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Mine water capture

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Abstract
The Kames No. 1 shaft discharge had been identified by the Scottish Environment Protection Agency as a priority polluting discharge. The colliery had been constructed on the flood plain of the River Ayr and Garpel Water and all that remain are two abandoned mineshafts. The discharge was emanating from the No. 1 shaft and causing pollution of the Garpel Water by direct contact, and of the River Ayr by diffuse pollution. Detailed hydrogeological studies were undertaken into the nature of the discharge. The main problems to be overcome were harnessing the discharge, managing the flow and constructing the subsequent downstream wetland treatment system, all within a flood plain scenario, without further pollution of the watercourses. This paper focuses on the engineering design and physical site works involved with the capture of the mine water from within the 330 m deep mineshaft. Successful capture of the mine water was found to be critical to engineering the downstream treatment option.

Key words: engineering, excavation, gravity, pollution, mineshaft, mine water

SITE SETTING

The former Kames Colliery is located in Muirkirk in Ayrshire (Hutton 1996) on the flood plain between the Garpel Water and the River Ayr, Figure 1. Kames Colliery was one of many collieries established in the 18th century to exploit the rich coal seams of Ayrshire located in the western area of the Midland Valley of Scotland. Kames No. 1 shaft was sunk in 1870 (330 m deep) and records note that the Kames workings were amongst the wettest of the Ayrshire Coalfields. Kames Colliery was closed in 1968 and the colliery was razed to the ground and the site returned to rural open space. The discharge was found to be emanating from the location of the Kames No. 1 shaft and was seen to be flowing into the Garpel Water.

DISCHARGE FLOW AND QUALITY DETAILS

The first anecdotal evidence of a mine water discharge upwelling from the former Kames No. 1 shaft location was by the National Coal Board in 1974 (Babtie 1982). At that time the flow towards the Garpel water was recorded at 47 L/s in January 1974 and 22 L/s in June 1974. Between 1980 and 1982 flow records (Babtie 1982) show the variation in discharge to be 35 L/s in winter and as low as 5 L/s in summer. There is then a gap in flow data records until 1995, when the Coal Authority commenced desk studies into the presence of abandoned mine drainage (Scott Wilson Kirkpatrick 1995). The 1995–1996 figures show a similar seasonal variation to the flows already presented, and record 35.3 L/s in February 1996, falling to 4.7 L/s in August 1996. It is therefore apparent that the flows from the discharge from the Kames No. 1 shaft are interrelated to the effect of seasonal inundation on the catchment.

The National Coal Board evidence in 1970 also provided a record of 70 mg/L total iron for the mine water. Table 1 shows a compilation of historical water quality records.

From the limited information recorded it was apparent that the discharge had reduced in quality from an initial 70 mg/L to around 14 mg/L over a 20-year period. The initial elevated iron content is not surprising, given the first flush concept (Younger 1995). Field measurements of dissolved oxygen taken by Babtie in 1996 showed, as expected, that the discharge was very low in oxygen. The iron is present in its dissolved form and on oxidation there is a slight rise in pH, then a fall to near neutral, demonstrating the net alkaline quality of the mine water discharge.

Treatment to improve the quality of the discharge was required to comply with the Scottish Environment Protection Agency's permissible limit of no greater than 1.0 mg/L of total iron entering a watercourse. This level was being exceeded by the uncontrolled discharge from the abandoned mine drainage. Babtie Group Ltd was commissioned by the Coal Authority in 1996 to

