South Western Branch (South Wales Group)

Investigation into the Movement of Ground Water from Bryn Pit above Ebbw Vale, Monmouthshire

By A. S. Parsons and M. D. Hunter (Member)*

Introduction

The authors have been involved in an examination of the movement of ground water in a section of the upper end of the Ebbw Valley in Monmouthshire. The purpose of the investigation was to decide on the effect on the surrounding water resources, both surface streams and reservoirs, of abstraction of approximately $6{\cdot}36 \times 10^3 m^3/d$ (1·4 mil gal/d) of flowing water from a disused mine, Bryn Pit, situated 1·2 km (¾ mile) NE of Beaufort at 41 m (1350 ft) AOD on high ground at the head of Ebbw Vale. The River Authority were approached for a licence under the Water Resources Act 1963 by the British Steel Corporation (RTB Division), Ebbw Vale, and because of the relative scarcity of unexploited water in this area, the effect of abstraction on existing water usage had to be considered. Supplies which might be affected include:

(a) Water abstraction at Blackrock (4 km or 2½ miles E of Bryn Pit) from an underground spring system at the rate of $2{\cdot}5 \times 10^3 m^3/d$ (0·55 mil gal d) used for Brynmawr's domestic consumption.

(b) Supplies to Carno Reservoir, used by the Ebbw Vale UDC for their domestic supply. This was 1·2 km (¾ mile) NW of the pit and at a level of less than 396 m (1300 ft) AOD.

(c) Shon Sheffrey Reservoir (Tredegar UDC domestic supply), fed from springs at 366 m (1200 ft) AOD and situated 4·8 km (3 miles) W of the pit.

(d) The headwaters of the Clydach, Ebbw Fach, Ebbw Fawr and Sirhowy streams which all emerge from the plateau on which Bryn Pit was situated. All of these streams have dry-weather flows less than $4{\cdot}5 \times 10^3 m^3/d$ (1 mil gal/d) and the effect of abstracting $6{\cdot}36 \times 10^3 m^3/d$ (1·4 mil gal/d) from Bryn Pit could threaten the dry-weather flow of one or more of these streams. The headwaters of the Ebbw Fawr are completely abstracted under dry weather conditions for use by the steelworks, the effluent from which forms the source of the river.

It was realized that there was a possibility that the steelworks were already utilizing some of the water flowing in Bryn Pit since this water formed the probable supply to some of the springs in the Ebbw Valley but the BSC would still prefer to abstract directly from the pit where the water quality was high.

The proposed investigation of the fate of water from Bryn Pit involved the addition of radioactive tritium in the form of tritiated water. Since tritium is an isotope of hydrogen, it provides an almost perfect tracer for water movement since there is no possibility of loss by chemical or other interaction with the strata. Tritium emits very low energy *beta*-particles (electrons) and measurement has to be carried out in a laboratory from samples taken on site.

Previous work had been carried out by BSC using a limited amount of fluorescein dye in Bryn Pit. This had failed to indicate any ground water interconnections, almost certainly due to loss of the dye by adsorption during seepage through the old mine workings.

Consultation

It was obviously desirable to obtain as much technical information as was available in relation to the old mine workings—the nature of the aquifer, its geological structure, its porosity or permeability, the angle and direction of the slope, whether the water table was confined by clay or other top cover, the thickness of the aquifer, together with an indication of any geological faults in the area and how much water was being pumped by local mines. A meeting was therefore held with engineers of the National Coal Board, steel works personnel, and officers and members of the water undertakers involved, and this provided considerable assistance and detailed information on the geological structure of the area, which contributed largely to the success of the investigation. From these discussions it emerged that the ground was composed of lower seam outcrop mudstone shales, and at a lower depth hardstone rocks, accompanied by old ironstone workings at deeper levels, and this was corroborated by reference to a detailed plan (dated 1852) of the ironstone workings. It was the opinion of Mr. Bowen, National Coal Board Engineer, with which there was general agreement, that water was being transferred via fractured rocks into headings and that there was no need to think of a large

*Mr. Parsons is with the United Kingdom Atomic Energy Authority and Mr. Hunter is Pollution Prevention Officer to the Usk River Authority

water-bearing stratum acting as an underground porous aquifer. Mr. Evans, Water Engineer, Richard Thomas & Baldwins, Ebbw Vale, indicated that measurements of the Bryn Pit water showed that 18 × 10^3m^3 (4 mil gal) per week were normally present and that this fluctuated between 4·5 and 45 × 10^3m^3 (1 and 10 mil gal) per week according to dry or wet conditions. The fluorescein experiment had been unsuccessful, although daily observation had been made over 3 months at seepage sites supplying Ebbw Fawr. During the discussion both Drill Ground Pit and Prince of Wales Pit in the Ebbw Vale were indicated as the most southerly points before the coal seam barrier prevented water from travelling underground further down the valley.

