery, Nottinghamshire

Environmental Protection Programme

Internal Report IR/04/025

BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/04/025

# Hydrochemical characterisation of the Sherwood Sandstone Group in the vicinity of Thoresby Colliery, Nottinghamshire

B A Klinck, D Beamish and J Trick



*Key words colliery spoil, leachate, groundwater plume*

*Cover illustration*

Rotary drilling rig used to recover core for porewater extraction

*Bibliographical reference*

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# Foreword

This report is the published product of a study by the British Geological Survey (BGS) HiRES Geophysical surveys project. It describes the hydrochemical investigations carried out in the summer of 2003 in the vicinity of Thoresby Colliery to validate airborne geophysical investigations and interpretations.

# Acknowledgements

Mr Rowan McFerran, of Thoresby Estate Office is thanked for providing access onto the Estate for drilling. Mr David Edwards of Newark and Sherwood District Council arranged access to the Sherwood Forest visitor centre and drilling was carried out with the permission of English Nature. Of the individuals who have contributed to the project we would particularly like to thank the following: Dave Buckley for providing the down-hole geophysical logs for this study, pore water extraction was completed at BGS Wallingford with the help of Richard Shaw, and groundwater chemical analysis was performed in the BGS laboratories at Keyworth under the quality control of Shaun Reeder. Keith Tivey of the Environment Agency was very helpful in providing the background data used to construct the Durov Plots.

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# Summary

This report describes the detailed ground investigations that were carried out in the vicinity of Thoresby Colliery as part of the BGS HiRES research programme and their results.

The introduction to the report briefly describes the background airborne geophysics acquired as part of the joint Geological Survey of Finland (GTK) - British Geological Survey (BGS) trial airborne environmental and geological surveys flown in June 1999. The main objective of these surveys was to test the efficiency of the GTK airborne electromagnetic (AEM) system in the mapping of potential pollution problems in the UK environment. The survey in the vicinity of Thoresby Colliery identified a conductivity anomaly that was attributed to migration of colliery spoil leachate as a groundwater plume to the east of the site.

Three boreholes were drilled into the geophysical anomaly. Section 2 of the report discusses the results of groundwater monitoring and pore water extraction from the drill core. The groundwater flow direction has been determined to be to the east of the colliery.

Down hole geophysical logging is reported and it is demonstrated that there is a very strong correlation between the borehole induction logs, total dissolved solids and chloride in the pore waters.

A comparison of background groundwater quality and pore water chemistry with published colliery spoil leachate data indicates that it is possible to explain the core, pore water chemistry as a result of mixing of groundwater with a colliery spoil leachate source term. The close similarity of the Cl/Br ratio of pore waters in the groundwater plume with Thoresby Colliery process waters provides supporting evidence for this model to explain the origin of the plume and hence of the AEM anomaly.

# 1 Introduction

The Geological Survey of Finland (GTK) in collaboration with the British Geological Survey (BGS) flew a series of four trial airborne environmental and geological surveys in June 1999; the trials were co-sponsored by the Department of the Environment, Transport and the Regions and the Environment Agency. The main objective of these surveys was to test the efficiency of the GTK airborne electromagnetic (AEM) system in the mapping of potential pollution problems in the UK environment. Gamma spectrometric and magnetometric measurements were also collected to see to what extent these techniques provide complementary information. The surveys and initial results provided by all of the techniques employed are described by Beamish et al. (2000a,b).

One of the four areas, the Shirebrook survey, included a 13 km x 9 km area in northern Nottinghamshire. Here one of the objectives was to examine the influence of collieries situated above the Triassic Sherwood Sandstone aquifer. The AEM survey data, when converted to conductivity, revealed extensive zones of enhanced subsurface conductivity in the vicinity of all the collieries in the survey area. The purpose of the present report is to provide information regarding subsequent investigations to confirm the geochemical nature of the conductive zone identified in the vicinity of Thoresby Colliery.

## 1.1 AEM RESULTS

The AEM regional scale results obtained using E-W flight lines spaced at 200 m are shown in Figure 1. The nominal flight elevation was 40 m above ground. Here a half-space conductivity model, based on the high frequency (14 kHz) AEM data, is shown selectively contoured on the base topographic map. Black contours denote values in excess of 100 mS/m and three levels of colour (red, yellow, blue) then denote values decreasing to 20 mS/m. According to background studies, this cut-off level should identify anthropogenic sources of enhanced conductivities. It is clear from the results that highly conductive features (predominantly black contours) occur in association with all of the colliery spoil areas including the former pits of Clipstone, Langwith, Shirebrooke, Warsop Vale as well as the active pits of Thoresby and Welbeck. Away from the immediate vicinity of spoil zones, less conductive anomalies suggesting a plume-like geometry are observed.

The zone around Thoresby Colliery, shown as a 3 km x 2 km rectangle in Figure 1 was selected for further ground-based studies. The area was overflown with ‘in-fill’ flight lines thus providing an E-W flight line separation of 50 m. Figure 2 shows the AEM conductivity results obtained at high frequency (HF, shallow) and low frequency (LF, deeper) across the 3 km x 2 km area, centred on the Thoresby site. Conductivity values are contoured between a low value of 20 mS/m (blue line) and 70 mS/m (magenta line). It can be seen that the lower frequency results (Fig. 2b) indicate a more extensive high conductivity anomaly (> 70 mS/m) to the east of the mine. The eastern-most area, largely beyond Easting 464 km, lies outside the mine perimeter. This area contains the locations of 4 ground-based Vertical Electric Soundings (VES, star symbols) together with the 3 boreholes locations (red symbols) drilled. A detailed view of VES and borehole locations is shown on the base topographic map in Figure 3.

## 1.2 VES SOUNDINGS

A more detailed assessment of subsurface conductivity variations was made at the four VES locations (Figure 3) in 2002. The soundings were undertaken in March 2002 (VES 1,2 and 3) and in July 2002 (VES 4). The Schlumberger VES soundings were made with the ABEM SAS3000 Terrameter. Maximum AB/2 expansions were 200 m (VES 1), 160 m (VES 2), 160 m (VES 3) and 200 m (VES 4).

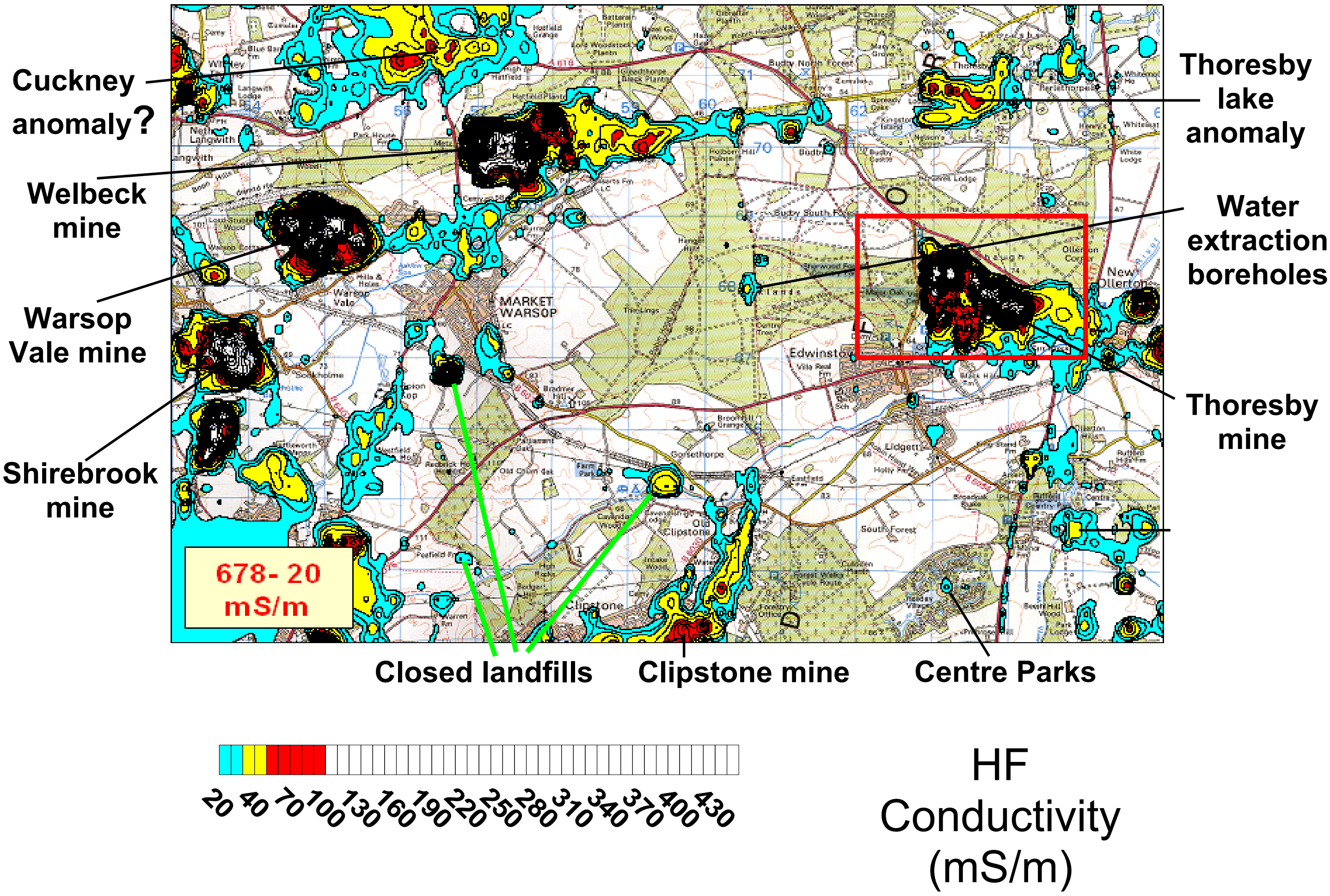



Figure 1 Half space conductivity model obtained from 14 kHz data across 13 x 9 km Shirebrook survey area. Data shown used 200 m east-west flight lines at a nominal elevation of 40 m. Conductivity values contoured in the range 20 to 450 mS/m. Areas with values > 100 mS/m are shown as black contours. Base topographic map (© Crown copyright. All rights reserved).

The one-dimensional conductivity models obtained at the 4 locations are shown in Figure 4. Two types of model are used. A conventional 'discrete-layer' inversion model is indicated by the red line with infill. This model assumes a discontinuous (layered) conductivity profile. A regularised 'Occam' inversion model is indicated by the blue line. This model forces the profile to be smoothly varying. The regularised models indicate that the most conductive parts of the profiles occur between 30 and 60 mbgl (VES sounding sites 1,2 and 3) and between 50 and 70 mbgl (VES sounding site 4). The most conductive zone in the models is that at VES sounding 3 (66 mS/m). The discrete layer models indicate transitions to a highly conductive zone at depths of : 17.3 m (VES 1), 12.6 mbgl (VES 2), 13.8 mbgl (VES 3) and 31.8 mbgl (VES 4). These depths are similar to the depths to the water levels in the nearest boreholes (see Table 1).

When comparing VES results with the results from borehole geophysical logging the distances between the centre of the VES sounding and the borehole locations should be noted. Distances range from 145 m (VES 1 to BH 1), 51 m (VES 2 to BH 2), 152 m (VES 3 to BH 2) and 280 m (VES 4 to BH 3).

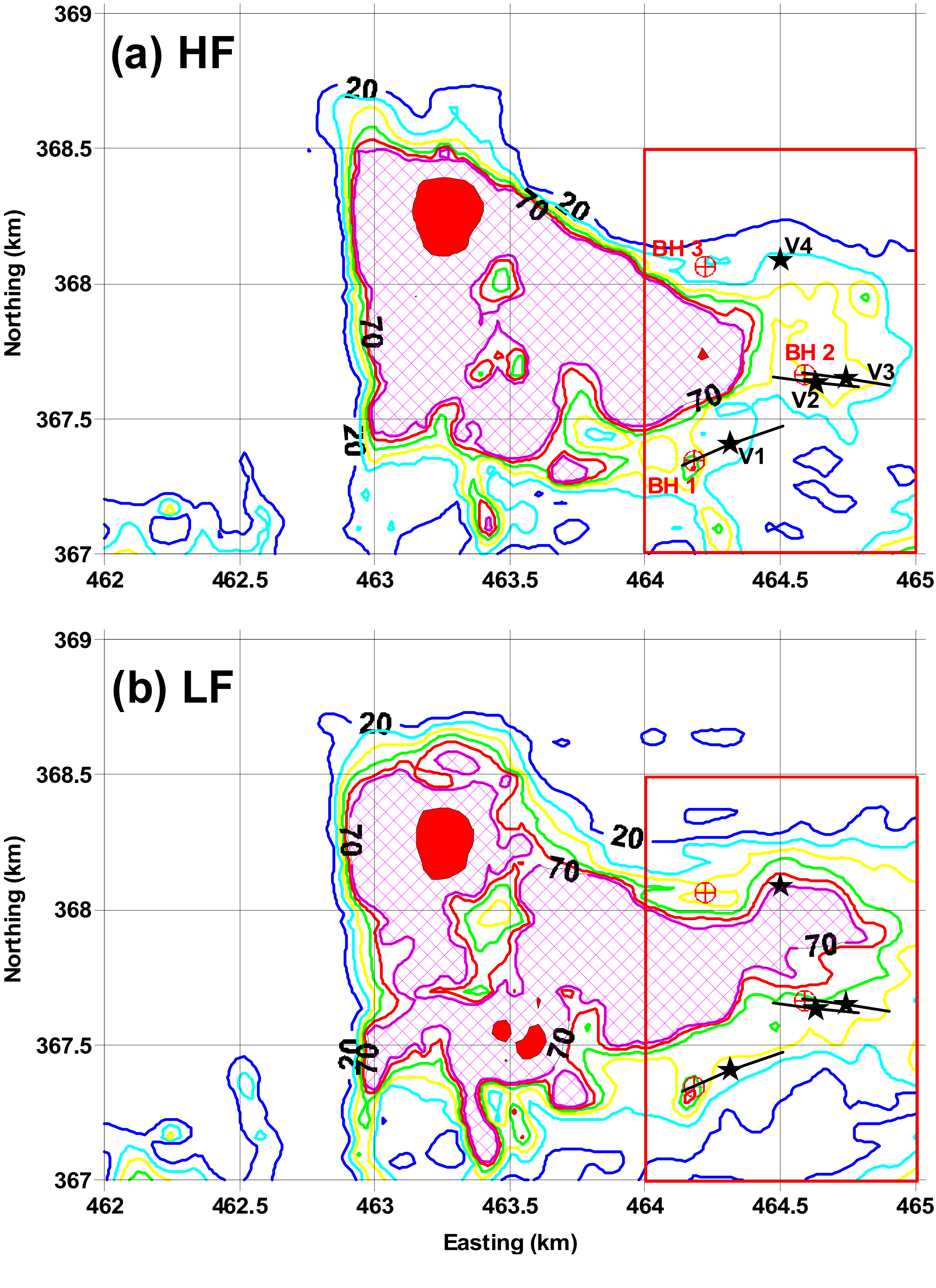



Figure 2 AEM conductivity models across 3 x 2 km area centered on Thoresby Colliery. (a) High frequency (shallow), (b) Low frequency (deeper) results. Values contoured in the range 20 to 70 mS/m. Values less than 20 mS/m considered to be background. Values > 70 mS/m in cross-hatch. Values > 200 mS/m in red.