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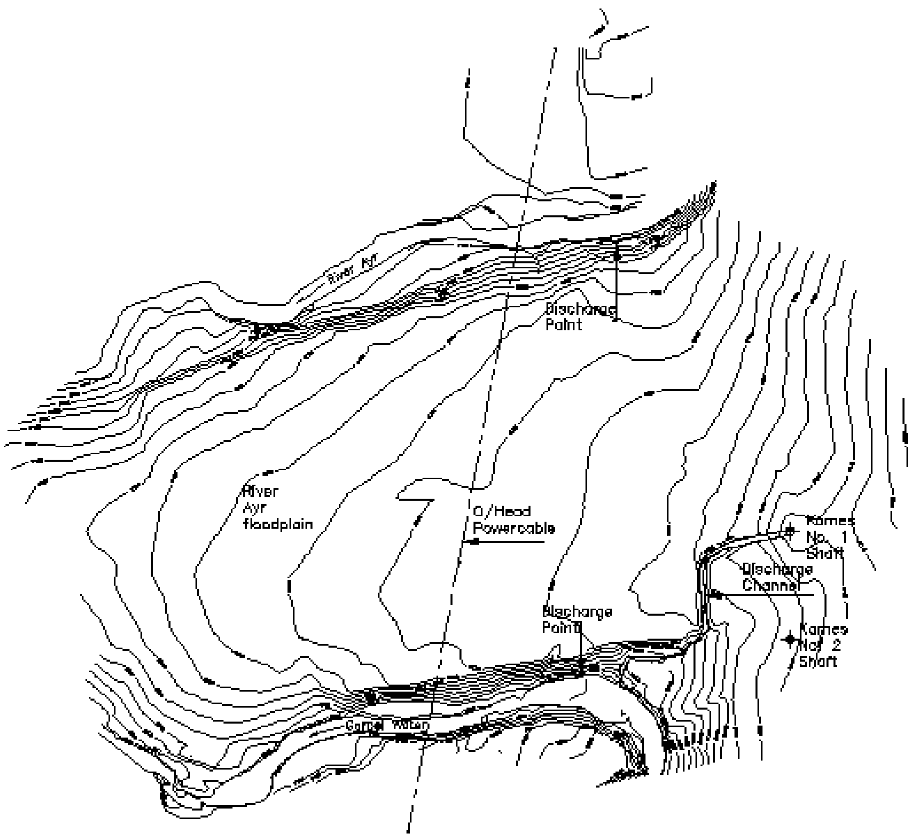

Figure 1. Location of Kames No. 1 shaft and associated discharges

undertake studies and design a suitable treatment system.

TREATMENT FEASIBILITY

The 1996 desk study (Babtie 1996) identified that improvement of the discharge quality could be achieved by passive treatment, incorporating aeration cascades and constructed wetlands. This would reduce the impact on the Garpel Water and meet the requirements to upgrade river quality set by the Scottish Environment Protection Agency. Such a treatment system would depend upon two very key factors: the suitability of the flood plain for construction of a wetland and the difference in level between the discharge location and the wetland area. In particular, would there be enough head of mine water to drive it through the wetland to its discharge to the Garpel Water without pumping?

Better flow monitoring had been identified at the outline design stage as necessary to gauge the optimum flows for input to the design (Babtie 1996). It was necessary to establish the design parameters, and during the outline design phase these were agreed to be: total iron of 20 mg/L; pH near neutral; and a maximum flow of 36 L/s.

The area for the construction had been assessed and sized according to the anticipated rates for iron precipitation and settlement, and required the relocation of overhead power cables to fit into the available landtake

Table 1. Historical water quality results for the Kames No. 1 discharge

Period	Total iron mg/L	pH	Acidity, mg $CaCO_3$/L	Conductivity µS/cm	Sulphate mg/L	Mn mg/L
1980 – 82	28.0 – 32.0	6.4	46.5	1100–1500		
1991 – 92	11.3	6.7–7.0	21.0			
1992 – 94	4.6	7.0–7.9	8.2			
1994 – 95	14.4	6.4–7.0	23.5	945	244.0	1.95

within the floodplain. Ground investigation provided information on the groundwater and the depth and nature of made ground. No obstructions or buried foundations were encountered during the investigation. An assessment of flood risk was also undertaken.

Following the ground investigation, a greater thickness of made ground was identified over the floodplain and above the Kames No. 1 shaft. On the one hand, this was advantageous for the design of the wetlands and settlement ponds, but on the other, a much greater excavation would be required to harness the flow from the shaft.