Planning the Radioactive Investigation

Tracer and Health Considerations

The method of determining the destination of the water flowing through Bryn Pit was to add tritium tracer in the form of tritiated water at the pit and to sample all possible ground water springs or abstraction points to which the water might be transported.

The amount of tracer to be used is governed by two considerations: (1) The requirement of complete safety to water users should the tracer be transported to a potable water supply. The recommended maximum drinking water tolerance for non-occupationally exposed persons is 0·003 μCi/ml, based on an intake for a period of 70 years. Hence the tracer should ideally leave Bryn Pit at a concentration of this order of magnitude, with obvious safety factors arising from the fact that underground dilution would necessarily occur and that the duration of any tracer in potable water would only be a few days, which would represent an extremely small fraction of the 70 years on which the drinking water tolerance is based. (2) Sufficient tracer had to be used for subsequent detection allowing for dispersion during the flow underground and for dilution which might occur in the ground water reservoir. The amount of tracer selected was 50 Ci of tritiated water and this would be injected into the flow in Bryn Pit over a period of 24 h to avoid the possibility of any transient high tracer concentrations. This also ensured that the "pulse" of tracer issuing at any sampling points would not be so short that it could be missed by daily sampling. This amount of tracer could be detected if it was diluted in 3228 × 10^3m^3 (710 mil gal) of water.

Sampling system (Fig. 1). In order to ensure that all possible destinations of the Bryn Pit water were assayed, samples were obtained from 14 water sources in the district, as follows:

- A Ebbw Fawr, Riverside Pumping Station. This station is situated in Ebbw Vale just above the steelworks and would provide evidence of any tracer seepage to the river from springs or adits N of this point. All the water in the river at this point is then pumped further upstream to sample point C.
- B RTB viaduct, sampling an adit on the E side of Ebbw Vale.
- C Pumping Station above Glan-yr-Avon, representing the river plus water returned from A. This point is just S of Beaufort.
- D Pughs Level, an adit on the E side of Ebbw Vale, known to be connected with the Bryn Pit workings.
- E Piped discharge near Newchurch on the E side of Ebbw Vale.
- F Drill Ground Pit, deep ground water pumped within the steelworks.
- G Prince of Wales Pit, deep ground water pumped within the steelworks, 1·2 km (¾ mile) S of point F.
- H Ebbw Fawr, above the conflux with Ebbw Fach and 6·4 km (4 miles) downstream of the steelworks.
- J Shon Sheffrey, upper springs. Supply to the reservoir, 4·8 km (3 miles) W of Bryn Pit.
- K Upper reaches of River Sirhowy, 1·6 km (1 mile) S of Tredegar.
- L Ebbw Fach, head of the river.
- M The Clydach at Blackrock, 4·0 km (2½ miles) E of Bryn Pit.
- N Gisfaen Springs, domestic water supply to Brynmawr, just E of M.
- O Pumped abstraction in the Claisfer tributary, draining the plateau to the north and 5·6 km (3½ miles) NW of Bryn Pit.

Injection of Radioactive Tracer

The depth of the Bryn Pit shaft was 32 m (105 ft) and a journey of 20 min was necessary to reach a point suitable for addition of the tracer to the stream. The Bryn Pit stream flowed through a rectangular measuring weir and then poured down a vertical shaft to a lower level of the mine. It was convenient to add the concentrated tracer to the stream at the point of entry into the vertical shaft. The 50 curies of tritiated water were added to 10 litres of distilled water contained in a Mariotte vessel and mixed thoroughly. The outflow orifice of the vessel had been adjusted previously to give a constant rate injection over a period of 24 h, thus ensuring a safe initial concentration of tritium in the water and a long pulse which would not easily be missed at the sampling points.

