The influence of minewater recovery on surface gas and water discharges in the Yorkshire Coalfield.

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Abstract: The closure of the majority of the mines in the Yorkshire Coalfield, has left a complex interconnected system of mining areas where minewater is either pumped to protect remaining mines and prevent surface discharges or, left to recover naturally. In addition, there are several historical surface gravity discharges which require treatment to reduce environmental pollution. Monitoring of those areas where water is recovering has shown that the minewater has recovered exponentially in a similar way to a standard pumped aquifer recovery test. The rapid initial recovery has led to the pressurisation of mine gases within the workings which has resulted in the migration of mine gases to surface along permeable beds and along fractures both natural and mining induced. The paper discusses the mechanisms behind the minewater recovery and the movement of gases to the surface using sites from the Yorkshire coalfield. Examples of the use of gas pressure relief wells and methods of active drainage to prevent or reduce the risks to the environment and the general public are also given.

1 INTRODUCTION

After centuries of pumping there is a regional recovery of the groundwater levels in the British coalfields. The complete closure of a coalfield, and cessation of pumping, will result in the ultimate flooding of all the old workings and subsequent rebound of water levels until equilibrium is reached. In the Durham coalfield 300 years of pumping had de-watered the strata between depths of 150 m and 600 m and rebound is now reaching the surface (Younger, 1993; Younger & Bradley, 1994). Where minewater flows into surface watercourses the latter may become grossly polluted, with extensive precipitation of ochrous ferric hydroxide on streambeds. Minewater may also become polluted with organic compounds derived from spills of lubricating and hydraulic oils underground. The time scale of minewater rebound is difficult to determine. However, modelling and monitoring can indicate the timing when discharge may occur.

Abandoned mine workings commonly contain mine gases which may saturate adjacent permeable strata. These gases may be driven ahead of rising minewater causing potentially hazardous emissions at the surface. The principal gas associated with working coalmines is methane. During mining operations, methane is liberated into the mine ventilation system and vented to atmosphere. In addition, methane drainage above longwall panels by inclined underground boreholes is common practice. However, not all the methane is removed by these processes, and substantial volumes may accumulate in mining voids and fractured rock. Falling atmospheric pressure causes the gas to expand and migrate from the workings causing potentially dangerous situations (Carter & Durst, 1956).

In abandoned mine workings or where there is little or no active ventilation, blackdamp (oxygen-depleted air, consisting mainly of nitrogen but also rich in carbon dioxide) may accumulate. Other gases such as carbon monoxide and hydrogen sulphide, both of which are poisonous at very low concentrations, are occasionally encountered in old workings. Radon may also occur, particularly in the vicinity of fault zones.

2 GEOLOGICAL SETTING OF THE YORKSHIRE COALFIELD.

The exposed Coal Measures dip generally to the E or NE where they become overlain by water bearing Permian strata. This paper is largely concerned with Area 5 (Figure 1) which lies on the western edge of the coalfield and extends northwards from Rotherham to Barnsley. The southwest boundary from Sheffield to Stocksbridge approximates to the limit of the coalfield, but then turns east to exclude Penistone and Denby Dale. The other boundaries are partly fault controlled. There is an area of Coal Measures to the west of this boundary between Penistone and Denby Dale and this has been included in this summary.

The area lies entirely on the exposed coalfield and the coal measures strata dip to the NE. There are no operational mines. The area is almost devoid of glacial deposits and there are only localised alluvial clays which will not have a significant effect on the movement of water or gas.

The Carboniferous strata extend from the base of the coal measures in the west up to the Oaks Rock in the east, and include the Lower and Middle Coal Measures. There are a number of thick sandstone beds in the Middle and Lower Coal Measures including the Oaks Rock, Woolley Edge Rock, Silkstone Rock, Penistone Flags and Grenoside Rock. Since these are resistant to weathering, they often form scarps or “edges” and have a large surface outcrop. Many of these sandstones are significant aquifers and can influence the movement of water and gas since some have been drained by adjacent mineworkings.

Towards the base of the Coal Measures, in the outcrop area, there have been extensive fireclay workings (some of may still be operational) and a number of thin seams have been worked in association with these. Most of these are to the west of the old British Coal boundary (in the vicinity of Denby Dale), but may have an effect on the movement of water and/or gas. Opencast mining has taken place along the outcrop and may also affect the movement of water and gas.