There were limited records of the shaft construction and none of the condition of the shaft on abandonment, therefore the mechanism by which the mine water was travelling through the shaft to the point at which it surfaced was not known. Also, and most importantly, was the recorded flow realistic? Would the flow change once the shaft had been accessed and the mine water flow secured to the surface? Would there be any loss of head? These were fundamental questions which carried risks associated with the success of the design and the effectiveness of the performance of the subsequent treatment solution.

The outline design was developed on the basis that from the point of discharge at approximately 210 m Above Ordnance Datum there was a 7 m fall to the Garpel Water. Within this fall a 2 m high aeration cascade would be required to assist with the iron oxidation and precipitation process. The engineers also needed to take advantage of the natural fall in designing the wetland to promote flow through the cells. At outline design stage it was therefore critical that the mine water flow and relative levels were established before progressing with further refinement of the treatment system design.

MINESHAFT INVESTIGATION

An initial exploratory investigation to expose the Kames No. 1 shaft was carried out in May 1998. It was established that if a return valve on a ventilation pipe had been left open, water would have been able to enter the pipe and that could explain how the water was travelling to the surface.

The alternative theory was that the whole shaft was acting as a conduit for mine water and that artesian water conditions were present because of the shaft structure. Piezometers installed adjacent to the shaft and across the site showed a different water table to the head of water in the shaft, and in general were in agreement with the river levels on either side of the flood plain. Also, the groundwater level immediately adjacent to the shaft was 3 m higher than elsewhere on the site.

The investigation of the shaft showed that the first theory was likely to be correct. A discrete upwelling from a point within the shaft was observed (Figure 2). The shaft area was secured and the shaft was left in this disturbed state to allow the flow to be monitored and further checks on quality to be made.

The water flows were found to be within the original design parameters, and this gave comfort for design of the wetland scheme. It was, however, agreed to undertake a more extensive investigation coupled with the permanent interception of the mine water. A contract was designed and let for the interception of the discharge, the creation of a conduit to the surface and a surface exit structure.

CREATING THE HARNESS

The works commenced in February 1999, and it was immediately apparent that this was going to be a very

Figure 2. Discrete upwelling within the Kames No. 1 shaft

Figure 3. View of the excavation to intercept the Kames No. 1 shaft (located bottom left)

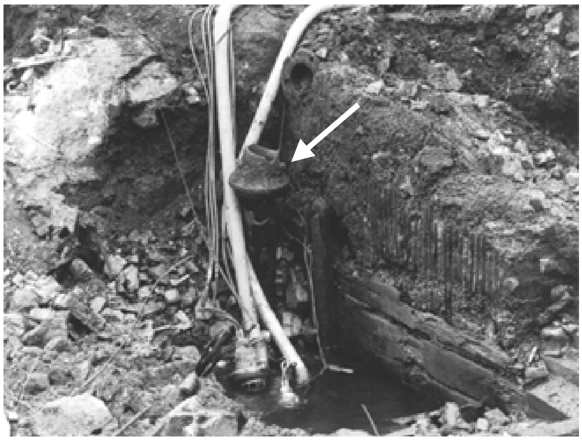

Figure 4. Cast iron pipe visible within shaft

large excavation. Figure 3 shows the depth and extent of the excavation and the presence of many of the substructures and underground services associated with the former colliery buildings.

Where underground services were uncovered and not totally removed they were sealed to prevent further movement of polluted groundwater into the adjacent surface waters.

The shaft was uncovered at approximately 1 m depth below the existing ground level and the excavation was kept dry by sump pumping.

Figure 4 shows a cast iron pipe of 300 mm diameter, which is most likely the ventilation pipe discerned during initial investigations. During the excavation work it was noted that the mine water was not using the whole shaft as a conduit and was primarily upwelling adjacent to the cast iron pipe. The cast iron pipe was found to be only 3 m in length. Below this level there was no evidence of the pipe. Excavations were completed at 8 m below ground level on bedrock.

The bolted steel segments that formed the shaft lining can be seen in Figure 5, these were removed to bedrock level. Cohesive clay was placed outwith the main upwelling area to form an impermeable barrier prior to capping the shaft with a reinforced concrete slab. The concrete slab extends beyond the steel segments in accordance with best practice guidance for stabilisation of mineshafts.