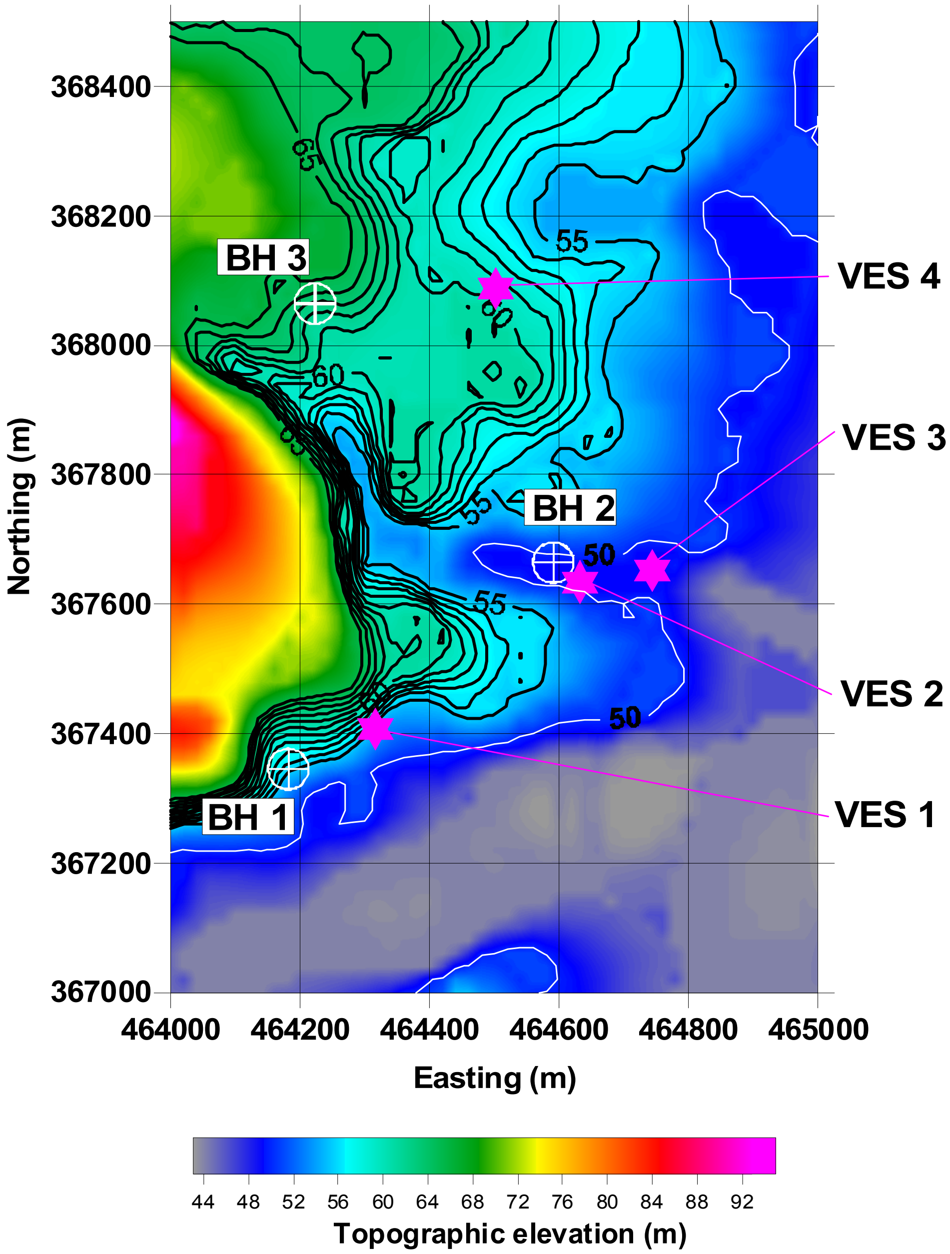



Figure 3 Locations of 4 VES soundings (sounding centres) and 3 Borehole locations shown on base elevation contour plot.

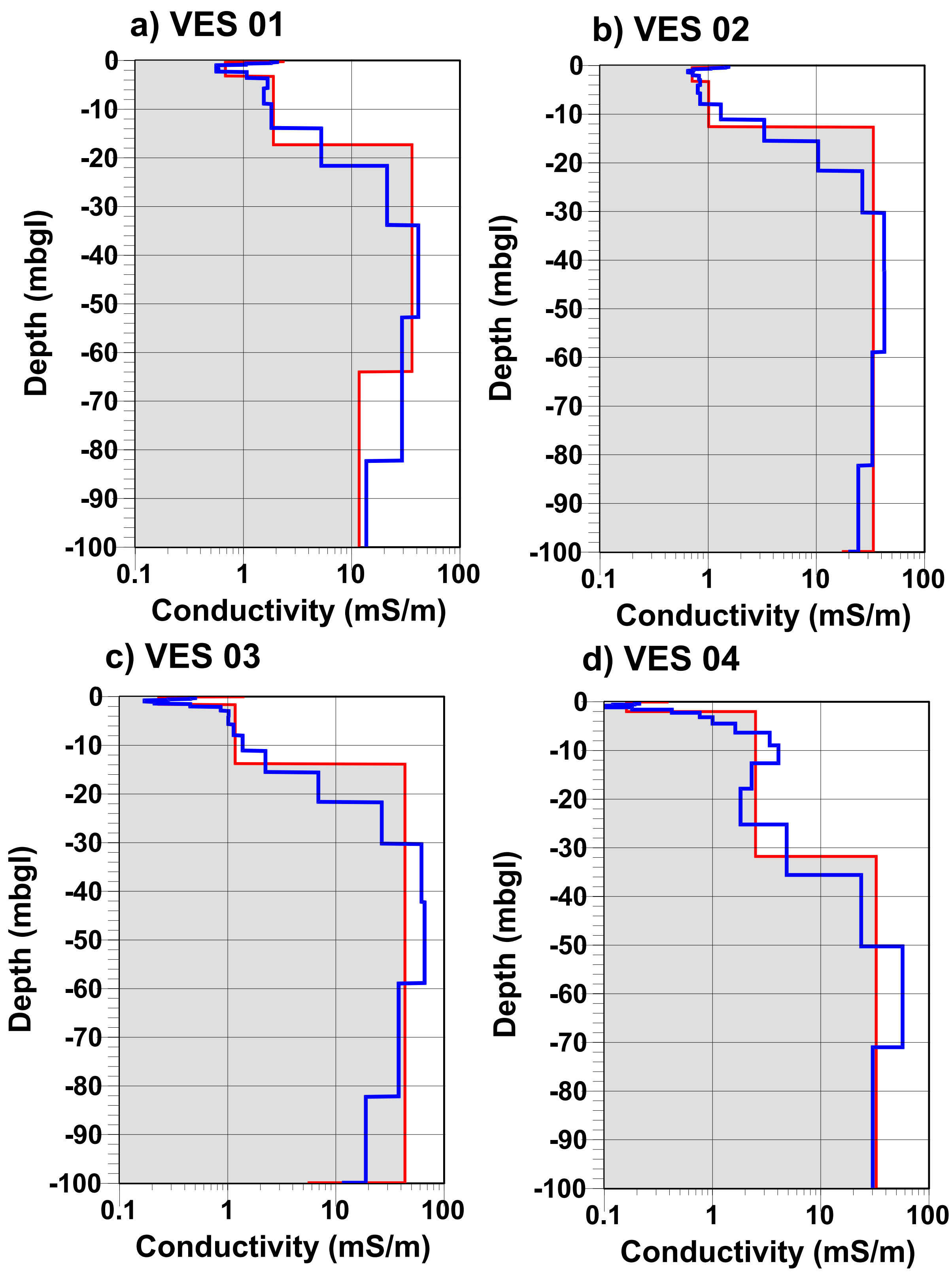



Figure 4 1D conductivity models obtained from 4 Vertical Electric Soundings. Red line with infill indicates a few layer model. Blue line indicates an equivalent smooth (Occam) model.

### 1.3 BOREHOLE DRILLING PROGRAMME

Three boreholes sites were selected to provide information on hydraulic gradient and to recover core for pore water extraction. The borehole locations were constrained to some extent by access limitations, in particular it was not possible to secure permission to drill on land managed by Thoresby Colliery.

The boreholes were drilled using rotary-cored air flush and a temporary plastic casing was installed to prevent the upper twelve metres of unconsolidated material running into the hole. The boreholes were levelled to a benchmark at the electrical substation at SK 64179 67225. After a few days to allow the holes to stabilise the groundwater levels were measured with an electric tape dipper. Table 1 provides details of the borehole locations and calculated elevations.

A suite of borehole geophysical logs was also run including gamma, resistivity, induction, temperature and electrical conductivity. Using the induction log, which is a better indication of formation conductivity changes than the EC log, intervals of core were selected for pore water extraction by centrifugation. The pore waters were preserved and analysed for major and minor elements by Induced Coupled Plasma Atomic Emission Spectroscopy (ICP-AES). The results of the pore water analyses are tabulated in Appendix 1.

The remaining core was logged and then disposed of and the borehole temporary completions removed prior to the boreholes being backfilled as agreed with the site custodians.

Background geochemical information for producing groundwater wells was obtained from the Environment Agency. Thoresby Colliery permitted access onto their site to sample a borehole, used to abstract process water, and the settlement lagoons where process water and mine drainage are allowed to settle before discharge. For health and safety reasons it was not possible to sample the highly conductive lagoon feature indicated by the highest conductivities in Figure 2.

Table 1 Borehole Details

| **Borehole Number** | **Easting** | **Northing** | **Elevation (m aod)** | **Water Level (m bgl)** | **Date Dipped** |
|---|---|---|---|---|---|
| Thoresby 1 | 64182 | 67345 | 53.38 | 15.99 | 7/04/03 |
| Thoresby 2 | 64591 | 67664 | 48.76 | 12.80 | 7/04/03 |
| Thoresby 3 | 64223 | 60064 | 61.92 | 25.40 | 8/04/03 |

# 2 Results

### 2.1 LITHOLOGICAL DESCRIPTION

Figures 5, 6, and 7 synthesise the results of the lithological logging of the boreholes. In general core recovery was of the order of 90%. In all three boreholes the upper part of the sequence consisted of soft sand with occasional pebbles. This is considered to be the weathered top to the underlying sandstone. The sequence is dominated by laminated and bedded pebbly sandstone. Because of the highly conductive nature of the sandstones due to pore fluid composition it has not been possible to interpret the resistivity log in terms of porosity or sand content.

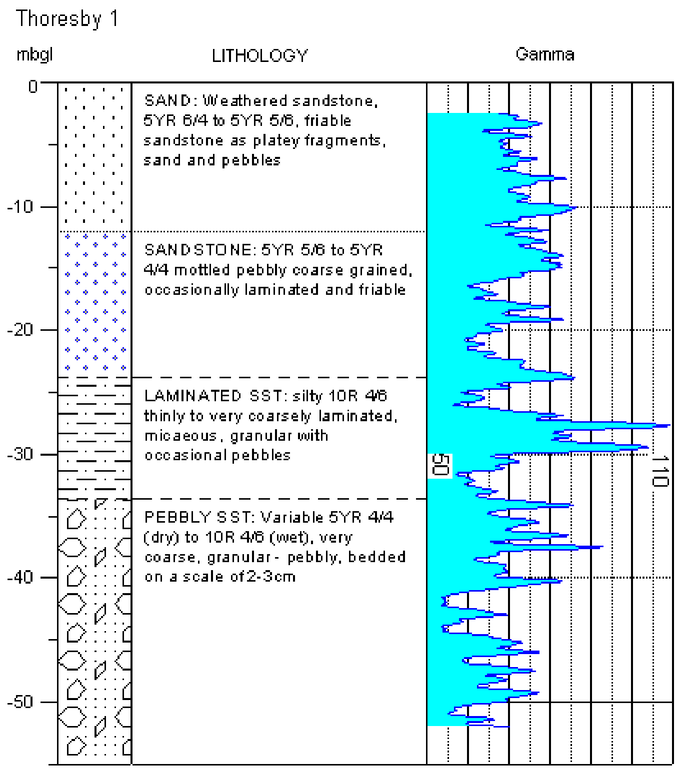



Figure 5 Lithological log for Thoresby 1

The sandstones show a range of lithologies ranging from dominantly medium and course grained light brown to dark reddish brown sandstones to course granular moderate reddish brown to dark reddish brown pebbly sandstones. Sub-rounded to well-rounded, flat, elongate discoid and oblate pebbles range in size from 10 to 50mm and consist predominantly of quartzite. The sandstones are often bedded and occasionally bedding plane surfaces are micaceous. In borehole Thoresby1 the sandstone become thinly laminated with micaceous partings between 24 and 34 mbgl.

The natural gamma log indicates that some mudrocks are present in the sequences. In general these were not recovered during coring. In Thoresby 1, Figure 5, a gamma peak is associated with the laminated sandstone sequence that has higher clay content than the sandstones and pebbly sandstones in the rest of the sequence. Figure 6 shows a distinct natural gamma peak corresponding to a loss of core that has been attributed to a mudstone band in Thoresby 2 at around 25 metres depth. In Figure 7 the gamma log is quite noisy but a quite well defined peak at about 43 metres depth corresponds to about 0.5 metres of core loss that may be attributed to the presence of a mudstone band in Thoresby 3.