The general dip of the coal measures is to the NE, but this is locally affected by faults and folds. This fault pattern follows the regional trend for the Yorkshire Coalfield, with a NE-SW set and a second set at approximately 90^{o} to this. The major NW-SE faults are the Mapplewell (north of Barnsley) and, the

Silkstone/Blacker Hill and Wentworth faults to the south. The area is limited to the south by NE-SW faulting associated with the Don Monocline. These faults and folds have an important effect on the movement of water and gas.

In the southeast corner of the area the effect of the Don and Tankersley faults has been to produce a pitching anticlinal structure dipping to the NE broken by a series of

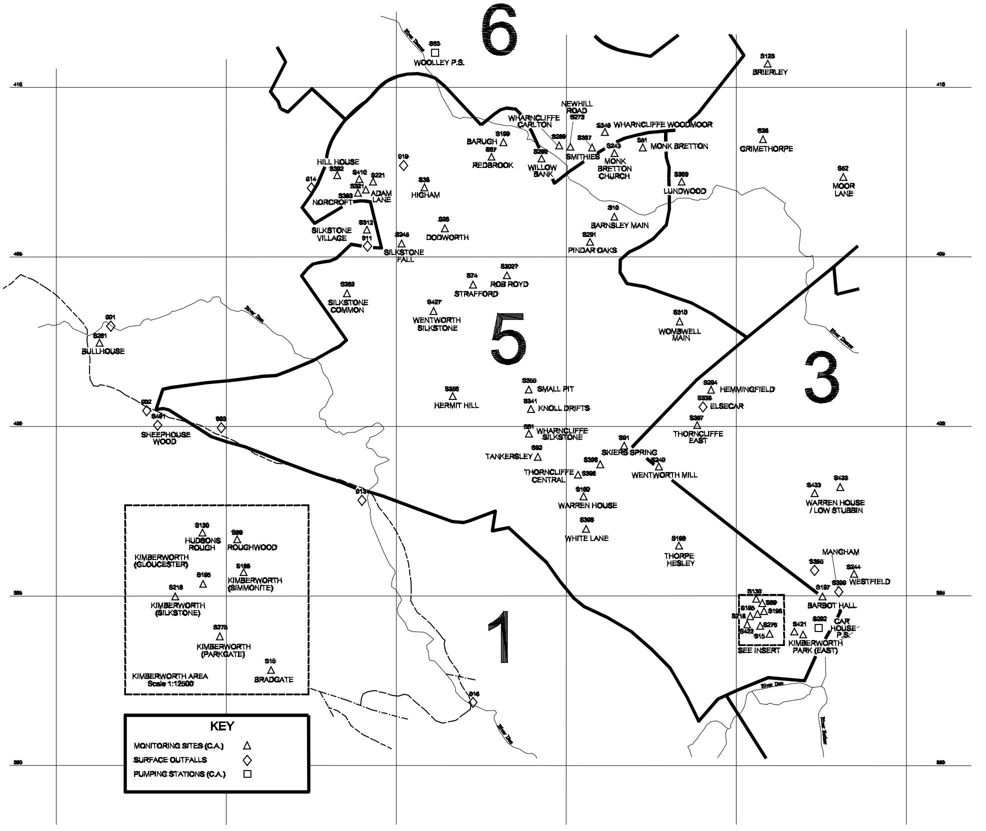

Figure 1 Location plan of Area 5 of the Yorkshire Coalfield showing monitoring sites together with venting and pumping sites

NW to SE trending faults. This structure forms a natural trap for any gas migrating through the strata or old workings (Figure 2). If the faulting is permeable the gas will migrate along the crest of the anticline to the outcrop.

3 RECENT MINING IN THE YORKSHIRE COALFIELD

Intensive mining has been carried out in the area since the industrial revolution, working from the shallow seams at outcrop, often associated with ironstone. The most extensive workings were in the Middle Coal Measures including the Newhill, Meltonfield, Barnsley and Swallow Wood. The Lower Coal Measures contain several seams worked by deep mining, including the Flockton, Parkgate and Silkstone (Blocking) and in the west of the area, there have also been workings in the Green Lane, New Hards, Wheatley Lime and Whinmoor seams.