Pipes were cast into the slab to convey the mine water to the surface in a controlled manner for future treatment, Figure 6. The pipes were raised simultaneously, Figure 7, within protective concrete sleeves, as the excavation was backfilled to the existing ground surface.

There had been no loss of head during the capture process and the flow remained constant, which can be observed in Figure 8. There was an extended period of monitoring over twelve months to ensure that the mine water discharge had stabilised while the detailed design of the wetland treatment system continued.

Figure 5. The shaft lining is exposed, dressed off and prepared for concrete

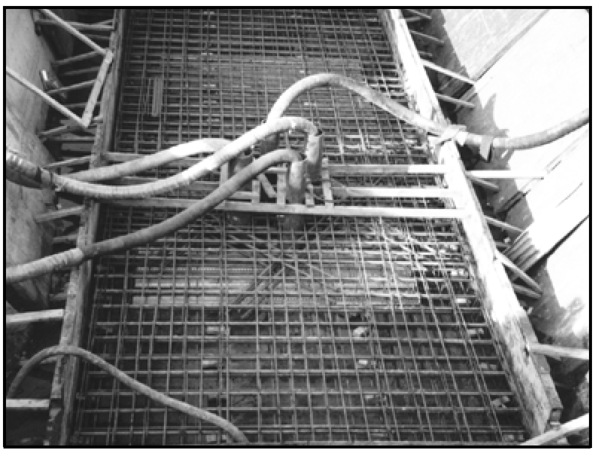

Figure 6. The shaft cap is prepared for the concrete pour; dewatering pipes in centre

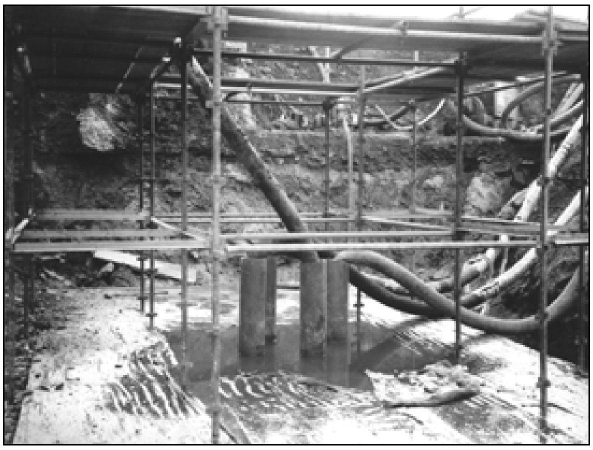

Figure 7. Shows the staging to bring the discharge point up to ground surface

Figure 8. Finished mine water discharge point (the harness)

CONCLUSIONS

At the commencement of the assessment of a treatment solution for the Kames discharge there was uncertainty relating to the nature and behaviour of the mine water. In particular, would there be any loss of flow or effective head of discharge by capturing the mine water from the shaft? The concept of the downstream treatment was formed around a gravity solution and was designed on the basis that sufficient height would exist between the shaft location and the wetlands to permit gravity flow through the wetland cells to the final discharge point into the river.

An 'options appraisal' looked at the risks associated with the design of the treatment scheme, and questions remained over the flow and quality parameters of the discharge. The ultimate risk was that the downstream system would be incompatible with the discharge should it change due to a blockage in the shaft or other hydrogeological situations such as the impact of dewatering for a nearby opencast mine.

By investigating and monitoring the circumstances of the Kames discharge and the influencing factors, hydrogeological and environmental, greater certainty has been possible for the design of the downstream system. The completed treatment system was constructed during the summer of 2000 and is operating effectively, with mine water continuing to flow from its harness.

In the authors' experience it is not always possible to fully investigate the emergence of a mine water discharge or all of the potential influencing factors and, to this end, an acceptance of the risks, which were successfully reduced at Kames, may be an inevitable aspect of the ongoing treatment of mine water discharges.

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