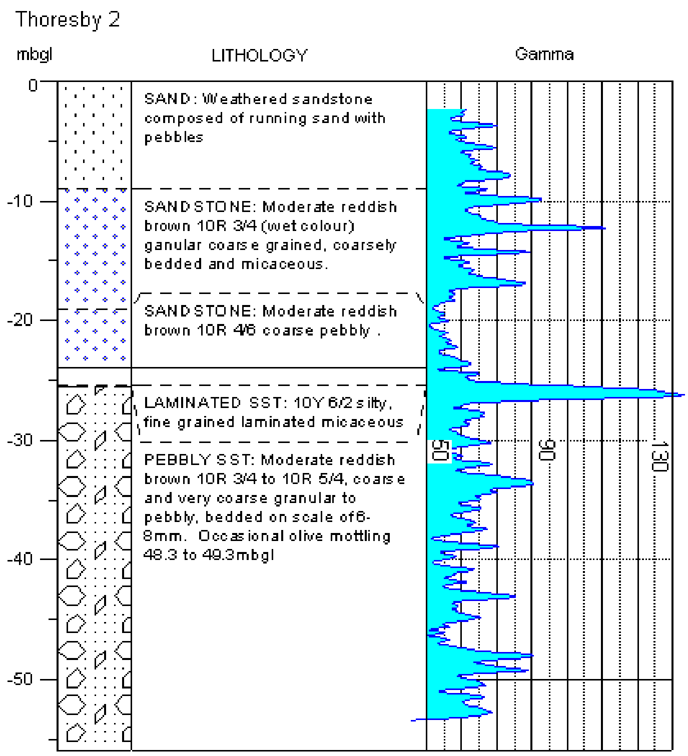



Figure 6 Lithological log for Thoresby 2

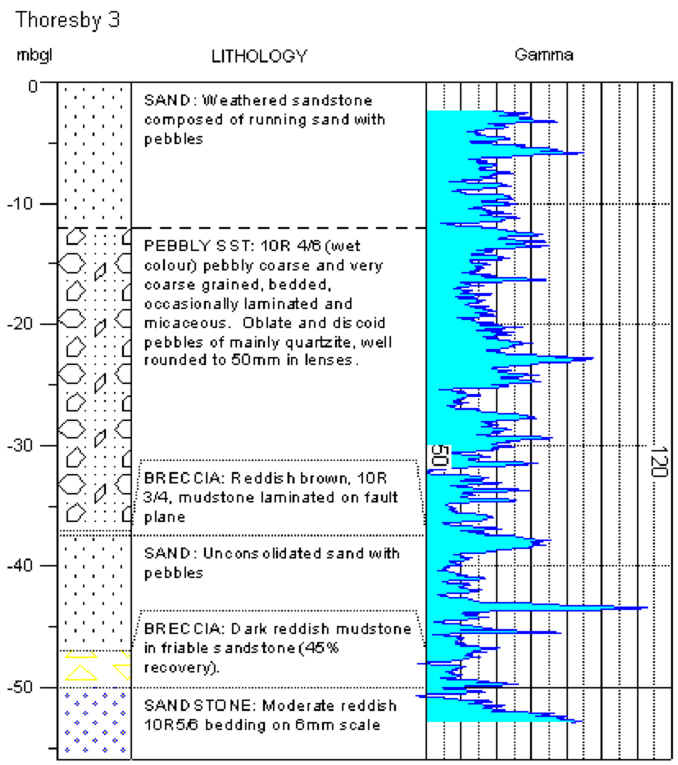



Figure 7 Lithological log for Thoresby 3

## 2.2 GROUNDWATER FLOW DIRECTION

Based on the data provided in Table 1 the hydraulic gradient is 0.203 on an azimuth of 91.6°. The elongated shape of the conductivity anomaly is consistent with flow in this direction, away from Thoresby Colliery, of a dissolved contaminant plume. The temperature and electrical conductivity logs of the well bore fluid are reproduced in Figure 8. On the whole the flow appears to be homogeneous in boreholes Thoresby1 and Thoresby 3. In Thoresby 1 at around 45 mbgl there is a very slight increase in temperature and a reduction in fluid electrical conductivity (EC) that possibly corresponds to a slight increase in flow at that depth. In Thoresby 2 the pattern is different and there is inflow at around at 25 and 27 metres that may be fissure controlled, or alternatively due to a perched condition of different composition on the postulated mudstone band at around 25 metres. The main body of the contaminant plume is below 27 metres.

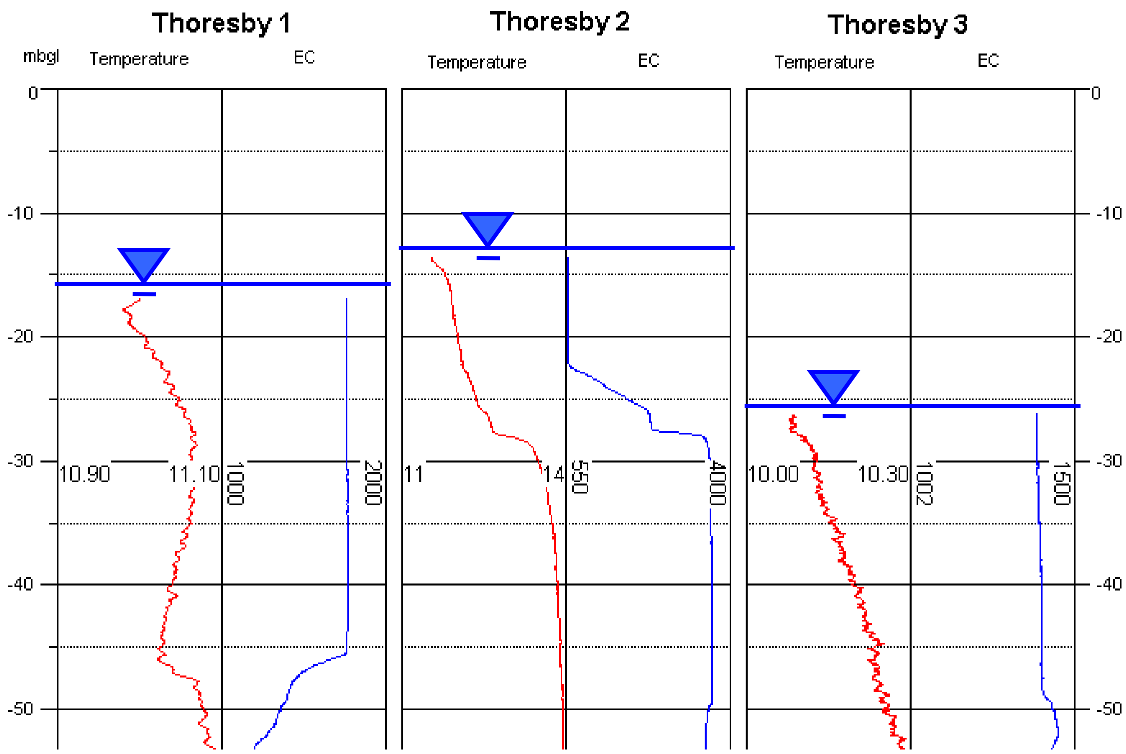



Figure 8 Temperature and Electrical Conductivity logs for the Thoresby boreholes

## 2.3 HYDROCHEMISTRY

Sections of core and unconsolidated sand were selected from each borehole for pore water extraction; core selection was based on features seen on the induction logs. Three other water samples were obtained from Thoresby Colliery. These were a sample of borehole water that is used for processing on the site and that is completed in the Sherwood Sandstone (BGS Well Record SK66 NW /30), a sample from the Storm Tank, and a sample from the final settlement pond.

### 2.3.1 Background Water Quality

In order to determine the impact of the colliery spoil on groundwater quality it has first been necessary to establish the background hydrochemistry of the Sherwood Sandstone in the vicinity of the site.

Table 2 EA boreholes used for background information

| EA Reference | Name | Data used | Easting | Northing |
|---|---|---|---|---|
| 39480880 | Budby Forest | 12/12/95-21/3/01 | 60400 | 70700 |
| 39480870 | Budby | 10/10/88 | 61700 | 70704 |
| 39770700 | Kirton | 24/7/92-28/1/03 | 68300 | 68800 |
| 38480450 | Boughton | 13/6/75-12/6/95 | 67000 | 69800 |

Hydrochemical information has been provided by the Environment Agency (EA) for a number of production boreholes completed in the Sherwood Sandstone. Table 2 provides details of the EA monitored boreholes used in this study.

The Durov Plot in Figure 9 illustrates the compositional range of these groundwaters. Kirton and Boughton boreholes are on the down gradient side of the site and the Budby boreholes are on the up gradient side of the site. The water types classify as a Ca-Mg-HCO3-Cl type.

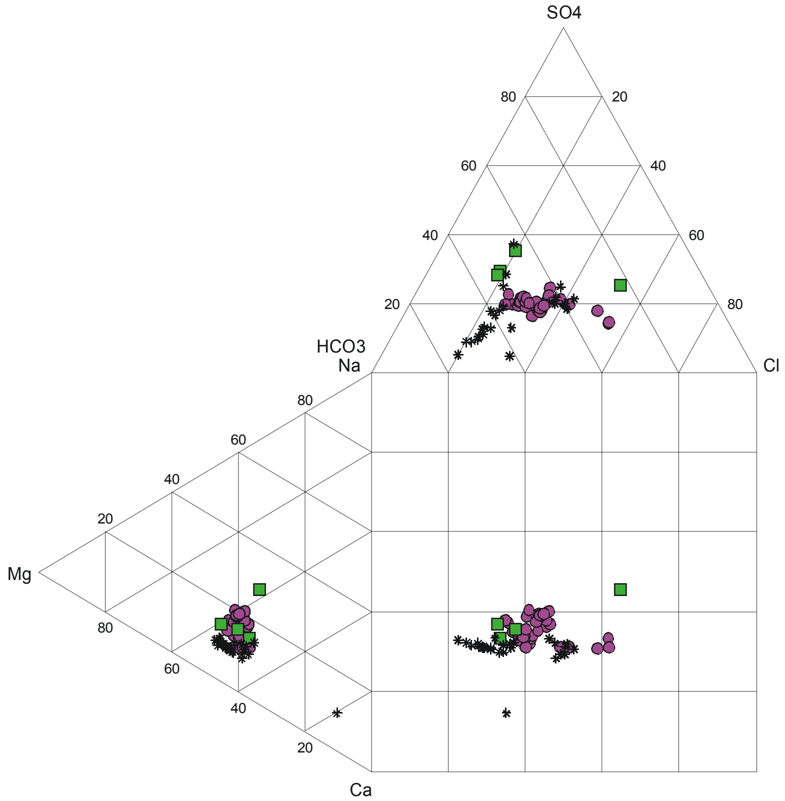



Figure 9 Hydrochemistry of EA monitoring wells (Budby = green squares; Boughton = pink circle, and Kirton = black cross)

### 2.3.2 Source Term Water Quality

A literature search has provided information on colliery spoil leachate quality for tips in neighbouring Derbyshire and Yorkshire areas (Banks et al., 1997). This study demonstrated that mine waters in general are characterised by low chloride (typically between 10 and 40mg/l), unlike colliery spoil leachates that tend to have chloride concentrations in excess of 1000 mg/l. These values are in sharp contrast to Coal Measure formation brines reported by Downing and Howitt, (1969) with chloride concentrations in excess of 14000 mg/l.

Although it was not possible to collect any leachate from the Thoresby spoil tips two process-water samples were collected. The complete analysis for these waters is provided in Appendix 2. This water derives from borehole water that is used in dust suppression and coal washing. Effluents are first led to a concrete bunded storm tank where some settlement occurs and finally to a lagoon where some of the water is recirculated into the processing loop. The main feature of the storm tank effluent is high potassium and high chloride concentration, reduced iron of 5 mg/l and aluminium below detection, values more typical of diluted formation water. The effluent is net alkaline with a pH of 7.17.

### 2.3.3 Plume hydrochemistry

The chemical profiles for the three investigation boreholes are presented in Figures 10-12. The profiles selected are the induction log, which gives a good representation of the formation conductivity, total dissolved solids (TDS), (i.e. the sum of anions and cations), and chloride. It is evident from the plots that in all three cases the plot of chloride mirrors the induction log most closely. This is expected, as chloride is the main contributor to the TDS.

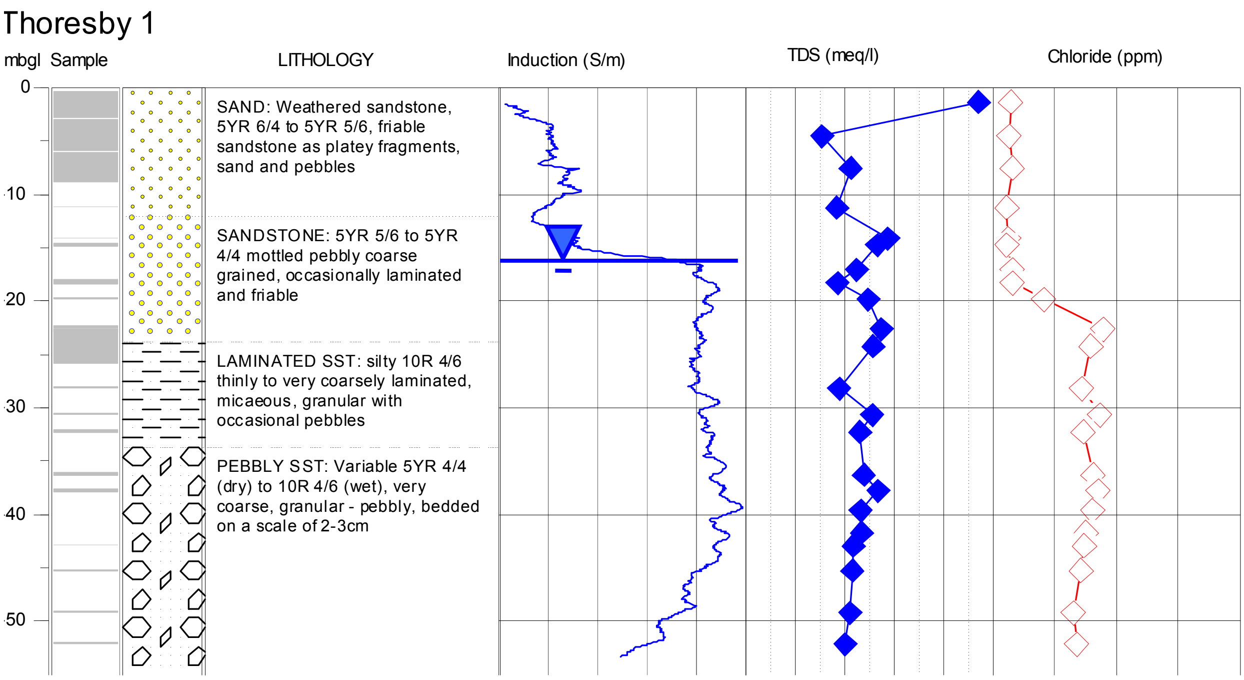



Figure 10 Pore water chemistry for Thoresby 1.

