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THE PROBLEM OF WATER TABLE REBOUND AFTER MINING ACTIVITY AND ITS EFFECT ON GROUND AND SURFACE WATER QUALITY

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The Forth River Purification Board covers an area of about 4600 sq km in East Central Scotland, its boundary being determined by the watershed of the Forth basin. Within this area there is an interesting and diverse geology ranging from metamorphic Dalradian rocks in the north, through Silurian shales in the south to the younger Old Red Sandstone and Carboniferous strata of Central Scotland. These younger rocks lie in the structural feature of the rift valley and are interspersed with intrusive and extensive igneous rocks of contemporaneous ages, some of which form notable local geographical features. Fife Region, in the north east part of the Board's area, has a long history of mining.

Mining activity, whether it is by opencast or deep mining methods, has a great effect upon the hydrogeology of the area and also interferes with the natural surface water hydrology. In a temperate climate such as that of the UK there is constant recharge of the saturated zone by infiltration from the surface. This means that mining nearly always has to be accompanied by pumping to remove the excess groundwater. In time, the groundwater can be removed from a large geographical area leading to a depressed water table or piezometric level. This in turn reduces the amount of water available for baseflow in surface watercourses which can affect potable water supplies, agricultural interest and the quantity available for the dilution of effluents. In 1966 the Forth River Purification Board noted in its annual report that flows in the River Ore had decreased dramatically with the cessation of pumping from several collieries that had been closed(ref. 1). The large scale dewatering of the Ore valley meant that there was insufficient base flow present in the river during dry periods which resulted in a deterioration in water quality downstream of various discharges. This was a temporary situation on this particular river as water table rebound eventually restored better base flows but streams in mining areas which do not receive pumped waters can be depleted for many years.

In a mining area, groundwater can reach the surface in two ways, either by pumping from a working mine or opencast site or by gravitational discharge through a variety of exits. A pumped discharge is subject to control under the Rivers (Prevention of Pollution) (Scotland) Act 1951 whereby a consent has to be issued by a River Purification Board before the discharge can take place. Conditions applied by the Board will probably cover the flow rate, the iron and suspended solids concentrations and the point of discharge. Legislation in Scotland is different to that in England and Wales where pit waters are not subject to consent if discharged as raised. The real problem for the pollution control authorities is not with the pumped mine waters but with the natural discharges that occur when a coalfield has been abandoned and the groundwater is allowed to rise back to its natural level, a process know as water table rebound.

During the course of mining the rock structure changes in response to stress leading to fissuring. Air penetrates the rock mass allowing the formation of iron sulphate salts which can be dissolved in groundwater, thus contaminating it. The resulting ferruginous waters are low in organic matter but high in dissolved iron salts and often contain free sulphuric acid. The pH can fall to below 2 and if there are ironstone beds present in the strata, the iron levels may reach 2000 mg/l although such extremes are not common in Fife. Once mining ceases altogether in a coalfield the water level rises until it is in equilibrium, usually to a level more or less the same as in pre-mining days. This is water table rebound. The term 'water table'rebound is not strictly correct when applied to coalfields because the hydrogeology is usually very complex in coal-bearing rocks but it is a useful shorthand term to describe the processes taking place. If the topography and geology of an area are such that groundwater can only come to the surface as baseflow in streams then it is unlikely that any serious diminution of surface water quality will occur. If, as is more likely, man-made access to the surface from the mine workings is below the final free water table or the piezometric surface then groundwater can flow easily into local watercourses giving rise to the ferruginous discharges that affect so many abandoned coalfields.

In the Fife coalfield coal was worked from Carboniferous rocks of the Limestone Coal Group through to the Upper Coal Measures (ref. 2). Much of the coalfield was abandoned during the late 1960's and within 10 years ferruginous discharges began to aopear in some local rivers, particularly the River Ore. The area involved is about 70 sq km consisting structurally of a syncline plunging northeast with the Lower Limestone Group outcropping at the south of the syncline and the Passage Group at the north. Over 20 important seams were worked in the Limestone Coal Group and the whole area is overlain by superficial deposits. Most of the surface drainage flows west to east through the Ore valley to the Leven but a low watershed east of Dunfermline splits the rest of the drainage to the Lyne Burn. Some minor streams run directly to the estuary. The progress of water table rebound in the Ore valley could be followed from 1976 onwards as new ferruginous discharges came to the Board's attention, some of these being of minor importance but several having serious economic consequences. Nor was the Ore valley the only area to be affected, as a major breakout occurred on a small stream, the Keithing Burn, whilst several more of lesser importance were reported on other watercourses. Table 1 lists some of these discharges.