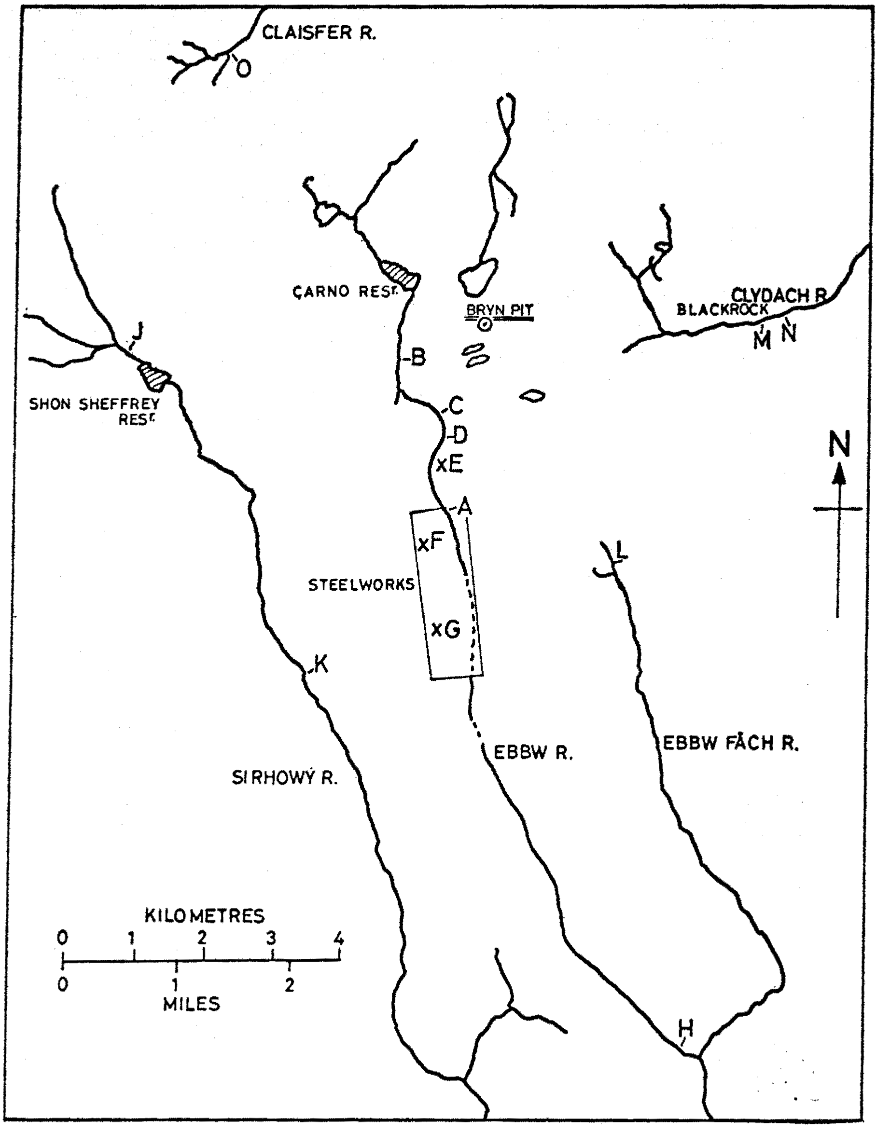

Fig. 1. Sampling points used for investigation into movement of ground water from Bryn Pit

The tap on the Mariotte vessel was opened and injection of tracer commenced at 09·30 hours on 8 July 1969. The injection rate was checked periodically. The first 8 litres were added at an average of 6·5 ml/min and the remaining 2 litres were added at a reducing rate due to the design of the vessel. Injection was completed by 14.00 hours on 9 July 1969.

Sampling. Sampling took place at approximately 12.00 hours, 1, 2, 3, 4, 6, 8, 11, 14, 18, 23, 25, 28 and 35 days after the start of injection. The samples were taken in 138 g (1 oz) capacity glass vials. These had watertight screw-on metal lids incorporating a rubber washer.

Measurement of samples and qualitative results. The samples were transported to the Wantage Research Laboratory* and measured by a liquid scintillation spectrometer. A 2-ml aliquot of each sample was added to a dioxane-based scintillant and the light pulses due to the tritium were

*Now transferred to AERE, Harwell

measured and compared with those from a standard tritium solution. The natural "background" was measured using water taken from Bryn Pit prior to the injection.

Samples taken during the first two days were measured as soon as possible in case the tracer was present so that the planned sampling programme could be modified if necessary. In fact the original times were used and also extended.

Five sampling stations showed connection with the Bryn Pit water. These were A, B, C, D and F. The specific activity of each sample is shown in Table 1 as disintegrations per minute per g of sample. The complete results are plotted graphically in Fig. 2. Tracer levels at Stations A, B and C had fallen almost to background by the 28th day but further samples of D and F were taken 35 days after injection.

Quantitative Assessment of Results

Initially only qualitative indications of interconnection between the sampling points and Bryn Pit were investigated. However, the clear tracer results obtained from 5 separate stations indicated an unexpectedly complex division of the water flowing through the pit and provided the opportunity for a more quantitative analysis of the results.

Such an analysis requires information on the quantity of tracer injected (a nominal 50 Ci), the time variation of the concentration of tritium at the various effluent points, and the flow rate of each at these points. All of these (particularly the flow rates) are only known approximately and this limits the accuracy of the analysis.