In Thoresby 1 the departure in trend of the TDS curve is due to a very high sulphate concentration (3272 mg/l) in the upper 3m-sampled interval. There is no obvious natural explanation for this and it is thought to be due to an analytical error, a theory supported by the very poor ionic balance for this sample (-66%). Both the induction log and the chloride concentration confirm that a chloride plume occupies the whole water column, the maximum concentration is about 450 mg/l.

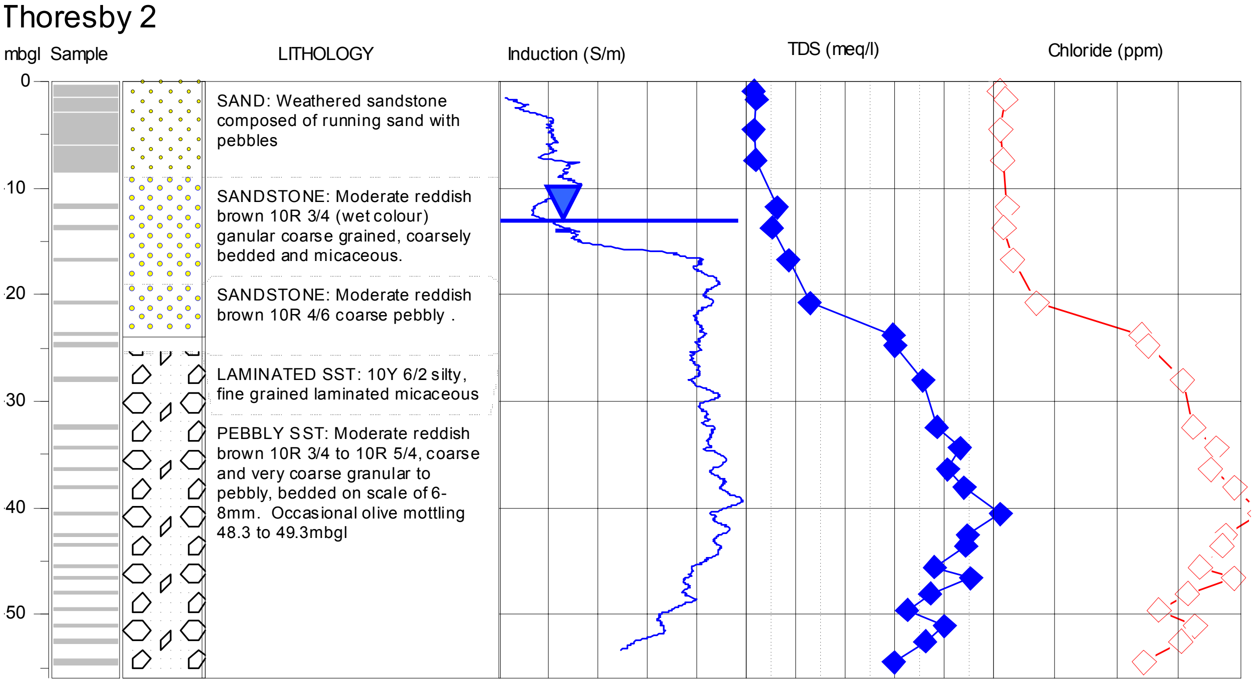



Figure 11 Pore water chemistry for Thoresby 2

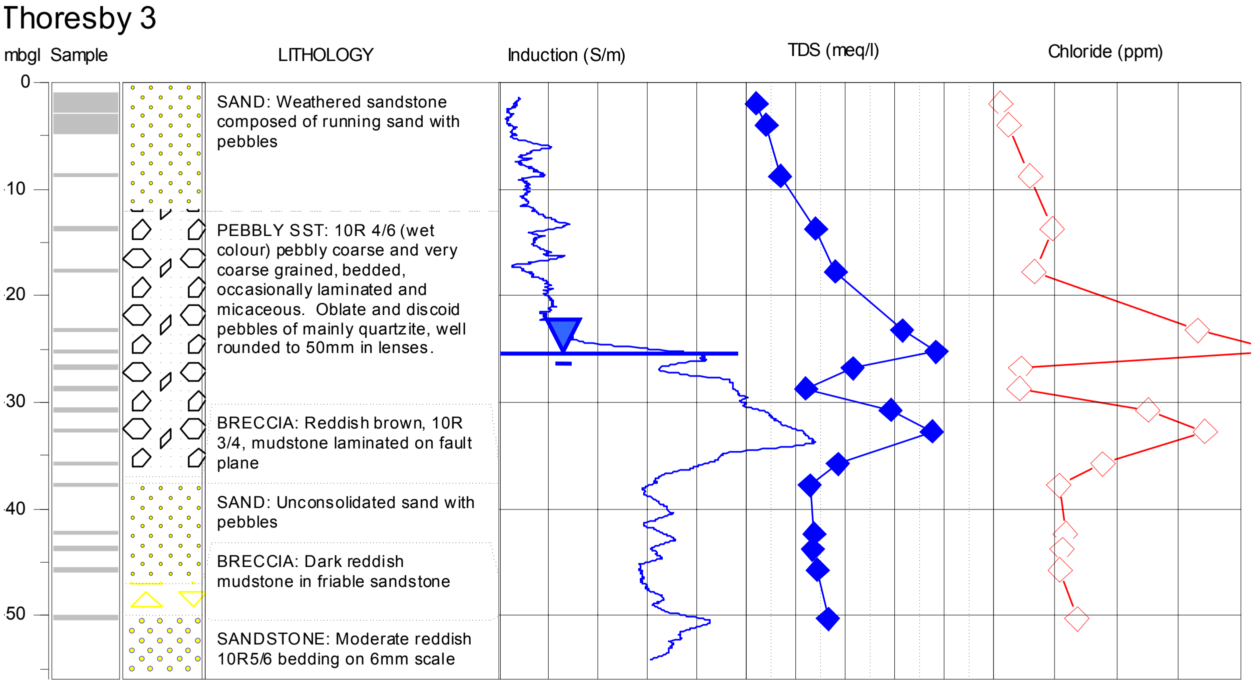



Figure 12 Pore water chemistry for Thoresby 3

In borehole Thoresby 2 the chloride/ TDS contaminant plume shows an increase in concentration at about 20mbgl and the overall shape of the curve suggests some density stratification. Maximum chloride concentration is 1083 mg/l.

Thoresby 3 borehole has a distinct profile with a pronounced chloride plume in both the unsaturated and saturated zones. In the unsaturated zone chloride concentration gradually increases to 1165 mg/l near the water table where it rapidly drops off. This feature is believed to be related to road salting run off rather than infiltration of colliery spoil leachate as this borehole is very close to the main road. There is also high total organic carbon and ammonium content suggesting a possible anthropogenic source. In the saturated zone the contamination appears to occur as a lens at about 35mbgl with a maximum concentration of 857mg/l chloride.

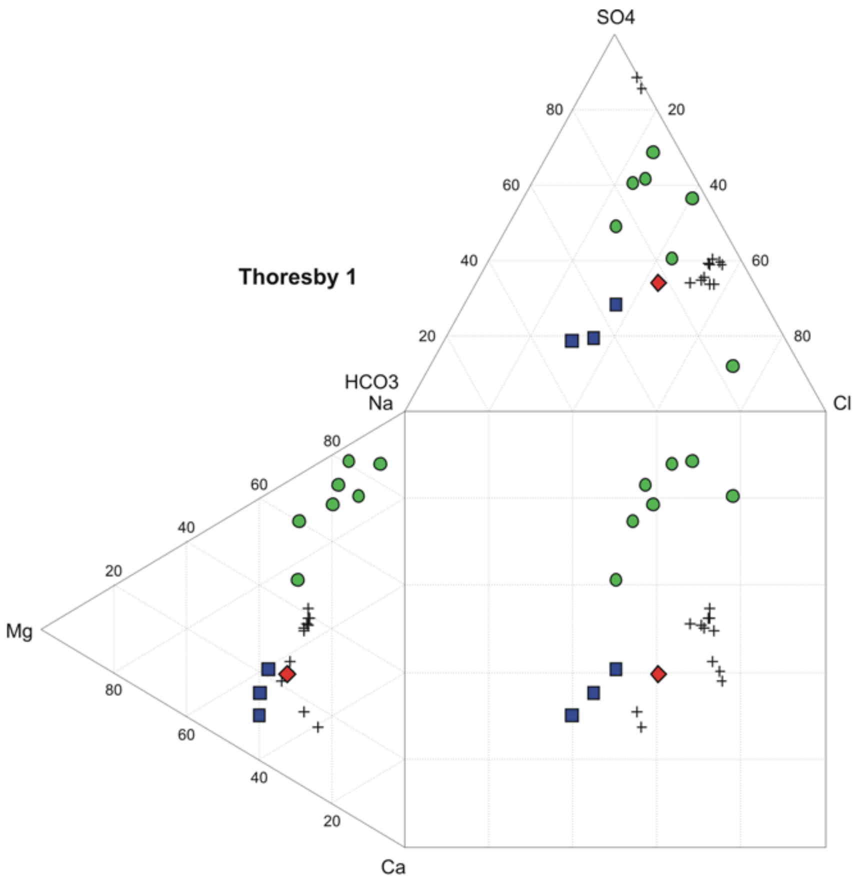
### 2.3.4 Evidence for a colliery spoil impact on groundwater

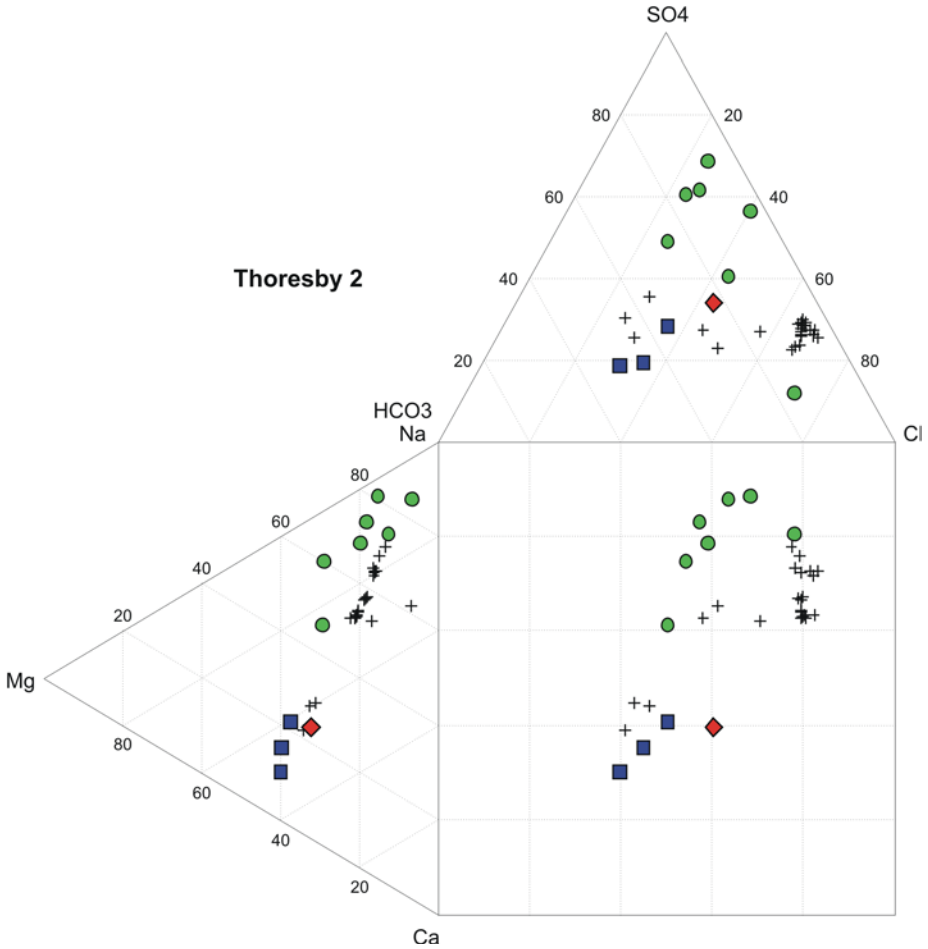
As well as the high chloride a number of other chemical parameters indicate a colliery spoil leachate source for the dissolved plume; in particular barium, potassium and sulphate. The latter two ions occur at concentrations in excess of background.

Figure 13 shows a Durov plot for each of the boreholes. The plot summarises the average major element composition for the EA boreholes (shown in Figure 9), data on colliery spoil leachates from the paper by (Banks et al., 1997), the chemistry of the Thoresby Colliery production well, and the chemistry of the pore water fluids for each borehole. A close inspection of the plots indicates that the pore water chemistry tends to fall in a field defined by the colliery spoil samples with some overlap, especially in Thoresby 1 and Thoresby 2, with the background wells. This is strong supporting evidence that the groundwater in the Thoresby wells is a mixture of a colliery spoil type and typical Sherwood Sandstone groundwater. The Thoresby Colliery production borehole tends to fall within the field of the pore waters indicating some impact from the colliery due to increased chloride and sulphate.

The anions chloride and bromide are generally considered to behave conservatively, i.e. they do not undergo attenuation processes in the aquifer matrix. Since the only effect of the aquifer flow on the colliery leachate is dilution the ratio of chloride to bromide should remain constant.

This is examined further in Figures 14 to Figure 16 that show the chloride – bromide ratio profile for each of the Thoresby boreholes. The red dashed line at 100 corresponds to the two process waters analysed from the site. It is evident that the chloride/ bromide ration in the plume as indicated by the chloride profile on the plots is strikingly constant at around 100.