However, by the end of the 1960's there were some 86 major deep mine operating collieries in the Yorkshire coalfield with an additional 16 water pumping sites. At the end of the century the number of collieries had fallen to 10, half of which were in the Selby coalfield (production commencing in the 1980's) and the number of pumping stations had fallen to 3. Only one pumping station (Carr House) protects active mining at Maltby colliery. Many of the mines were connected either by direct roadway of indirect goaf connections. Those close to the outcrops often intercepted unrecorded workings. Consequently mining has left a large volume of interconnected voids allowing water to fill down dip and displace gas contained in those voids.

4 WATER DISCHARGES

Prior to the closure of the majority of mines water was pumped to prevent water building up in the older shallow workings so endangering the deeper workings Within the area there are seven permitted water outflow together with a further 42 water level monitoring sites. The total water discharged averages less than 100 l/s.

The Bullhouse project was a £1.1million scheme to treat contaminated minewater discharges containing up to 50 mg/l of iron to the River Don from the Bullhouse Mine. This was high profile scheme and was amongst the discharges causing the most significant downgrading of a receiving water in the UK. The treatment scheme comprises an underground collection sump, two pumping stations, an overland pipeline and a large minewater treatment lagoon together with restoration of a disused quarry.

A research project has been designed to investigate means of passive removal of ammonia from minewater discharges at the Woolley pumping station just to the north of Area 5 which discharges some 170 l/s of minewater through settling ponds and wetlands. The raw minewater discharges up to 100 mg/l total iron. Improvements to the flow regime through ponds and removal of unnecessary dividing banks effected immediate improvement in discharge quality at low cost. Novel 'fabric filter' walls were devised to strain fine suspended iron solids from the discharge and a simple flocculation dosing system was incorporated to further control water quality. The scheme includes the largest wetland in the UK dealing with minewater with some 40,000 wetland plants of various selected species forming the treatment system. Wetlands were proposed as the potential means of breaking down ammonia. A pilot study has also been undertaken into increasing the effectiveness of 'ochre' by the use of sludges to promote the accretion of dissolved iron contained within raw minewater discharges.