TABLE I

Major ferruginous discharges in Fife

Name	Ave flow l/s	Ave Iron mg/l	Ave loading kg/day	Origin	Receiving Watercourse
Pitfirrane	138	2	24	Drainage adit	Lyne Burn
Fordell Castle	239	19	392	Drainage adit	Keithing Burn
Blairenbathie	40	4	13	Pit shaft	Ore
E. Colquhally	22	8	15	Drainage adit	Ore
Minto pit	45	29	112	Drainage adit	Ore
New Carden(1+2)	10	17	12	Borehole/ fissures	Ore
Kinglassie	14	16	19	Drainage adit	Lochty Burn

The River Purification Board's interest is in the effect upon the receiving waters which varies according to the flow and chemical composition of the discharge and the size of the watercourse. The flora and fauna are seriously affected and the characteristic coating of ferric hydroxide and bacterial slime is aesthetically objectionable. Some streams can be classified as badly polluted whether chemical or biological criteria are used but the effects extend beyond simply polluting rivers.

Economic consequences of these discharges became evident early on when the Board received complaints from a farmer that he was unable to drain land that was newly waterlogged. On inspection the ground, some 2 ha in area, was found to be saturated with iron-bearing waters welling up from an old borehole and seeping through the drift from fissures, rendering the land useless for grazing dairy cattle. Not far from the farm, ferruginous water was found to have flooded the foundations of a church and affected some houses whilst a nearby market-garden received an unwelcome spring in the middle of a pathway. A report of a 450 KV power line pylon being surrounded by upwelling water caused alarm for a while until the authorities satisfied themselves that the pylon was safe in spite of the water. Had this not been so, the cost of remedying the situation would have been high and as the water is a 'natural' discharge, the cost could not have been reclaimed from anywhere. These examples all occurred in a zone of discharge brought about by the combination of geological and topographical features in the district, where the groundwater discharged through fissures or seepage.

Serious problems can arise as a result of the larger volumes of water which may come from old drainage adits and pit shafts even although they tend not to affect property.. In Fife a breakout occurred in 1977 from a drainage adit at Fordell Castle (ref. 3). This adit had been a major gravity drain for 9 sq km of the coalfield and prior to 1977 only discharged intermittent small flows. It had taken about 10 years for the rebound to reach the surface through the day level although the fall off in flow through time suggested that a blockage on the adit had withstood a certain head before collapsing. Initially the flow was 380 l/s but after a year it had dropped to 260 l/s and now (late 1980) averages a steady 240 l/s. Similarly the iron concentration has fallen from 28 mg/l to 19 mg/l reducing the initial loading on the receiving waters from 0.6 to 0.4 T/d. Whilst the reduction is welcome it does not help the main victims of the breakout, the town of Inverkeithing and its papermill. The Keithing Burn is grossly polluted by the iron water and its value amenity to the town has dropped sharply. Pleasure boats that anchor at its mouth become fouled with the ochre stain. The papermill has had to discontine making high quality photocopying paper because of the iron left in the water even after treatment and had with some difficulty to find a new source of process water. They have to spend considerable sums on the pre-treatment of their supply as there is no alternative available. On the Ore another three pit/adits contribute 0.1 T/d iron to the river (Fig. 1). In total, the River Ore carries some 0.6 T/d iron before its first tributary joins it. The river is fishless in its lower reaches but the iron only causes light staining on the stones. The effects of the iron are unfortunate because the river had shown considerable improvement since it stopped receiving pumped waters and coal washery effluents. It is not known whether it will ever recover sufficiently to support fish.