SO4
Thoresby 1
HCO3
Na
Cl
Mg
Ca
20
40
60
80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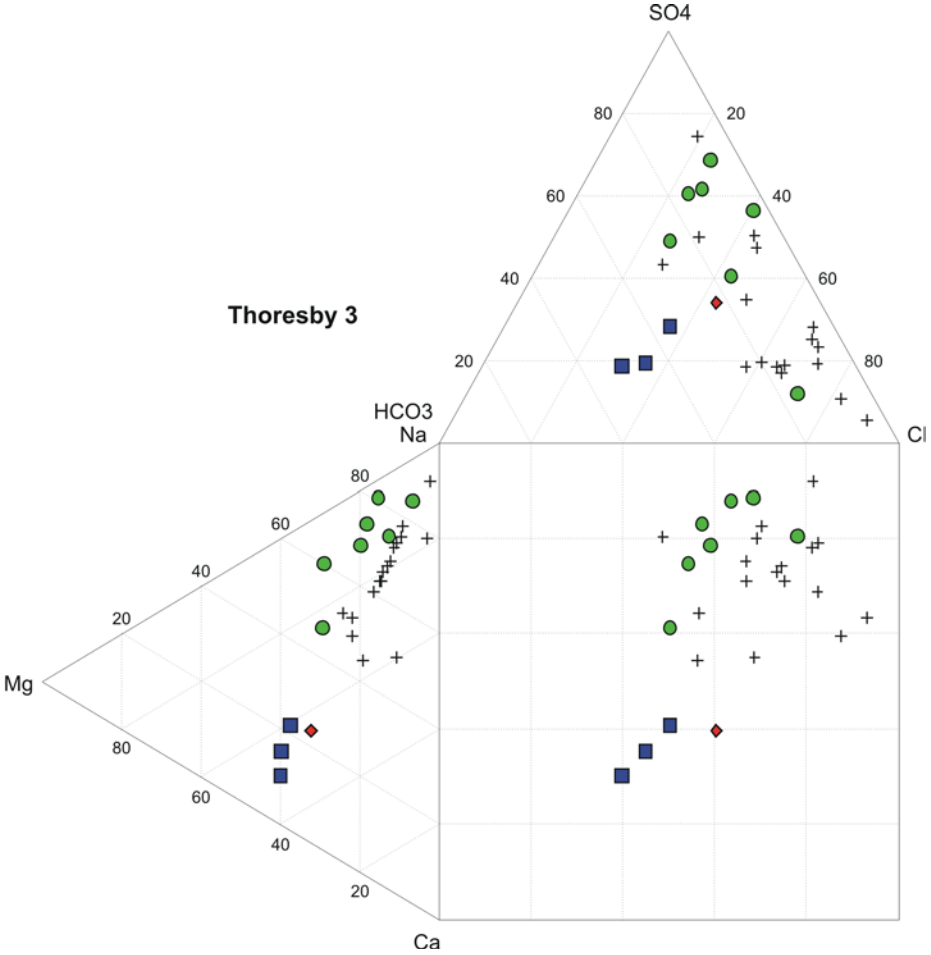


Figure 13 Durov plot of background water chemistry (blue squares), Thoresby Colliery borehole (red diamond), colliery spoil leachates (green circles) and pore water chemistry (crosses).

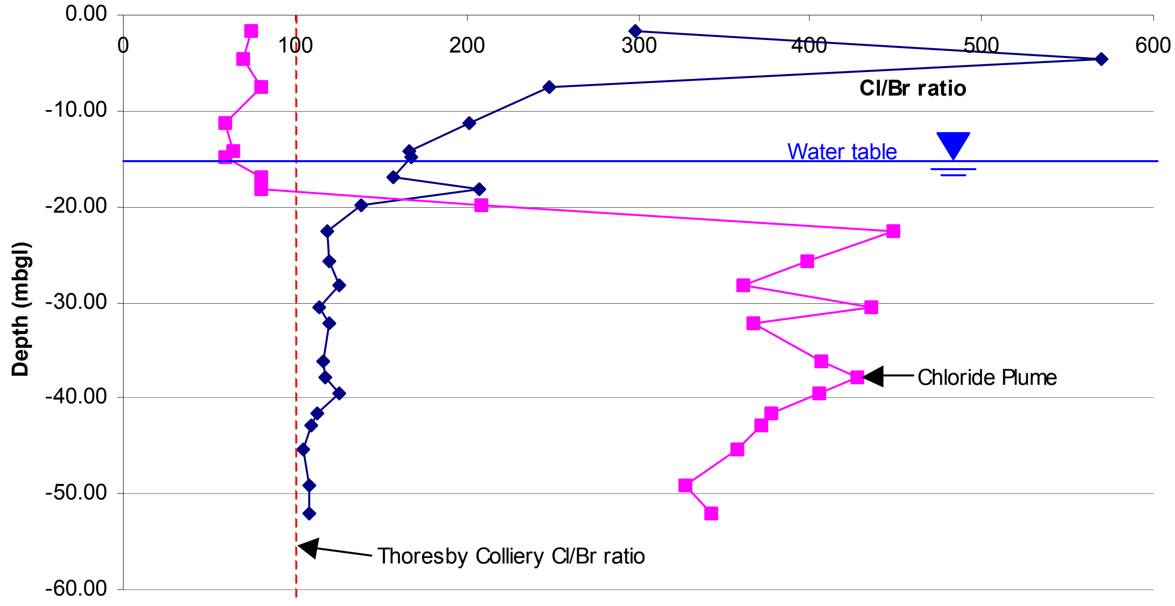


Figure 14 Thoresby 1 Chloride/Bromide Ratio

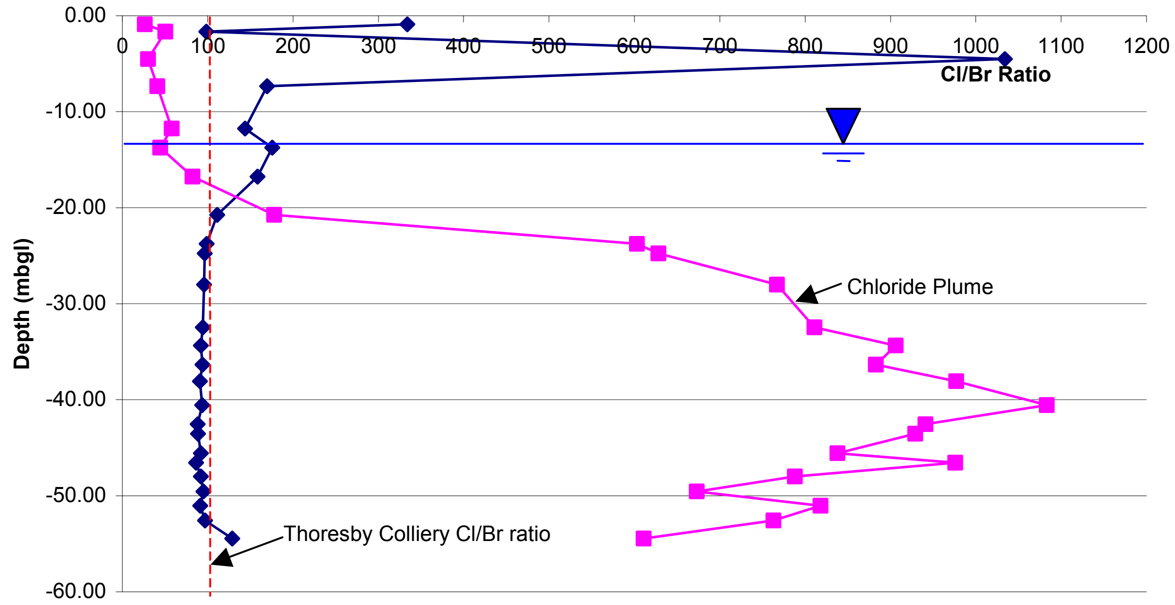


Figure 15 Thoresby 1 Chloride/Bromide Ratio

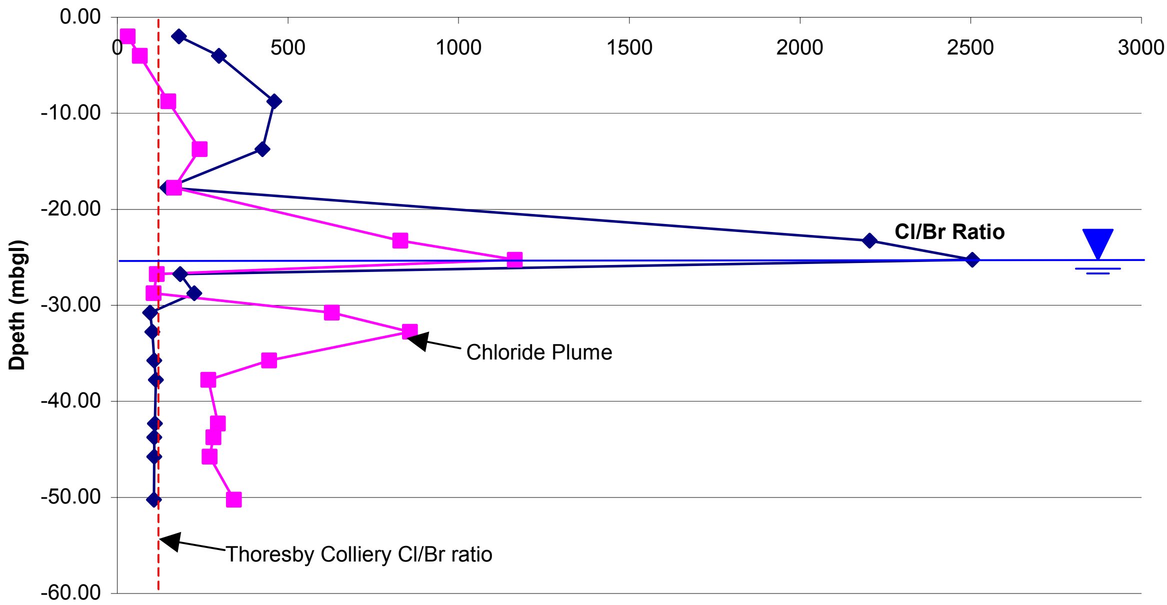


Figure 16 Thoresby 3 Chloride/Bromide Ratio

# 3 Conclusions

The three, cored boreholes have confirmed that there is a groundwater plume with high concentrations of total dissolved solids, compared to background, moving east from the Thoresby Colliery on a hydraulic gradient of 0.023 towards 90.6°. This result is consistent with the AEM data and with the ground-based geophysics.

The plume is characterised by being net alkaline with chloride concentrations falling somewhere between typical Sherwood Sandstone Group, background water compositions and fluid chemistry more typical of colliery spoil leachates. That the Colliery is having a minor impact on the groundwater at the Colliery is evidenced by the chemistry of the Thoresby Colliery abstraction borehole, which shows increased chloride and sulphate over background. These anions are also present in process waters at the colliery.

The Durov plots indicate that the chemistry of the pore waters could result from the mixing of a typical Sherwood Sandstone composition with a colliery spoil leachate. Weight is added to this interpretation by the fact that the chloride/ bromide ratio in the plume is very similar to the process water Cl/Br ratio found at Thoresby Colliery.