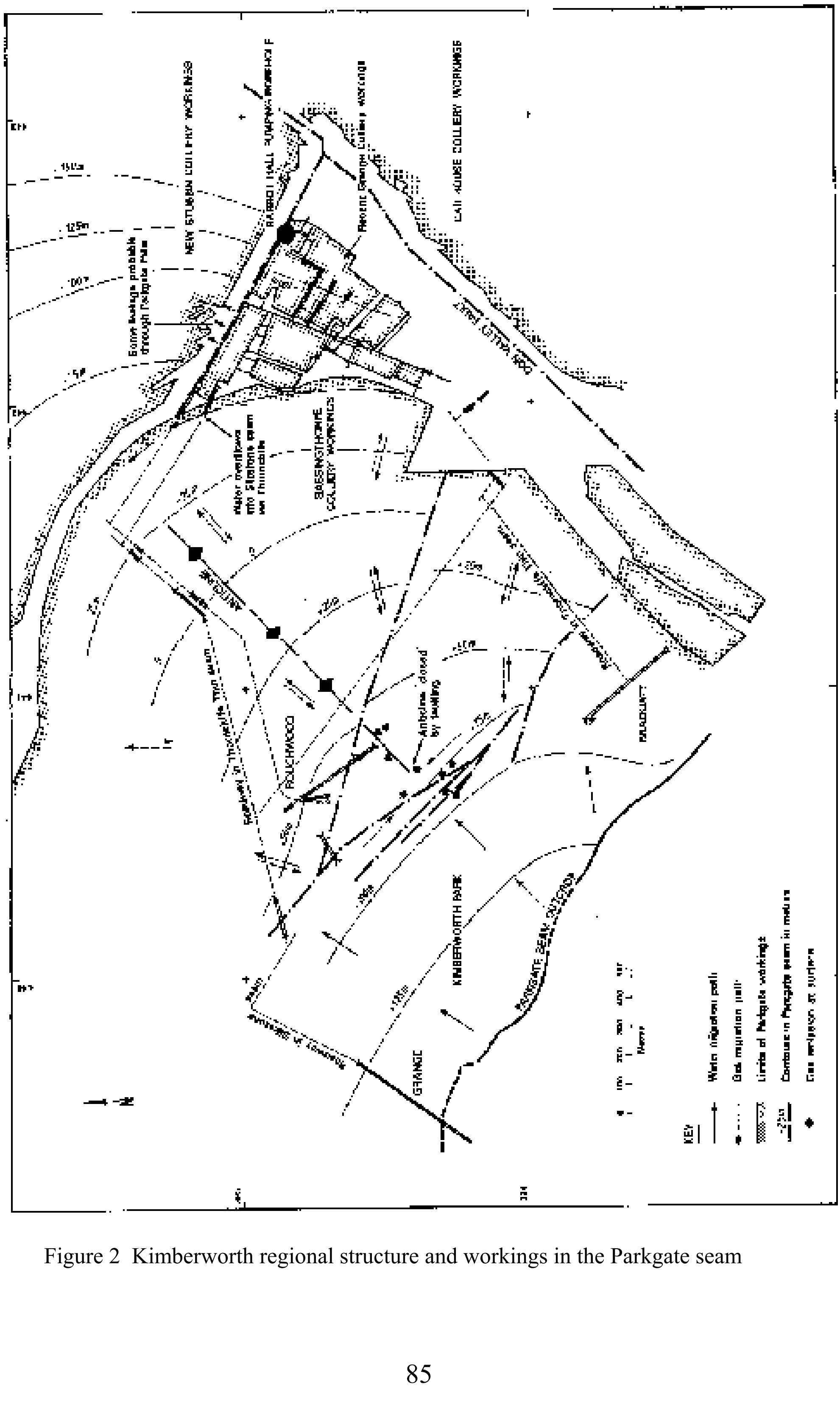

Figure 2 Kimberworth regional structure and workings in the Parkgate seam

This method could provide a more effective means of treatment of gravity minewater drainages in areas where land availability is restricted.

At least ten minewater treatment schemes involving the neutralisation of minewater acidity by alkaline injection have been undertaken in the Yorkshire Coalfield. Major plants have been located at the abandoned Ferryman/Riddings, Caphouse and Warncliffe Silkstone mines. The plants essentially comprise bulk line silo's feeding to a lime slurry mixing station with consequent injection into minewater flow. Controls included pH probes and cleaning devices for the feed systems to promote reliability of use.

Considerable expertise in the construction of economic plants that can operate reliably unattended apart from regular inspections, has been gained and this element will be of considerable advantage to any project requiring chemical treatment to ensure compliance with discharge consent conditions. Economic methods of handling and disposal of 'ochre' sludge have also been devised with the use of drying beds, filter press systems and the sale of the 'ochre' to industry for use as dyebase. The remote locations of sites made it essential for the design to take into account the potential extent of vandalism and the disruption to continual operations that this could cause.

5 WATER RECOVERY

The monitoring of minewater recovery in several coalfields in the UK suggests that mine workings behave in a way similar to a confined aquifer. A time dependent plot of recovery (residual drawdown) follows an exponential curve whose time constant will be a characteristic of the workings, similar to the Theis method of interpreting a confined aquifer recovery (Theis, 1935). This method can be used to predict minewater recovery rates to determine when and where surface outflows may occur. An example of a recovery curve is given in Figure 3 which shows the measured and predicted recovery at Barnsley Main colliery.

It would be expected that there would be a totally different recovery curve for each coalfield or mining area. However, recovery rates show overall similarities between areas suggesting separate areas have similar permeability and that the total water inflow is proportional to the area worked and method of working. Calculations of overall average permeabilities can be made from measured minewater inflows and the area of mine workings. For example, results from four separate mining areas in Lancashire gave values of permeability (water) of between 1.6×10^{-3} and 8.8×10^{-3} m/day.

The hydraulic gradient of the recovering minewater is also the key to predicting when surface emissions may occur as well as the likely flow rate. Figure 4 shows the recovery curves over time for several monitoring sites in Area 5 (Figure 1 for key),which has an overall west to east gradient of 1 in 160. This gradient is higher than the gradients elsewhere in the UK, which lie between 1 in 500 and 1 in 1000. The difference in gradient is believed to be due to the movement of minewater through