The pumping rates for Stations A, C and F were supplied by the Water Engineer's Depart-

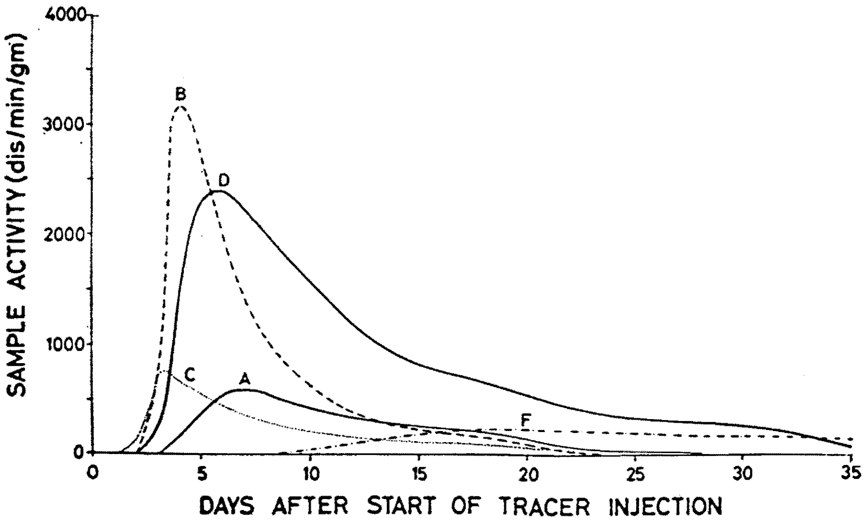

Fig. 2. Variations in specific activity of water at five sampling stations

Table 1. Specific Activities of Samples Taken at Sampling Stations

Disintegrations per minute per gramme of sample

Sample	Days after start of injection												
	1	2	3	4	6	8	11	14	18	23	28	35	98*
A	—	—	—	183	563	554	372	301	208	59	31	—	—
B	—	—	837	3200	1950	1030	479	267	165	13	18	—	—
C	—	149	731	668	451	299	196	146	100	27	28	—	—
D	—	5	264	1560	2407	1990	1360	902	659	397	317	95	—
F	—	—	—	—	—	—	73	169	217	203	173	145	22

ment, Ebbw Vale works. A V-notch weir was installed at Station D (Pugh's Level) but this was only read infrequently and flow values during the passage of the pulse have had to be extrapolated from readings taken before and after arrival of the tracer. The flow at Station B was very small and was estimated.

By analysing the tracer concentration and flow at each sample point, the following quantitative assessment was made of the percentage of Bryn Pit water at each site:

Station A. All the water from this site was pumped to Station C and the fraction is included in the figures for this point.

Station B. The small flow, estimated at 1·09 m^3/h (140 gal/h), contained 0·5 per cent of the Bryn Pit water.

Station C. The initial pumping rate after tracer was detected at this station was 42·3 × $10^3 m^3$ (9·3 mil gal)/week, reducing to about 35·0 × $10^3 m^3$ (7·7 mil gal)/week over the following two weeks. Using these values, the amount of tracer located at this site was 26 per cent of that injected at the pit.

Station D. The flow rate fell from 35·5 m^3/h (7800 gal/h) when the tracer arrived to about 4·1 m^3/h (3100 gal/h) three weeks later. By correlating this reducing flow with the tracer concentration variations in time, it is estimated that 12·5 per cent of the tracer appears at this site.

Station F. Water was pumped from this pit at approximately 47·7 × $10^3 m^3$ (10·5 mil gal)/week and during the first 35 days of the investigation, 27 per cent of the tritium was abstracted from this pit. A significant amount of tracer was still present in the water and further sampling was undertaken 98 days after tracer injection. The tracer value showed that the concentration was decreasing exponentially, as might be expected in a well mixed system, and the total tritium abstracted from this point was 58 per cent.

The total tritium which can be accounted for by this quantitative analysis is 97 per cent. The errors involved in this assessment are probably as high as 10 or 20 per cent and the estimate of an almost perfect tracer balance is somewhat fortuitous. However, the results indicate that all the major outflow points arising from Bryn Pit have been sampled. They also show that the Drill Ground Pit is abstracting all the available water in its area, since the tracer balance shows that no significant amounts of tritium remain in the ground water system after approximately 100 days.

Conclusions

The tritium tracer investigation has shown that water flowing through Bryn Pit is discharged at several points into the Upper Ebbw Valley and also contributes to underground water abstracted from the Drill Ground Pit. The transit time is only a few days and the tracer discharge was almost complete within 100 days, showing a fairly small storage capacity for the system.

This investigation illustrates the value of radioactive tracer techniques, which could be applied economically and safely to the study of many different types of problems associated with ground water flow, retention times, interconnections and storage.

Acknowledgments

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