# Appendix 1

Pore water Chemistry for the Thoresby Boreholes

| LIMS Code | Borehole | Depth (m) | pH | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{2-}$ | $NO_3^-$ | Cation Total | Anion Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | meq $l^{-1}$ | meq $l^{-1}$ |
| 10595-0001 | 3 | 1.00-3.00 | 6.86 | 13.8 | 2.31 | 19.9 | 8.02 | <22 | 31.3 | 48.9 | 5.65 | 2.03 | 2.01 |
| 10595-0002 | 3 | 3.00-5.00 | 7.05 | 12.6 | 1.27 | 61.4 | 6.75 | <22 | 66.3 | 93.5 | 14.3 | 3.63 | 4.07 |
| 10595-0003 | 3 | 8.50-9.00 | 6.87 | 8.56 | 1.71 | 126 | 2.54 | <22 | 150 | 84.2 | 26.6 | 6.17 | 6.45 |
| 10595-0004 | 3 | 13.50-14.00 | 7.66 | 48.9 | 20.9 | 167 | 8.01 | 133 | 242 | 230 | <0.020 | 11.72 | 13.83 |
| 10595-0005 | 3 | 17.50-18.00 | 7.89 | 79.9 | 50.3 | 203 | 25.3 | 172 | 167 | 357 | 1.03 | 17.88 | 15.00 |
| 10595-0006 | 3 | 23.00-23.50 | 7.69 | 168 | 75.3 | 316 | 9.83 | 113 | 829 | 147 | 0.396 | 28.85 | 28.33 |
| 10595-0007 | 3 | 25.00-25.50 | 7.81 | 169 | 87.6 | 393 | 8.45 | 96 | 1165 | 95.6 | 1.02 | 33.06 | 36.45 |
| 10595-0008 | 3 | 26.50-27.00 | 7.58 | 162 | 52.2 | 229 | 20.5 | <44 | 116 | 613 | 0.214 | 22.94 | 16.10 |
| 10595-0009 | 3 | 28.50-29.00 | 7.75 | 32.0 | 12.4 | 186 | 5.48 | 198 | 107 | 230 | 0.304 | 11.02 | 11.08 |
| 10595-0010 | 3 | 30.50-31.00 | 7.71 | 86.8 | 37.0 | 444 | 7.54 | 100 | 629 | 310 | 1.17 | 26.89 | 25.95 |
| 10595-0011 | 3 | 32.50-33.00 | 7.67 | 104 | 43.4 | 569 | 9.71 | 110 | 857 | 382 | 1.00 | 33.75 | 34.06 |
| 10595-0012 | 3 | 35.50-36.00 | 7.58 | 73.2 | 31.8 | 222 | 5.94 | 95 | 445 | 158 | 3.29 | 16.24 | 17.55 |
| 10595-0013 | 3 | 37.50-38.00 | 8.16 | 27.9 | 12.1 | 195 | 4.31 | 144 | 267 | 116 | 6.58 | 10.97 | 12.46 |
| 10595-0014 | 3 | 42.10-42.50 | 7.85 | 52.7 | 21.5 | 177 | 4.81 | 119 | 295 | 115 | 11.7 | 12.21 | 12.90 |
| 10595-0015 | 3 | 43.50-44.00 | 8.02 | 46.1 | 19.2 | 185 | 4.57 | 121 | 282 | 98.0 | 16.8 | 12.05 | 12.29 |
| 10595-0016 | 3 | 45.50-46.00 | 8.05 | 48.0 | 19.1 | 203 | 4.61 | 190 | 271 | 117 | 4.12 | 12.91 | 13.30 |
| 10595-0017 | 3 | 50.00-50.50 | 8.06 | 58.2 | 25.5 | 221 | 5.89 | 162 | 342 | 134 | 12.5 | 14.75 | 15.34 |
| 10595-0018 | 2 | 0.30-1.50 | 7.40 | 8.23 | 1.10 | 18.6 | 5.89 | <88 | 26.7 | 16.6 | 33.7 | 1.53 | 1.65 |
| 10595-0019 | 2 | 1.50-3.00 | 6.37 | 6.51 | 1.69 | 21.5 | 16.7 | <88 | 50.5 | 27.2 | 4.67 | 1.83 | 2.08 |
| 10595-0020 | 2 | 3.00-6.00 | 6.85 | 11.4 | 1.43 | 16.4 | 8.44 | <22 | 30.3 | 22.6 | 3.17 | 1.62 | 1.39 |
| 10595-0021 | 2 | 6.00-8.70 | 7.06 | 9.51 | 3.32 | 19.9 | 8.81 | <22 | 41.4 | 26.5 | 8.88 | 1.84 | 1.89 |
| 10595-0022 | 2 | 11.50-12.00 | 7.85 | 46.1 | 23.0 | 37.0 | 5.42 | 125 | 58.2 | 97.5 | 0.294 | 5.94 | 5.75 |
| 10595-0023 | 2 | 13.50-14.00 | 7.90 | 40.3 | 19.3 | 23.1 | 5.60 | 132 | 44.5 | 70.7 | 9.21 | 4.75 | 5.06 |
| 10595-0024 | 2 | 16.50-17.00 | 8.07 | 59.2 | 28.3 | 49.6 | 5.88 | 215 | 82.5 | 94.3 | 17.5 | 7.60 | 8.12 |
| 10595-0025 | 2 | 20.50-21.00 | 8.16 | 59.2 | 30.7 | 134 | 4.73 | 198 | 178 | 148 | 36.9 | 11.46 | 11.97 |
| 10595-0026 | 2 | 23.50-24.00 | 8.07 | 83.4 | 43.9 | 440 | 7.34 | 180 | 603 | 277 | 64.0 | 27.11 | 26.84 |
| 10595-0027 | 2 | 24.50-25.00 | 8.10 | 97.7 | 53.0 | 395 | 7.74 | 164 | 628 | 299 | 63.1 | 26.63 | 27.74 |
| 10595-0028 | 2 | 27.70-28.30 | 8.01 | 104 | 56.3 | 487 | 9.79 | 173 | 767 | 361 | 72.4 | 31.30 | 33.26 |
| 10595-0029 | 2 | 32.20-32.70 | 7.76 | 133 | 67.6 | 512 | 11.9 | 99 | 811 | 445 | 63.5 | 34.92 | 34.90 |
| 10595-0030 | 2 | 34.10-34.60 | 7.96 | 150 | 75.7 | 561 | 12.8 | 174 | 906 | 479 | 75.2 | 38.48 | 39.72 |
| 10595-0031 | 2 | 36.10-36.60 | 7.73 | 146 | 72.3 | 529 | 13.0 | 103 | 883 | 449 | 71.0 | 36.57 | 37.21 |
| 10595-0032 | 2 | 37.80-38.30 | 7.70 | 152 | 74.3 | 578 | 11.7 | 90 | 977 | 476 | 79.8 | 39.32 | 40.37 |
| 10595-0033 | 2 | 40.30-40.80 | 7.93 | 209 | 96.6 | 590 | 13.1 | 145 | 1083 | 676 | 84.5 | 44.41 | 48.51 |
| 10595-0034 | 2 | 42.30-42.80 | 7.98 | 180 | 84.6 | 503 | 15.4 | 173 | 941 | 574 | 76.6 | 38.23 | 42.70 |
| 10595-0035 | 2 | 43.30-43.80 | 7.92 | 184 | 87.0 | 501 | 14.6 | 146 | 929 | 566 | 74.7 | 38.56 | 41.72 |
| 10595-0036 | 2 | 45.30-45.80 | 7.67 | 174 | 83.9 | 401 | 12.9 | 83 | 838 | 449 | 69.8 | 33.35 | 35.59 |
| 10595-0037 | 2 | 46.30-46.80 | 7.87 | 208 | 98.7 | 463 | 14.1 | 121 | 976 | 582 | 82.7 | 39.02 | 43.13 |
| 10595-0038 | 2 | 47.80-48.20 | 7.89 | 169 | 81.0 | 391 | 14.2 | 105 | 788 | 458 | 74.3 | 32.49 | 34.85 |
| 10595-0039 | 2 | 49.30-49.80 | 7.82 | 143 | 69.8 | 351 | 13.8 | 115 | 673 | 386 | 75.8 | 28.53 | 30.29 |
| 10595-0040 | 2 | 50.80-51.30 | 7.81 | 187 | 89.3 | 427 | 15.0 | 128 | 818 | 483 | 77.2 | 35.68 | 36.68 |
| 10595-0041 | 2 | 52.30-52.80 | 7.96 | 162 | 77.3 | 384 | 14.4 | 149 | 763 | 410 | 78.5 | 31.54 | 34.12 |
| 10595-0042 | 2 | 54.10-54.80 | 7.81 | 139 | 66.9 | 313 | 16.5 | 111 | 611 | 335 | 87.2 | 26.50 | 27.70 |
| 10595-0043 | 1 | 0.30-3.00 | 1.53 | 147 | 44.3 | 61.3 | 29.5 | <88 | 75.0 | 3272 | 20.5 | 14.42 | 70.58 |
| 10595-0044 | 1 | 3.00-6.00 | 6.07 | 147 | 35.2 | 42.8 | 42.4 | <22 | 69.9 | 595 | 20.8 | 13.34 | 14.70 |
| 10595-0045 | 1 | 6.00-9.00 | 2.95 | 184 | 55.9 | 65.7 | 28.1 | <88 | 80.5 | 890 | 23.5 | 17.40 | 21.19 |
| 10595-0046 | 1 | 11.12-11.30 | 6.71 | 160 | 78.1 | 38.7 | 7.87 | <22 | 59.5 | 730 | 19.8 | 16.30 | 17.23 |
| 10595-0047 | 1 | 14.00-14.25 | 7.56 | 245 | 120 | 58.1 | 9.43 | <88 | 63.8 | 1219 | 2.26 | 24.88 | 27.26 |
| 10595-0048 | 1 | 14.50-15.00 | 7.38 | 241 | 114 | 71.5 | 9.36 | 55 | 59.8 | 995 | 3.05 | 24.74 | 23.43 |
| 10595-0049 | 1 | 17.00 | 7.28 | 182 | 60.5 | 125 | 17.3 | <88 | 80.7 | 871 | 4.85 | 19.95 | 20.66 |
| 10595-0050 | 1 | 18.00-18.50 | 7.55 | 134 | 54.9 | 145 | 12.6 | <88 | 80.2 | 647 | 1.71 | 17.84 | 15.94 |
| 10595-0051 | 1 | 19.70-20.00 | 7.87 | 175 | 83.7 | 153 | 19.7 | 126 | 208 | 610 | 72.4 | 22.83 | 21.91 |
| 10595-0052 | 1 | 22.20-23.00 | 7.50 | 146 | 85.4 | 217 | 14.7 | 62 | 448 | 467 | 133 | 24.15 | 25.60 |
| 10595-0053 | 1 | 25.50-26.00 | 7.87 | 127 | 72.4 | 240 | 14.2 | 119 | 399 | 424 | 91.9 | 23.09 | 23.57 |
| 10595-0054 | 1 | 28.00-28.30 | 7.74 | 131 | 62.7 | 115 | 10.3 | 90 | 361 | 194 | 101 | 17.06 | 17.39 |
| 10595-0055 | 1 | 30.50-30.75 | 7.67 | 204 | 92.6 | 109 | 11.4 | 70 | 436 | 407 | 92.9 | 22.85 | 23.47 |
| 10595-0056 | 1 | 32.00-32.50 | 7.79 | 131 | 65.7 | 195 | 12.1 | 102 | 367 | 363 | 89.1 | 20.72 | 21.06 |
| 10595-0057 | 1 | 36.00-36.50 | 7.73 | 138 | 64.4 | 180 | 13.1 | 91 | 407 | 410 | 92.6 | 20.35 | 23.05 |
| 10595-0058 | 1 | 37.50-38.00 | 7.79 | 197 | 91.2 | 146 | 19.7 | 96 | 427 | 436 | 95.6 | 24.22 | 24.29 |
| 10595-0059 | 1 | 39.60 | 7.60 | 170 | 74.9 | 108 | 15.5 | 66 | 406 | 394 | 105 | 19.72 | 22.48 |
| 10595-0060 | 1 | 41.70 | 7.83 | 149 | 69.9 | 174 | 18.7 | 132 | 378 | 341 | 83.7 | 21.26 | 21.32 |
| 10595-0061 | 1 | 42.80-43.00 | 7.90 | 128 | 57.5 | 155 | 16.5 | 139 | 372 | 331 | 82.4 | 18.32 | 21.04 |
| 10595-0062 | 1 | 45.18-45.40 | 7.83 | 132 | 60.7 | 174 | 18.5 | 113 | 358 | 293 | 81.5 | 19.67 | 19.42 |
| 10595-0063 | 1 | 49.07-49.27 | 7.97 | 132 | 60.9 | 160 | 16.9 | 155 | 327 | 297 | 85.5 | 19.00 | 19.37 |
| 10595-0064 | 1 | 52.00-52.30 | 7.75 | 127 | 58.4 | 142 | 18.0 | 94 | 342 | 276 | 97.4 | 17.76 | 18.55 |
| 10595-0065 | 1 | 37.50-38.00 | 7.73 | 164 | 75.3 | 150 | 18.7 | 95 | 389 | 393 | 87.1 | 21.39 | 22.17 |
| 10595-0066 | 1 | N/A | 7.05 | 1.36 | 0.084 | 1.42 | <0.500 | <44 | 4.05 | 5.79 | 0.071 | 0.14 | 0.24 |
| 10595-0067 | 1 | N/A | 6.03 | 0.332 | 0.050 | <0.350 | <0.500 | <44 | <0.050 | <0.050 | 0.113 | 0.02 | 0.00 |