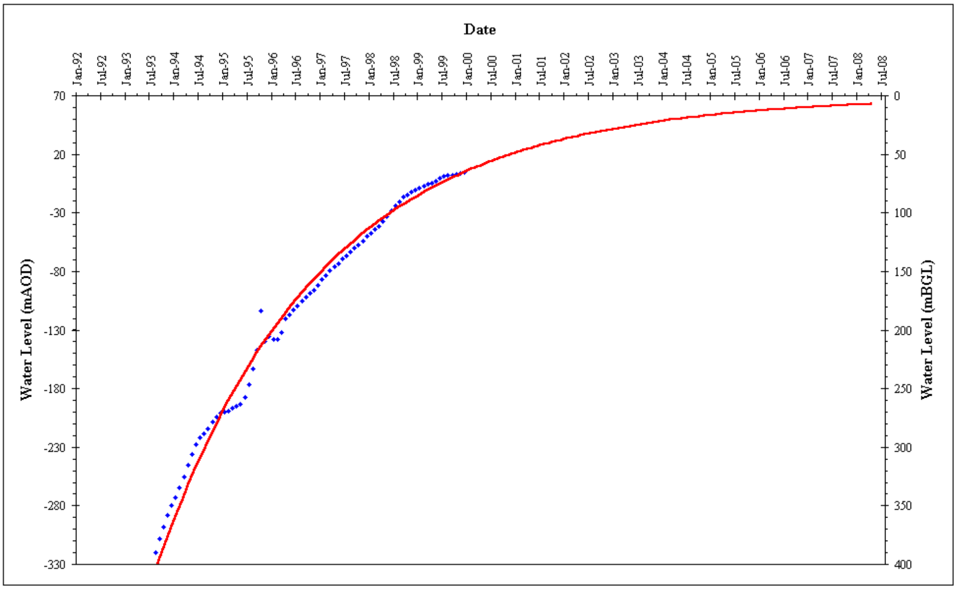

Figure 3 Water recovery at Barnsley Main

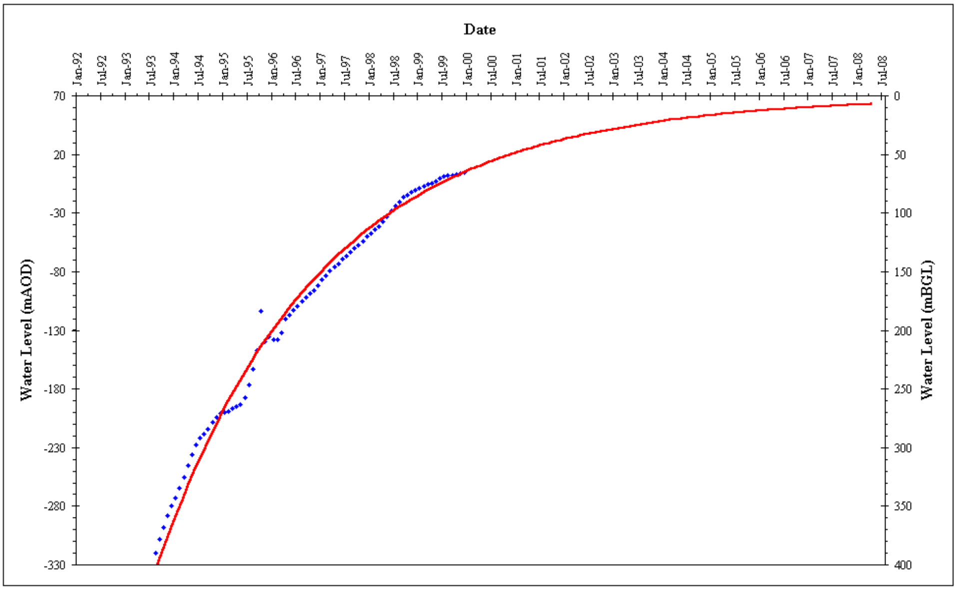

Figure 4 Water recovery in Area 5

narrow coal pillars and into the deeper modern workings down dip. Both the fluctuations in recovery and the flow of water into deeper mine workings affect the emissions of mine gas from the workings and permeable strata (Section 6).