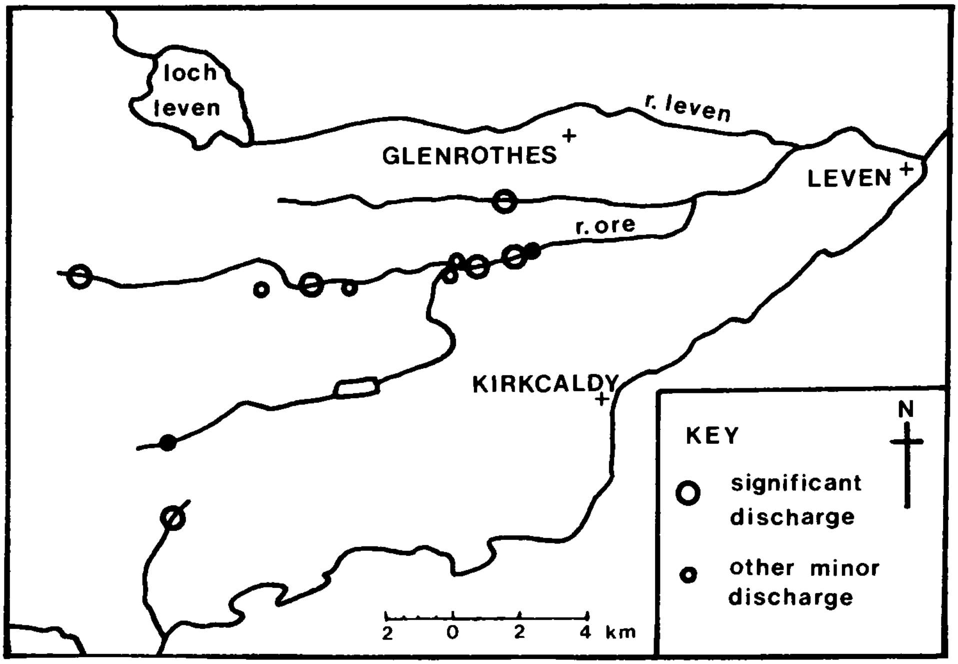

Fig. 1. Ferruginous Discharges in Central Fife

The decline in quality of surface waters in an abandoned coalfield does not have to be insidious. It can be sudden and spectacular as shown in an example outwith the Forth River Purification Board's area when acid minewater broke out of an old mineshaft at Dalquharran in Ayrshire, Scotland in October 1979. With an iron concentration of about 1000 mg/l and a pH of 3.5 it ruined one of the best salmon rivers in Ayrshire and nearly brought about the closure of a factory employing 500 people by contaminating the process water. The significance of this particular case was not so much that it happened but that it had been predicted with great accuracy by the staff of the Clyde River Purification Board. When the National Coal Board refused to take any responsibility an action was brought against them under Section 22 of the Rivers (Prevention of Pollution) (Scotland) Act 1951 and they were accused of "causing or knowingly permitting" pollution to enter the stream. The Sheriff ruled that the NCB were not guilty. He said they did not cause the pollution because the entry of polluted water into the stream did not come about by reason of any active operation or positive act on the part of the NCB (ref. 4). The case is now the subject of an appeal but the Government has already made it clear that it will not release funds to the Scottish Development Agency enabling them to treat the water. This illustrates some of the legal difficulties involved in allocating responsibility for alleviating or preventing pollution from abandoned mine workings, as the National Coal Board relinquish ownership of the site when they cease working a pit.

Remedial measures are always costly and often impractical even if financial responsibility can be determined. There are usually two options open and a third possibility if the coalfield is near the sea. Firstly, chemical treatment using neutralisation with lime followed by settlement or simply oxidation and settlement can reduce the iron substantially but gives a sludge handling problem. It also requires sophisticated lime dosing equipment and qualified staff to supervise the plant. Secondly, it might be possible to continue pumping from suitably sited shafts which would dewater sensitive zones in the same way as on a working coalfield. This would be costly but would have the advantage of determining a specific discharge point thus obviating the uncontrolled breakouts (ref. 5). Lastly, if sea disposal is an acceptable alternative, a channel from the breakout to the sea can be constructed which at least protects the freshwater streams. Only one of these alternatives, oxidation and settlement, has been applied on an experimental basis to a ferruginous discharge with some success although the others are used in working coalfields. Until funds are made available it is unlikely that any more work will take place.

Some people argue that ferruginous discharges are a necessary evil resulting from the extraction of a valuable resource and that too much fuss is made about them. This may be so in purely aesthetic terms but there is no doubt that such discharges cause economic problems in some cases. As they are indirectly of a man-made origin, should not someone have the responsibility for compensating those affected by them?

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