| LIMS Code | Borehole | Depth (m) | $Br^-$ | $NO_2^-$ | $HPO_4^{2-}$ | $F^-$ | TOC | TIC | C Diff | Total P | Total S | S Diff | $NH_4^+$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $mg\ l^{-1}$ | $mg\ l^{-1}$ | $mg\ l^{-1}$ | $mg\ l^{-1}$ | $mg\ l^{-1}$ | $mg\ l^{-1}$ | % | $mg\ l^{-1}$ | $mg\ l^{-1}$ | % | $mg\ l^{-1}$ |
| 10595-0001 | 3 | 1.00-3.00 | 0.173 | 0.056 | <0.100 | 0.372 | 7.33 | <3.00 | -44.4 | 0.031 | 24.2 | 32.5 | 0.80 |
| 10595-0002 | 3 | 3.00-5.00 | 0.222 | 0.052 | 0.110 | 0.332 | 7.31 | 3.61 | 219.9 | 0.061 | 39.8 | 21.6 | <0.77 |
| 10595-0003 | 3 | 8.50-9.00 | 0.326 | 0.052 | 0.127 | 0.570 | 7.19 | 3.52 | 223.2 | 0.147 | 39.0 | 28.0 | <0.77 |
| 10595-0004 | 3 | 13.50-14.00 | 0.569 | 0.054 | 0.127 | 0.459 | 146 | 26.1 | -0.2 | 0.314 | 106 | 27.6 | <0.77 |
| 10595-0005 | 3 | 17.50-18.00 | 1.14 | 0.034 | <0.100 | 0.198 | 466 | 33.1 | -2.2 | 0.177 | 214 | 44.4 | 4.59 |
| 10595-0006 | 3 | 23.00-23.50 | 0.376 | <0.010 | 0.407 | 0.220 | 90.3 | 23.8 | 6.6 | 0.205 | 86.4 | 43.3 | 3.01 |
| 10595-0007 | 3 | 25.00-25.50 | 0.465 | <0.010 | 0.183 | <0.010 | 31.9 | 17.8 | -6.4 | 0.127 | 62.3 | 48.8 | <0.77 |
| 10595-0008 | 3 | 26.50-27.00 | 0.627 | <0.010 | 0.897 | 0.619 | 650 | 14.0 | 162.0 | 0.155 | 329 | 37.8 | <0.77 |
| 10595-0009 | 3 | 28.50-29.00 | 0.474 | 0.026 | <0.100 | 0.234 | 117 | 39.7 | 1.8 | 0.383 | 111 | 30.6 | 1.59 |
| 10595-0010 | 3 | 30.50-31.00 | 6.50 | <0.010 | <0.100 | 0.186 | 80.0 | 19.7 | 0.2 | 0.159 | 8403 | 98.8 | <0.77 |
| 10595-0011 | 3 | 32.50-33.00 | 8.34 | <0.010 | <0.100 | 0.198 | 80.6 | 23.1 | 6.4 | 0.141 | >10000 | | <0.77 |
| 10595-0012 | 3 | 35.50-36.00 | 4.10 | <0.010 | 1.595 | 0.017 | 65.8 | 16.7 | -12.2 | 0.139 | 77 | 31.3 | 1.52 |
| 10595-0013 | 3 | 37.50-38.00 | 2.36 | 0.021 | <0.100 | 0.221 | 17.5 | 30.0 | 5.4 | 0.159 | >10000 | | <0.77 |
| 10595-0014 | 3 | 42.10-42.50 | 2.67 | 0.017 | <0.100 | 0.129 | 7.01 | 23.5 | 0.3 | 0.124 | 7240 | 99.5 | <0.77 |
| 10595-0015 | 3 | 43.50-44.00 | 2.60 | <0.010 | <0.100 | 0.151 | <6.00 | 24.8 | 4.0 | 0.141 | 5360 | 99.4 | <0.77 |
| 10595-0016 | 3 | 45.50-46.00 | 2.49 | 0.013 | 0.119 | 0.166 | 10.8 | 38.5 | 2.7 | 0.161 | 5199 | 99.2 | <0.77 |
| 10595-0017 | 3 | 50.00-50.50 | 3.16 | <0.010 | 0.184 | 0.036 | <6.00 | 31.3 | -1.9 | 0.102 | 4790 | 99.1 | <0.77 |
| 10595-0018 | 2 | 0.30-1.50 | 0.080 | <0.010 | <0.100 | 0.228 | 13.0 | 4.94 | 450.4 | 0.064 | 6587 | 99.9 | 1.19 |
| 10595-0019 | 2 | 1.50-3.00 | 0.512 | 0.011 | <0.100 | 0.131 | 16.8 | <3.00 | -477.4 | 0.070 | 5129 | 99.8 | <0.77 |
| 10595-0020 | 2 | 3.00-6.00 | 0.029 | <0.010 | <0.100 | 0.229 | <6.00 | <3.00 | -44.4 | 0.054 | 5047 | 99.9 | <0.77 |
| 10595-0021 | 2 | 6.00-8.70 | 0.244 | 0.021 | <0.100 | 0.426 | <6.00 | 3.97 | 209.2 | 0.070 | 7338 | 99.9 | <0.77 |
| 10595-0022 | 2 | 11.50-12.00 | 0.404 | 0.034 | <0.100 | 0.309 | 35.9 | 25.0 | 1.7 | 0.100 | 2550 | 98.7 | <0.77 |
| 10595-0023 | 2 | 13.50-14.00 | 0.253 | 0.048 | <0.100 | 0.340 | 8.48 | 25.8 | -0.9 | 0.119 | 6047 | 99.6 | <0.77 |
| 10595-0024 | 2 | 16.50-17.00 | 0.520 | 0.227 | 0.300 | 0.074 | <6.00 | 40.9 | -3.4 | 0.124 | 4483 | 99.3 | <0.77 |
| 10595-0025 | 2 | 20.50-21.00 | 1.60 | <0.010 | 0.299 | 0.080 | <6.00 | 38.4 | -1.4 | 0.136 | 4470 | 98.9 | <0.77 |
| 10595-0026 | 2 | 23.50-24.00 | 6.09 | <0.010 | 0.227 | 0.012 | <6.00 | 35.2 | -0.6 | 0.124 | 5582 | 98.3 | <0.77 |
| 10595-0027 | 2 | 24.50-25.00 | 6.50 | 0.145 | 0.103 | 0.151 | <6.00 | 32.2 | -0.3 | 0.076 | 4713 | 97.9 | <0.77 |
| 10595-0028 | 2 | 27.70-28.30 | 8.01 | <0.010 | <0.100 | 0.065 | <6.00 | 34.9 | 2.4 | 0.069 | 4322 | 97.2 | <0.77 |
| 10595-0029 | 2 | 32.20-32.70 | 8.59 | <0.010 | 0.104 | <0.010 | <6.00 | 19.4 | -0.6 | 0.086 | 154 | 3.7 | 2.32 |
| 10595-0030 | 2 | 34.10-34.60 | 9.83 | <0.010 | 0.129 | <0.010 | <6.00 | 34.7 | 1.3 | 0.077 | 157 | -1.8 | <0.77 |
| 10595-0031 | 2 | 36.10-36.60 | 9.40 | <0.010 | <0.100 | <0.010 | 8.26 | 20.2 | -0.3 | 0.056 | 144 | -3.8 | <0.77 |
| 10595-0032 | 2 | 37.80-38.30 | 10.7 | <0.010 | <0.100 | 0.030 | <6.00 | 18.4 | 3.9 | 0.044 | 150 | -6.0 | 3.06 |
| 10595-0033 | 2 | 40.30-40.80 | 11.6 | <0.010 | <0.100 | <0.010 | <6.00 | 28.5 | 0.0 | 0.037 | 212 | -6.2 | <0.77 |
| 10595-0034 | 2 | 42.30-42.80 | 10.6 | <0.010 | <0.100 | <0.010 | <6.00 | 33.9 | -0.5 | 0.032 | 183 | -4.5 | <0.77 |
| 10595-0035 | 2 | 43.30-43.80 | 10.5 | <0.010 | <0.100 | 0.013 | <6.00 | 28.2 | -1.9 | 0.061 | 164 | -15.1 | <0.77 |
| 10595-0036 | 2 | 45.30-45.80 | 9.1 | <0.200 | <2.000 | <0.200 | <6.00 | 16.6 | 1.4 | 0.041 | 147 | -2.1 | <0.77 |
| 10595-0037 | 2 | 46.30-46.80 | 11.3 | 0.682 | <0.100 | 0.033 | <6.00 | 24.0 | 0.9 | 0.064 | 199 | 2.4 | <0.77 |
| 10595-0038 | 2 | 47.80-48.20 | 8.55 | 2.780 | <0.100 | 0.044 | <6.00 | 22.1 | 6.5 | 0.029 | 153 | -0.2 | <0.77 |
| 10595-0039 | 2 | 49.30-49.80 | 7.06 | 3.259 | <0.100 | 0.093 | <6.00 | 23.4 | 3.3 | 0.040 | 129 | 0.1 | <0.77 |
| 10595-0040 | 2 | 50.80-51.30 | 8.93 | 4.335 | <0.100 | 0.017 | <6.00 | 25.3 | 0.5 | 0.046 | 164 | 1.5 | 0.83 |
| 10595-0041 | 2 | 52.30-52.80 | 7.86 | 11.6 | 0.153 | <0.010 | <6.00 | 28.2 | -3.9 | 0.031 | 136 | -0.7 | <0.77 |
| 10595-0042 | 2 | 54.10-54.80 | 4.73 | 9.150 | <0.100 | 0.122 | <6.00 | 22.2 | 1.5 | 0.034 | 106 | -5.8 | <0.77 |
| 10595-0043 | 1 | 0.30-3.00 | 0.25 | <0.100 | <1.000 | 0.128 | 17.8 | <3.00 | -477.4 | 0.045 | 192 | -469.6 | <0.77 |
| 10595-0044 | 1 | 3.00-6.00 | 0.123 | <0.010 | <0.100 | 0.148 | 11.2 | <3.00 | -44.4 | 0.040 | 192 | -3.5 | 3.04 |
| 10595-0045 | 1 | 6.00-9.00 | 0.325 | <0.010 | <0.100 | 0.157 | 10.8 | <3.00 | -477.4 | 0.037 | 248 | -19.7 | <0.77 |
| 10595-0046 | 1 | 11.12-11.30 | 0.296 | <0.010 | <0.100 | 0.646 | <6.00 | 3.74 | 215.7 | 0.042 | 256 | 5.0 | <0.77 |
| 10595-0047 | 1 | 14.00-14.25 | 0.382 | 0.021 | <0.100 | 0.679 | 94.2 | 15.1 | 214.4 | 0.099 | 1225 | 66.8 | <0.77 |
| 10595-0048 | 1 | 14.50-15.00 | 0.356 | 0.017 | <0.100 | 1.33 | 137 | 9.35 | -15.7 | 0.115 | 373 | 11.0 | <0.77 |
| 10595-0049 | 1 | 17.00 | 0.514 | <0.010 | 0.477 | 2.94 | 74.9 | 14.6 | 219.1 | 0.082 | 5007 | 94.2 | <0.77 |
| 10595-0050 | 1 | 18.00-18.50 | 0.386 | 0.019 | <0.100 | 3.29 | 88.5 | 11.6 | 249.3 | 0.087 | 4342 | 95.0 | <0.77 |
| 10595-0051 | 1 | 19.70-20.00 | 1.50 | 0.034 | 0.295 | 1.56 | 6.66 | 25.0 | 0.8 | 0.099 | 2479 | 91.8 | <0.77 |
| 10595-0052 | 1 | 22.20-23.00 | 3.77 | <0.050 | <0.500 | 0.603 | 22.0 | 12.3 | 0.8 | 0.048 | 8275 | 98.1 | <0.77 |
| 10595-0053 | 1 | 25.50-26.00 | 3.33 | <0.050 | <0.500 | 0.146 | 9.19 | 24.3 | 3.5 | 0.092 | 2381 | 94.1 | <0.77 |
| 10595-0054 | 1 | 28.00-28.30 | 2.88 | <0.050 | <0.500 | 0.486 | <6.00 | 17.9 | 1.2 | 0.053 | 2365 | 97.3 | 1.37 |
| 10595-0055 | 1 | 30.50-30.75 | 3.81 | <0.050 | <0.500 | 0.118 | <6.00 | 13.9 | 1.1 | 0.045 | 2323 | 94.2 | <0.77 |
| 10595-0056 | 1 | 32.00-32.50 | 3.06 | <0.050 | <0.500 | 0.082 | <6.00 | 18.6 | -8.1 | 0.082 | 2518 | 95.2 | <0.77 |
| 10595-0057 | 1 | 36.00-36.50 | 3.50 | <0.050 | <0.500 | 0.108 | <6.00 | 21.3 | 16.0 | 0.045 | 2674 | 94.9 | <0.77 |
| 10595-0058 | 1 | 37.50-38.00 | 3.64 | <0.050 | <0.500 | 0.132 | <6.00 | 18.0 | -5.1 | 0.056 | 2541 | 94.3 | <0.77 |
| 10595-0059 | 1 | 39.60 | 3.23 | <0.050 | <0.500 | 0.211 | 6.67 | 13.0 | 0.3 | 0.059 | 2701 | 95.1 | <0.77 |
| 10595-0060 | 1 | 41.70 | 3.36 | <0.050 | <0.500 | 0.082 | <6.00 | 26.0 | 0.2 | 0.078 | 2270 | 95.0 | <0.77 |
| 10595-0061 | 1 | 42.80-43.00 | 3.39 | <0.050 | <0.500 | 0.110 | <6.00 | 28.5 | 4.0 | 0.040 | 2206 | 95.0 | <0.77 |
| 10595-0062 | 1 | 45.18-45.40 | 3.42 | <0.050 | <0.500 | 0.135 | <6.00 | 23.0 | 3.1 | 0.088 | 2376 | 95.9 | <0.77 |
| 10595-0063 | 1 | 49.07-49.27 | 3.03 | <0.050 | <0.500 | 0.054 | <6.00 | 33.1 | 7.7 | 0.076 | 2605 | 96.2 | <0.77 |
| 10595-0064 | 1 | 52.00-52.30 | 3.14 | <0.050 | <0.500 | 0.110 | 11.69 | 19.8 | 6.4 | 0.045 | 2246 | 95.9 | <0.77 |
| 10595-0065 | 1 | 37.50-38.00 | 3.32 | <0.050 | <0.500 | 0.107 | <6.00 | 19.4 | 3.4 | 0.052 | 2364 | 94.5 | <0.77 |
| 10595-0066 | 1 | N/A | 0.032 | <0.010 | <0.100 | 0.061 | <6.00 | <3.00 | -188.7 | 0.051 | 1573 | 99.9 | <0.77 |
| 10595-0067 | 1 | N/A | <0.020 | <0.010 | <0.100 | <0.010 | <6.00 | <3.00 | -188.7 | 0.013 | 5862 | 100.0 | <0.77 |