6 GAS EMISSIONS

Since the 1970's uncontrolled gas emissions have been detected at the surface at a number of sites despite the presence of a large number of passive vents into workings and shafts. Several of the emissions, running from Horbury in the north through Barnsley to Kimberworth in the south, have the common feature that the emission is associated with a gas-saturated sandstone at or close to the outcrop. In Barnsley the Woolley Edge rock was dewatered by workings in the subjacent Meltonfield seam. An initial problem was resolved by the use of venting trenches to protect the affected properties. However, with the closure of the last remaining collieries in the area and the cessation of pumping the problem recurred but with a greater severity. To trap the gas at source would require a number of deep boreholes into the workings of several mines which are feeding the sandstone. Therefore a pilot tests with a small gas extraction plant coupled to an angled borehole into the Woolley Edge Rock was carried out. The results (Figure 5) indicated that the gas could be controlled. Therefore, a plant capable of extracting up to 500 l/s of gas from a number of boreholes is being designed.

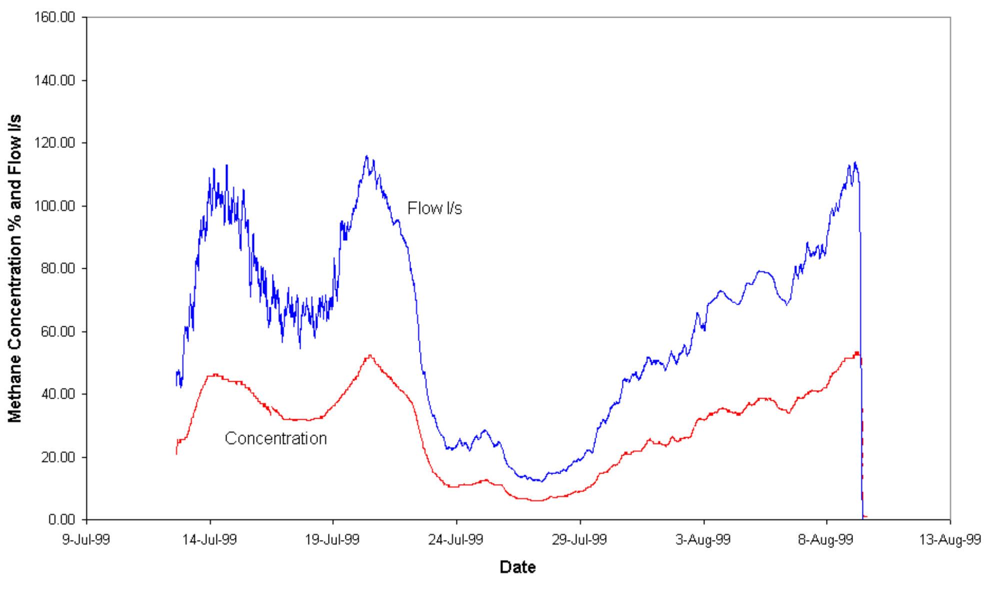

Figure 5 Gas pumping tests from sandstone at Barnsley

At Kimberworth, gas emissions were initially encountered from shafts associated with ancient shallow workings. Subsequently emissions occurred over a wider area with gas present in sandstone above the Parkgate seam which outcropped in the vicinity. Methane was the initially the problem but monitoring has shown that the composition of the gas in the sandstone varies from fresh air to blackdamp to methane (Figure 6). Since gas is absent in the shallow workings active pumping was attempted from gas filled workings in the Silkstone seam beneath the area. However, the gas was rapidly exhausted from the workings without affecting its presence in the sandstone. Evidence from the water recovery suggests that there is a correlation between water inflow and the appearance of mine gas in the sandstone. In particular, the fluctuating water levels at Barbot Hall (Figure 4) correlate well with the peaks of methane (Figure 6). It seems probable that the water flow into the deeper workings is displacing gas from the large reservoir to the east and subsequent increases in water level pressurise the gas forcing it into the sandstone. Evidence is provided by the observed increasing ethane/methane ratios during barometric pressure falls, which match ratios in the deeper workings. Significant reserves of gas exist to the east where some reservoirs, which continually emit gas at flows of some 300 l/s between 60% and 70% methane through passive vents, are estimated to be at least 0.5 x 10^6 m^3. Such reserves are being exploited by generating up to 10 MW of electricity or by supplying end users with flows up to 500 l/s.

