Installation of a Low-Cost Mine Water Discharge Monitoring System at the Charaat Gold Prospect, Kyrgyzstan and its Application to a 3-D Numerical Groundwater Flow Model

Scott C. Atkinson[1], Vladimir Stihin[2]

[1]*Atkinson Mine Water Consultants LLC, Golden, Colorado, U.S.A, scatkinson@amwc.us.com*
[2]*Charaat Gold Holdings Ltd., Bishkek, Kyrgyz Republic, vstihin@charaat.com*

Abstract A low-cost mine water discharge monitoring system was installed during the pre-feasibility and borehole testing stages at Charaat Gold Holdings Limited's gold prospect in the Middle Tien-Shan Mountains of western Kyrgyzstan. Three high precision Baski cutthroat flumes (www.baski.com) were installed in combination with the design and construction of multiple (currently six) semi-permanent reinforced concrete flume-box stations in challenging, severely space-limited mine adits. Construction of moulds was carried out using pre-cut plywood pieces (note: installations at previous sites used pre-cast fibreglass moulds), allowing for logistical ease of transport of materials to the remote winter mine camp via helicopters. The versatility of this technique allowed for quick set-up and reading of discharge rates – in minutes as opposed to hours as is commonly the case – allowing for greater measurement frequencies, while keeping capital costs down. Mine water discharge data collected over several months were used to calibrate a 3-D numerical groundwater flow model using Itasca Denver's finite-element code, MINEDW.

Key Words flume, groundwater modelling, mine dewatering, discharge rates

Introduction

Charaat Gold Holdings Limited's gold prospect in western Kyrgyzstan is situated in the Talas Alatua Mountains (a western extension of the Middle Tien-Shan) at an elevation of approximately 2350m above mean sea level (AMSL). The project area resides within the Slope Artesian Basin of the Chaktal Intermountain Artesian Basin (Hydrogeology of USSR 1971) where recharge to the groundwater system within the basin is entirely attributable to precipitation due to there being no lateral inflows from adjacent areas (SRK 2010).

Hydrogeologic field investigations began in January 2010 at Charaat's gold prospect. As part of pre-feasibility studies and borehole testing carried out to determine the groundwater conditions that could be encountered during mining operations, a three-dimensional (3-D) numerical groundwater flow model was produced using Itasca Denver's finite code element, MINEDW (Azrag, *et al.* 1998). Essential to the calibration of the model was the collection of mine water discharge data from actively drilled areas of the mine. Initially three monitoring stations were installed within Adit 4 (fig. 1), along with a further station installed in Adit 2 (no map shown), to measure groundwater discharge from underground excavation areas.

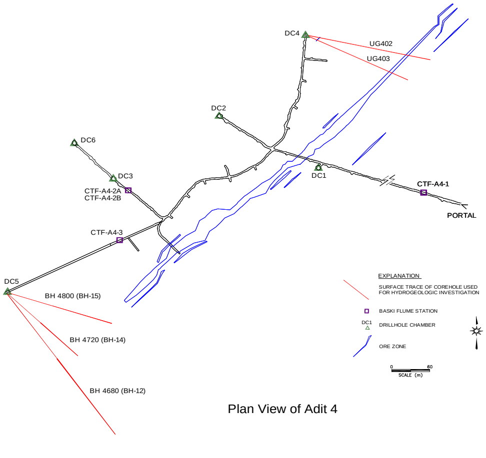

***Figure 1** Location of monitoring stations within the exploratory workings of Adit 4.*

Methods

Installation of Concrete Flume Boxes

The mine site in western Kyrgyzstan is only accessible during winter months via helicopter, severely limiting options for transporting the Baski flumes and all other relevant materials needed for constructing concrete flume boxes to the site. While previous installations of this design at other mine sites were carried out using concrete boxes moulded from precast fibreglass moulds, the decision was made to build concrete moulds using ¾ inch plywood pieces (19mm; fig. 2), transport the pieces via helicopter to the mine and assemble the plywood moulds on site. The simple process of assembling and constructing the concrete boxes is as follows:

- Four complete concrete box moulds were cut from sheets of ¾ inch (19mm) plywood at a shop in Bishkek prior to transport to the mine

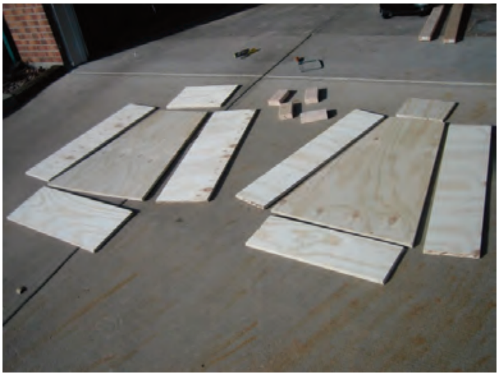

Figure 2 *View of the pre-cut plywood pieces used for the concrete moulds.*

site. All support pieces, involving two-by-fours (39 × 89mm) of various lengths, were also cut prior to transport to site. Two of the moulds were sized down to account for tighter than expected locations inside Adit 4, and were re-cut accordingly on site.