| LIMS Code | Borehole | Depth (m) | Mn | Total Fe | Reduced Fe | Oxidised Fe | Al | Co | Ni | Cu | Zn | Cr | Mo |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ |
| | | | | | | | | | | | | | |
| 10595-0001 | 3 | 1.00-3.00 | 0.414 | 0.558 | <0.10 | 0.56 | 0.551 | 0.022 | 0.017 | 0.047 | 0.207 | 0.013 | <0.015 |
| 10595-0002 | 3 | 3.00-5.00 | 0.465 | 1.02 | <0.10 | 1.02 | 0.532 | 0.004 | 0.029 | 0.067 | 0.111 | 0.011 | <0.015 |
| 10595-0003 | 3 | 8.50-9.00 | 0.076 | 1.10 | <0.10 | 1.10 | 0.476 | <0.002 | 0.008 | 0.048 | 0.046 | 0.005 | <0.015 |
| 10595-0004 | 3 | 13.50-14.00 | 0.023 | 1.82 | <0.10 | 1.82 | 0.711 | <0.002 | 0.025 | 0.088 | 0.156 | 0.009 | 0.041 |
| 10595-0005 | 3 | 17.50-18.00 | 0.278 | 0.483 | <0.10 | 0.48 | 0.196 | 0.016 | 0.024 | 0.116 | 0.064 | 0.051 | 0.075 |
| 10595-0006 | 3 | 23.00-23.50 | 0.025 | 1.91 | <0.10 | 1.91 | 0.728 | <0.004 | 0.015 | 0.081 | 0.086 | 0.010 | <0.030 |
| 10595-0007 | 3 | 25.00-25.50 | 0.018 | 1.66 | <0.10 | 1.66 | 0.612 | <0.002 | 0.005 | 0.047 | 0.058 | 0.006 | <0.015 |
| 10595-0008 | 3 | 26.50-27.00 | 1.985 | 1.33 | <0.10 | 1.33 | 0.532 | 0.003 | 0.011 | 0.103 | 0.068 | 0.006 | 0.081 |
| 10595-0009 | 3 | 28.50-29.00 | 0.021 | 1.37 | <0.10 | 1.37 | 0.543 | 0.002 | 0.009 | 0.063 | 0.058 | 0.009 | <0.015 |
| 10595-0010 | 3 | 30.50-31.00 | 0.004 | 0.066 | <0.10 | 0.07 | 0.026 | <0.002 | 0.008 | 0.029 | 0.032 | 0.006 | 0.021 |
| 10595-0011 | 3 | 32.50-33.00 | 0.005 | 0.076 | <0.10 | 0.08 | 0.026 | <0.002 | 0.007 | 0.040 | 0.039 | 0.006 | <0.015 |
| 10595-0012 | 3 | 35.50-36.00 | 0.027 | 1.50 | <0.10 | 1.50 | 0.556 | <0.002 | 0.006 | 0.050 | 0.046 | 0.007 | 0.028 |
| 10595-0013 | 3 | 37.50-38.00 | 0.002 | 0.057 | <0.10 | 0.06 | 0.015 | <0.002 | 0.013 | 0.027 | 0.027 | 0.005 | 0.016 |
| 10595-0014 | 3 | 42.10-42.50 | <0.002 | 0.039 | <0.10 | 0.04 | <0.010 | <0.002 | 0.007 | 0.018 | 0.025 | 0.004 | 0.019 |
| 10595-0015 | 3 | 43.50-44.00 | <0.002 | 0.043 | <0.10 | 0.04 | 0.020 | <0.002 | 0.005 | 0.017 | 0.022 | 0.003 | <0.015 |
| 10595-0016 | 3 | 45.50-46.00 | 0.002 | 0.041 | <0.10 | 0.04 | 0.018 | <0.002 | 0.003 | 0.012 | 0.019 | 0.004 | <0.015 |
| 10595-0017 | 3 | 50.00-50.50 | 0.003 | 0.029 | <0.10 | 0.03 | <0.010 | <0.002 | 0.002 | 0.010 | 0.016 | 0.006 | <0.015 |
| 10595-0018 | 2 | 0.30-1.50 | 0.591 | 0.046 | <0.10 | 0.05 | 0.232 | 0.007 | 0.008 | 0.025 | 0.117 | 0.010 | <0.015 |
| 10595-0019 | 2 | 1.50-3.00 | 0.223 | 0.034 | <0.10 | 0.03 | 0.143 | 0.004 | 0.009 | 0.026 | 0.097 | 0.014 | <0.015 |
| 10595-0020 | 2 | 3.00-6.00 | 0.499 | 0.084 | <0.10 | 0.08 | 0.113 | 0.004 | 0.029 | 0.030 | 0.091 | 0.008 | <0.015 |
| 10595-0021 | 2 | 6.00-8.70 | 0.447 | 0.051 | <0.10 | 0.05 | 0.067 | 0.002 | 0.020 | 0.022 | 0.041 | 0.009 | <0.015 |
| 10595-0022 | 2 | 11.50-12.00 | 0.011 | 0.023 | <0.10 | 0.02 | 0.010 | <0.002 | 0.004 | 0.011 | 0.019 | 0.004 | 0.038 |
| 10595-0023 | 2 | 13.50-14.00 | 0.002 | 0.034 | <0.10 | 0.03 | <0.010 | <0.002 | 0.005 | 0.017 | 0.020 | 0.006 | <0.015 |
| 10595-0024 | 2 | 16.50-17.00 | 0.002 | 0.029 | <0.10 | 0.03 | <0.010 | <0.002 | 0.005 | 0.020 | 0.024 | 0.005 | <0.015 |
| 10595-0025 | 2 | 20.50-21.00 | 0.003 | 0.041 | <0.10 | 0.04 | 0.021 | <0.002 | 0.004 | 0.016 | 0.022 | 0.005 | <0.015 |
| 10595-0026 | 2 | 23.50-24.00 | 0.003 | 0.043 | <0.10 | 0.04 | 0.013 | <0.002 | 0.003 | 0.011 | 0.044 | 0.005 | <0.015 |
| 10595-0027 | 2 | 24.50-25.00 | 0.002 | 0.027 | <0.10 | 0.03 | <0.010 | <0.002 | 0.002 | 0.010 | 0.027 | 0.004 | <0.015 |
| 10595-0028 | 2 | 27.70-28.30 | 0.021 | 0.028 | <0.10 | 0.03 | <0.010 | <0.002 | 0.003 | 0.009 | 0.035 | 0.005 | <0.015 |
| 10595-0029 | 2 | 32.20-32.70 | <0.002 | 0.013 | <0.10 | 0.01 | <0.010 | <0.002 | 0.004 | 0.014 | 0.026 | 0.003 | <0.015 |
| 10595-0030 | 2 | 34.10-34.60 | 0.012 | <0.010 | <0.10 | <0.01 | <0.010 | <0.002 | 0.003 | 0.015 | 0.030 | 0.004 | <0.015 |
| 10595-0031 | 2 | 36.10-36.60 | 0.003 | <0.010 | <0.10 | <0.01 | <0.010 | <0.002 | 0.008 | 0.040 | 0.038 | 0.004 | <0.015 |
| 10595-0032 | 2 | 37.80-38.30 | 0.003 | 0.012 | <0.10 | 0.01 | <0.010 | <0.002 | 0.004 | 0.023 | 0.043 | 0.004 | <0.015 |
| 10595-0033 | 2 | 40.30-40.80 | <0.002 | <0.010 | <0.10 | <0.01 | <0.010 | <0.002 | 0.001 | 0.007 | 0.036 | 0.004 | <0.015 |
| 10595-0034 | 2 | 42.30-42.80 | 0.004 | 0.020 | <0.10 | 0.02 | <0.010 | <0.002 | 0.003 | 0.011 | 0.049 | 0.004 | <0.015 |
| 10595-0035 | 2 | 43.30-43.80 | 0.003 | 0.021 | <0.10 | 0.02 | <0.010 | <0.002 | 0.006 | 0.013 | 0.062 | 0.005 | <0.015 |
| 10595-0036 | 2 | 45.30-45.80 | 0.003 | 0.015 | <0.10 | 0.02 | <0.010 | <0.002 | 0.002 | 0.011 | 0.047 | 0.003 | <0.015 |
| 10595-0037 | 2 | 46.30-46.80 | 0.005 | 0.020 | <0.10 | 0.02 | 0.048 | <0.002 | 0.006 | 0.011 | 0.069 | 0.004 | <0.015 |
| 10595-0038 | 2 | 47.80-48.20 | 0.002 | <0.010 | <0.10 | <0.01 | <0.010 | <0.002 | <0.001 | 0.008 | 0.028 | 0.003 | <0.015 |
| 10595-0039 | 2 | 49.30-49.80 | 0.003 | 0.010 | <0.10 | 0.01 | <0.010 | <0.002 | 0.002 | 0.015 | 0.057 | 0.003 | <0.015 |
| 10595-0040 | 2 | 50.80-51.30 | 0.009 | 0.016 | <0.10 | 0.02 | <0.010 | <0.002 | 0.005 | 0.018 | 0.059 | 0.003 | 0.002 |
| 10595-0041 | 2 | 52.30-52.80 | 0.005 | 0.010 | <0.10 | 0.01 | <0.010 | <0.002 | 0.002 | 0.009 | 0.039 | 0.005 | <0.015 |
| 10595-0042 | 2 | 54.10-54.80 | 0.004 | 0.013 | <0.10 | 0.01 | <0.010 | <0.002 | 0.002 | 0.010 | 0.049 | 0.004 | <0.015 |
| 10595-0043 | 1 | 0.30-3.00 | 9.64 | 0.053 | <0.10 | 0.05 | 0.239 | 0.027 | 0.259 | 0.060 | 0.260 | 0.013 | <0.030 |
| 10595-0044 | 1 | 3.00-6.00 | 11.5 | <0.010 | <0.10 | <0.01 | 0.036 | 0.061 | 0.409 | 0.108 | 1.001 | 0.012 | <0.015 |
| 10595-0045 | 1 | 6.00-9.00 | 13.0 | 0.040 | <0.10 | 0.04 | 0.186 | 0.029 | 0.299 | 0.037 | 0.261 | 0.012 | <0.015 |
| 10595-0046 | 1 | 11.12-11.30 | 0.391 | 0.011 | <0.10 | 0.01 | 0.022 | <0.002 | 0.017 | 0.015 | 0.061 | <0.002 | <0.015 |
| 10595-0047 | 1 | 14.00-14.25 | 0.004 | 0.024 | <0.10 | 0.02 | 0.020 | <0.002 | 0.006 | 0.020 | 0.036 | 0.003 | <0.015 |
| 10595-0048 | 1 | 14.50-15.00 | 0.005 | 0.024 | <0.10 | 0.02 | 0.028 | <0.002 | 0.005 | 0.020 | 0.038 | 0.004 | <0.015 |
| 10595-0049 | 1 | 17.00 | 0.150 | 0.038 | <0.10 | 0.04 | 0.035 | <0.002 | 0.010 | 0.036 | 0.020 | 0.007 | <0.015 |
| 10595-0050 | 1 | 18.00-18.50 | 0.392 | 0.069 | <0.10 | 0.07 | 0.054 | <0.002 | 0.010 | 0.038 | 0.028 | 0.004 | <0.015 |
| 10595-0051 | 1 | 19.70-20.00 | 0.057 | 0.052 | <0.10 | 0.05 | 0.019 | <0.002 | 0.006 | 0.024 | 0.031 | 0.004 | <0.015 |
| 10595-0052 | 1 | 22.20-23.00 | 0.005 | 0.034 | <0.10 | 0.03 | <0.010 | <0.002 | 0.004 | 0.018 | 0.019 | 0.003 | <0.015 |
| 10595-0053 | 1 | 25.50-26.00 | 0.003 | 0.021 | <0.10 | 0.02 | <0.010 | <0.002 | 0.005 | 0.015 | 0.012 | 0.005 | <0.015 |
| 10595-0054 | 1 | 28.00-28.30 | 0.002 | 0.021 | <0.10 | 0.02 | <0.010 | <0.002 | 0.004 | 0.016 | 0.017 | 0.003 | <0.015 |
| 10595-0055 | 1 | 30.50-30.75 | 0.004 | 0.024 | <0.10 | 0.02 | <0.010 | <0.002 | 0.003 | 0.011 | 0.023 | 0.003 | <0.015 |
| 10595-0056 | 1 | 32.00-32.50 | 0.005 | 0.023 | <0.10 | 0.02 | <0.010 | <0.002 | 0.002 | 0.006 | 0.010 | 0.003 | <0.015 |
| 10595-0057 | 1 | 36.00-36.50 | <0.002 | 0.020 | <0.10 | 0.02 | <0.010 | <0.002 | 0.002 | 0.006 | 0.025 | 0.003 | <0.000 |
| 10595-0058 | 1 | 37.50-38.00 | 0.002 | 0.019 | <0.10 | 0.02 | <0.010 | <0.002 | 0.002 | 0.010 | 0.032 | 0.003 | <0.015 |
| 10595-0059 | 1 | 39.60 | 0.005 | 0.022 | <0.10 | 0.02 | <0.010 | <0.002 | 0.002 | 0.015 | 0.031 | 0.003 | <0.015 |
| 10595-0060 | 1 | 41.70 | 0.006 | 0.032 | <0.10 | 0.03 | <0.010 | <0.002 | 0.004 | 0.027 | 0.035 | 0.003 | <0.015 |
| 10595-0061 | 1 | 42.80-43.00 | 0.002 | 0.018 | <0.10 | 0.02 | <0.010 | <0.002 | 0.002 | 0.012 | 0.031 | 0.004 | <0.015 |
| 10595-0062 | 1 | 45.18-45.40 | 0.003 | 0.025 | <0.10 | 0.02 | 0.011 | <0.002 | 0.001 | 0.009 | 0.023 | 0.003 | <0.015 |
| 10595-0063 | 1 | 49.07-49.27 | 0.005 | 0.021 | <0.10 | 0.02 | <0.010 | <0.002 | 0.003 | 0.018 | 0.025 | 0.003 | <0.015 |
| 10595-0064 | 1 | 52.00-52.30 | 0.003 | 0.017 | <0.10 | 0.02 | <0.010 | <0.002 | 0.003 | 0.017 | 0.019 | 0.003 | <0.015 |
| 10595-0065 | 1 | 37.50-38.00 | 0.008 | 0.019 | <0.10 | 0.02 | <0.010 | <0.002 | 0.003 | 0.018 | 0.031 | 0.002 | <0.015 |
| 10595-0066 | 1 | N/A | <0.002 | 0.013 | <0.10 | 0.01 | <0.010 | <0.002 | 0.002 | 0.004 | 0.013 | 0.002 | <0.015 |
| 10595-0067 | 1 | N/A | 0.003 | 0.029 | <0.10 | 0.03 | <0.010 | <0.002 | <0.001 | <0.002 | 0.014 | <0.002 | <0.015 |

# Appendix 2

Thoresby Colliery data

| LIMS Code | Sample Code | pH | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{2-}$ | $NO_3^-$ | Cation Total | Anion Total | Balance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | meq $l^{-1}$ | meq $l^{-1}$ | % |
| | | | | | | | | | | | | | |
| 10768-0001 | Storm Tank | 7.17 | 1701 | 469 | 6668 | 82.2 | 46 | 12390 | 236 | 37.9 | 418.21 | 357.45 | 7.83 |
| 10768-0002 | Final Pond | 7.10 | 777 | 221 | 3115 | 46.1 | <22 | 6705 | 346 | 37.5 | 194.72 | 197.89 | -0.81 |
| 10768-0003 | BH Thorseby | 7.92 | 71.5 | 31.6 | 44.4 | 7.29 | 114 | 127 | 135 | 60.8 | 8.95 | 9.27 | -1.73 |

| LIMS Code | Sample Code | $Br^-$ | $NO_2^-$ | $HPO_4^{2-}$ | $F^-$ | TOC | TIC | C Diff | Total P | Total S | Reduced S | S Diff | $NH_4^+$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | % | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | % | mg $l^{-1}$ |
| | | | | | | | | | | | | | |
| 10768-0001 | Storm Tank | 122 | <0.50 | <5.00 | 2.32 | <6.00 | 10.4 | 12.8 | <0.10 | 118 | <0.200 | 33.2 | 9.22 |
| 10768-0002 | Final Pond | 68.1 | 1.14 | <5.00 | 1.06 | <6.00 | 4.93 | 187.8 | <0.10 | 132 | <0.200 | 12.2 | 9.18 |
| 10768-0003 | BH Thorseby | 0.730 | 0.746 | <0.100 | <0.010 | <6.00 | 22.1 | -1.4 | 0.045 | 42.4 | <0.200 | -6.3 | 11.9 |

| LIMS Code | Sample Code | Mn | Total Fe | Reduced Fe | Oxidised Fe | Al | Co | Ni | Cu | Zn | Cr | Mo | Cd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ | mg $l^{-1}$ |
| | | | | | | | | | | | | | |
| 10768-0001 | Storm Tank | 3.19 | 4.44 | 5.39 | <0.95 | <0.100 | <0.020 | 0.085 | <0.020 | 0.419 | <0.020 | <0.150 | <0.020 |
| 10768-0002 | Final Pond | 2.81 | 0.059 | 1.38 | <1.33 | <0.100 | 0.043 | 0.131 | <0.020 | 0.118 | <0.020 | <0.150 | <0.020 |
| 10768-0003 | BH Thorseby | 0.078 | 0.048 | 0.07 | <0.02 | 0.026 | <0.002 | 0.004 | 0.013 | 0.030 | <0.002 | <0.015 | <0.002 |

# References

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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