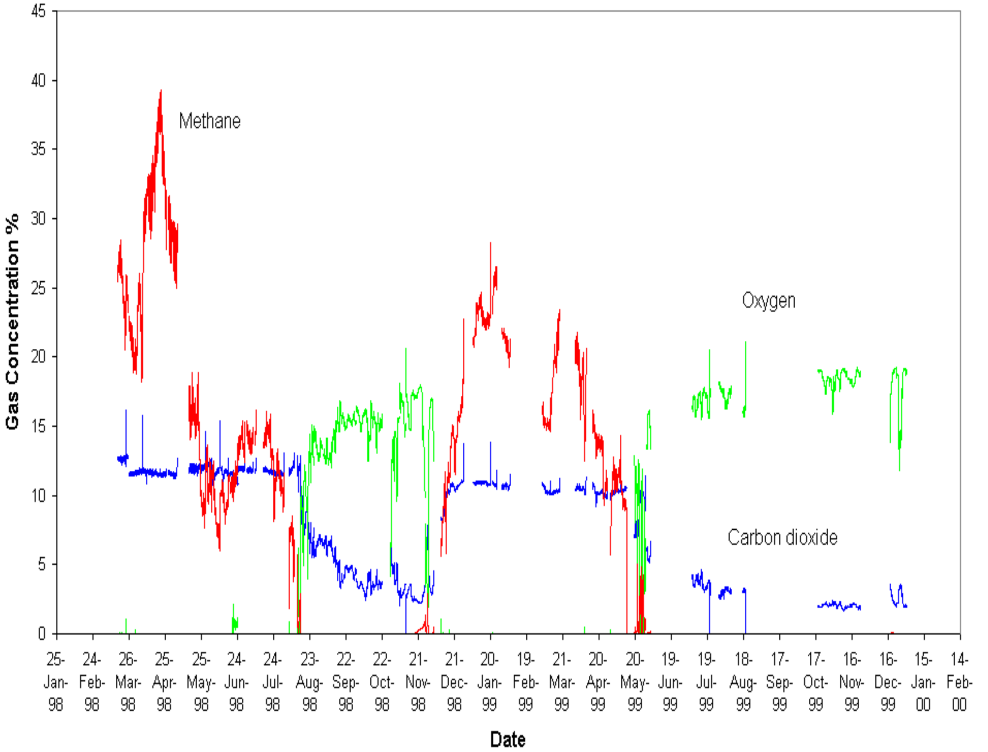

Figure 6 Gas concentrations in sandstone at Kimberworth

7 CONCLUSIONS

Minewater recovery in the UK coalfields recovers exponentially and recovery rates can be treated in a similar manner to that of a confined aquifer recovery.

Minewater recovery rates are similar in different coalfields and mining areas suggesting separate areas have similar permeability's and that the total water inflow is proportional to the area of workings and their method of work.

Gas emissions in the Yorkshire coalfield are often associated with sandstone aquifers which have been dewatered by mining.

Minewater recovery is responsible for displacing gas from the workings into the permeable beds.

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Wpływ odbudowy ciśnień wód kopalnianych na wydobywanie się gazu i wód na powierzchnię w Zagłębiu Yorkshire

Robin Burrell & Keith Witworth

Streszczenie: Zamknięcie większości kopalń w Zagłębiu Yorkshire pozostawiło skomplikowany połączony system obszarów pogórniczych, gdzie woda jest albo wypompowywana dla ochrony pozostałych kopalń i uniknięcia wypływów powierzchniowych, albo pozostawiona do naturalnej regeneracji. Dodatkowo znajduje się tu kilka historycznych grawitacyjnych wypływów wód podziemnych na powierzchnię , które wymagają oczyszczania, aby zmniejszyć zanieczyszczenie środowiska. Monitoring terenów, gdzie następuje odbudowa ciśnień wody wykazuje, iż proces ten przebiega ekspotencjalnie w podobny sposób jak podnoszenie się zwierciadła wody po standardowym próbnym pompowaniu. Nagła początkowa odbudowa ciśnień doprowadziła do zwiększenia ciśnienia gazów kopalnianych w obrębie wyrobisk, co spowodowało ich migrację na powierzchnię wzdłuż warstw przepuszczalnych i szczelin, naturalnych jak i poeksploatacyjnych. Artykuł porusza kwestię mechanizmów odbudowy ciśnień wody i migracji gazów na powierzchnię na przykładzie Zagłębia Yorkshire. Podano również przykłady zastosowania otworów odgazowujących oraz metod aktywnego drenażu w celu zapobiegania lub redukcji ryzyka zanieczyszczenia środowiska.