- Rebar and reinforcing metal mesh were also procured and transported to site.
- After being transported to the mine site, the concrete box moulds were assembled using wood screws; reinforcing wire mesh, rebar handles and grout plugs were set up in the moulds (fig 3); silicone sealant was used to seal the corners of the moulds so concrete would not seep out, while the insides of the plywood mould were doused with diesel to keep the concrete from sticking to the wooden moulds.
- Concrete was prepared and mixed with sodium silicate (whose purpose is described below) and poured into moulds (fig 4); the freshly poured moulds were kept in a room at 25 °C or higher and kept moist.
- Moulds were left to cure a minimum of 72 hours, during which time the selected monitoring sites in the adit were prepared, e.g. cleared, dug out and levelled, along with discharged water channelled around.
- Once hardened, the concrete flume boxes were transported to their prepared location in the mine. The boxes were grouted to the ground via the grout holes in the bottom using a grout pump. Special care was given to ensure the bottoms of the concrete flume boxes were level.
- Once the grout was cured (72 hours), water was channelled back though the box. Through channelling and the construction of dams and levees, all flow within the adit was channelled through the flume box.

Figure 3 *View of the assembled bottom portion of the mould, wire mesh and rebar handles.*

Figure 4 *View of the curing concrete; mould bottom is removed.*

Prolonging the life of concrete boxes in low pH conditions

To decrease the effects of low pH mine water discharge on the concrete boxes, as well as a measure to prevent scouring and to increase the longevity of the boxes' usefulness, a small amount of sodium silicate was included in the concrete mixture that was poured into the moulds. Each concrete box was also coated with two coats of sodium silicate before being installed inside the adit.

Implementing the monitoring regime

Initially, monitoring at each station was carried out twice per day (morning and afternoon), to account for diurnal pressure changes in the mine, and was reduced to a single daily reading after a two-month period. To take a measurement, the Baski flumes are lowered into the concrete flume box (fig 5), the articulated wing walls are set against the sides and a seal is made using clay or

Figure 5 *Baski flume in concrete flume box; note the tight fit between the rib of the drift and cart track.*

Figure 7 *Increased flow following borehole testing overran capacity on the Baski flume at CTF-A4—2.*

plumbers' putty. Set up of the Baski flumes can be carried out in a matter of minutes, allowing for greater frequencies of sampling. Readings are taken on the upstream gauge on the Baski flume and the value given is converted to a rate of discharge (conversions are provided by Baski, Inc.). A water balance for an adit is determined by the equation (as per the balance for Adit 4):

Total Discharge (CTF-A4—1) =
Discharge from DC-3 (CTF-A4—2) + Discharge from DC-5 (CTF-A4—3) + from all other areas

Actual discharge data are shown graphically in figure 6. The mine water discharge data from the first month of data collection were used in the initial calibration of the groundwater flow model. More current data are continually used to re-calibrate the model.

Updates and Adjustments

Unexpected increases in flow following borehole testing in drill chamber six (DC6) during October 2010 caused mine discharge to exceed the capacity of the Baski flume at monitoring station CTF-A4—2 (fig. 7). A second concrete flume box was

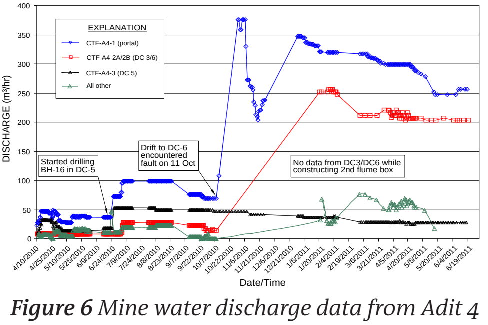

Figure 6 *Mine water discharge data from Adit 4 since the beginning of monitoring.*

Figure 8 *Second concrete flume box and more expansive levee stations CTF-A4—2A and 2B.*

installed at the same location (renaming the two stations CTF-A4—2A and 2B, respectively; fig. 1) and more expansive levee building was carried out (fig. 8) to capture the entirety of the flow. Similarly, the same set-up was deployed outside the entrance to Adit 4 in the spring of 2011 to be able

Figure 9 *Discharge from Adit 4.*

to capture the increased cumulative flow discharging from the portal at Adit 4 (fig. 9).

Conclusions

Monitoring of mine water discharge rates in remotely located hard rock environments, such those encountered at the Charaat gold prospect in western Kyrgyzstan, presents many challenges of financial, logistical and technical natures. Capital costs associated with the acquisition or purchase of precision instruments can be significant and may discourage mine operators from installing a full array or an appropriate number of monitoring stations. Installation of such devices in severely space-constricted areas, as are often found in hard rock mine environments, may limit the effectiveness of certain devices which require larger footprints for obtaining accurate data. Similarly, the risk of damage to precision equipment from machinery movement and other traffic in these severely space-restricted areas is greatly elevated.

The installation of the mine water monitoring scheme at the Charaat gold prospect in Kyrgyzstan is an excellent example of how simple, yet effective advances in field techniques can address the challenges highlighted above:

Capital Outlays: Baski cutthroat flumes offer easy portability between monitoring stations, as well as (using Baski's flume throat width conversion kits, which come in 2, 4 and 8 inch widths) the ability to easily change throat widths on the flumes depending upon flow volumes. The ability to quickly set up the devices within the prefabricated concrete flume boxes resulted in fewer cutthroat flumes needing to be purchased, shipped to Kyrgyzstan and transported to site. Designing simple concrete moulds using plywood, in place of fibreglass moulds, and construction of concrete boxes using materials readily available locally onsite in locations around the world, further reduced costs.

Space Restrictions and Efficacy: The design of the concrete flume boxes, in conjunction with the use of the Baski flumes, allowed for installation of high precision Baski flumes in a mine adit that at times was less than three metres wide with cart tracks running down the centre.

Risk of Damage: The ability to remove the Baski flumes when not taking measurements decreased the chances of damage occurring to the devices during movement of mine equipment. Similarly, should one of the concrete flume boxes be run over by a vehicle, or otherwise be damaged, replacement was simple, straight forward and inexpensive.

Acknowledgements

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