Yanfolila Gold Mine Open Pit Slope Depressurisation, Mali

Gareth Lottreaux[1], Karen Nicole King[2], Angus Errol Rowland3

[1] *WSP, Hydrogeologist, Water Services Unit, 33 Sloane Street Bryanston, 2191 South Africa*

[2] *WSP, Hydrologist, Water Services Unit, 33 Sloane Street Bryanston, 2191 South Africa*

[3] *Piteau Associates, Hydrogeologist, Operations Manager, 25 Rudd Road, Illovo, South Africa 2196*

Abstract

WSP carried out a risk mitigation and dewatering implementation programme for the Yanfolila Gold Project in southwestern Mali. The project centred on the development of two open pits; the Komana East and Komana West pits. The main tasks associated with the project included a risk mitigation study of the Komana West pit in order to determine whether the pit was hydraulically connected to the Sankarani River – approximately 200 meters from the pit – and to install a network of peripheral dewatering/ depressurisation boreholes around the two pits in order to depressurise a 60 meter thick saprolite layer by dewatering the underlying fractured rock aquifer.

Long-term (14-day) pump testing of boreholes between the Sankarani River and the Komana West pit was undertaken. Water levels in the pumping borehole and a network of monitoring boreholes were monitored throughout the test to identify indications of the system reaching steady state flow conditions, which would indicate water being drawn in from the river. Electrical conductivity and pH values were measured at regular intervals in the river upstream of the pumping well and in the pump discharge water in order to determine any similarities in quality, which would further indicate inflow from the river. Pump testing also indicated potential efficacy of depressurising the saprolite through pumping from the underlying fractured aquifer. Following this, drilling and pump testing of 27 dewatering boreholes around the perimeters of the two pits was undertaken in order to recommend a pumping regime for the mine.

The study found that there was no hydraulic link between the Sankarani River and the Komana West pit, thus significantly decreasing risks to mining in this area. It was further determined that the saprolite could be effectively depressurised through dewatering the underlying fractured rock aquifer.

The main applications of this study are that the Komana West pit can be developed without risk of flooding from the Sankarani River. Furthermore, effective depressurisation of the saprolite means that the open pits can be designed with 'dry' slopes, resulting in steeper slope angles, minimised stripping ratios and thus improved overall profit margins for the mine, as well as reducing the risk of collapse within the pits.

Keywords: Yanfolila, dewatering, slope depressurisation, hydraulic connectivity

Introduction

WSP carried out a risk mitigation and dewatering implementation programme for the Yanfolila Gold Project in southwestern Mali. The project centred on the development of two open pits; the Komana East and the Komana West Pits. The area shows a typical tropical weathering profile with hard laterites present at the surface in many areas. A virtually ubiquitous saprolite unit exists across the area, with a typical thickness of approximately 60 meters across the site. This is underlain by a weathered, saprock zone, which exhibits abundant hard rock zones with extensive relict fractures, many of which are open. The saprock transitions downwards into fresh bedrock, which is typically fractured in its upper 20-30 meters, with the frequency and intensity of fracturing reducing rapidly below this.

The site is bound to the west and north by the Sankarani River, which forms the international border between Mali and Guinea. The Komana West pit is located approximately 200 meters to the east of the Sankarani River. The site setting of the Komana West pit re;ative o the Sankarani River is shown in Figure 1, with a West-East cross section, including the interpreted groundwater surface, is shown in Figure 2.

The purpose of the investigation was to:

- Determine whether the Sankarani River is hydraulically connected to the area to be exposed during development of the Komana West pit, which could pose a flooding risk to the pit, as well as have an impact on slope stability;

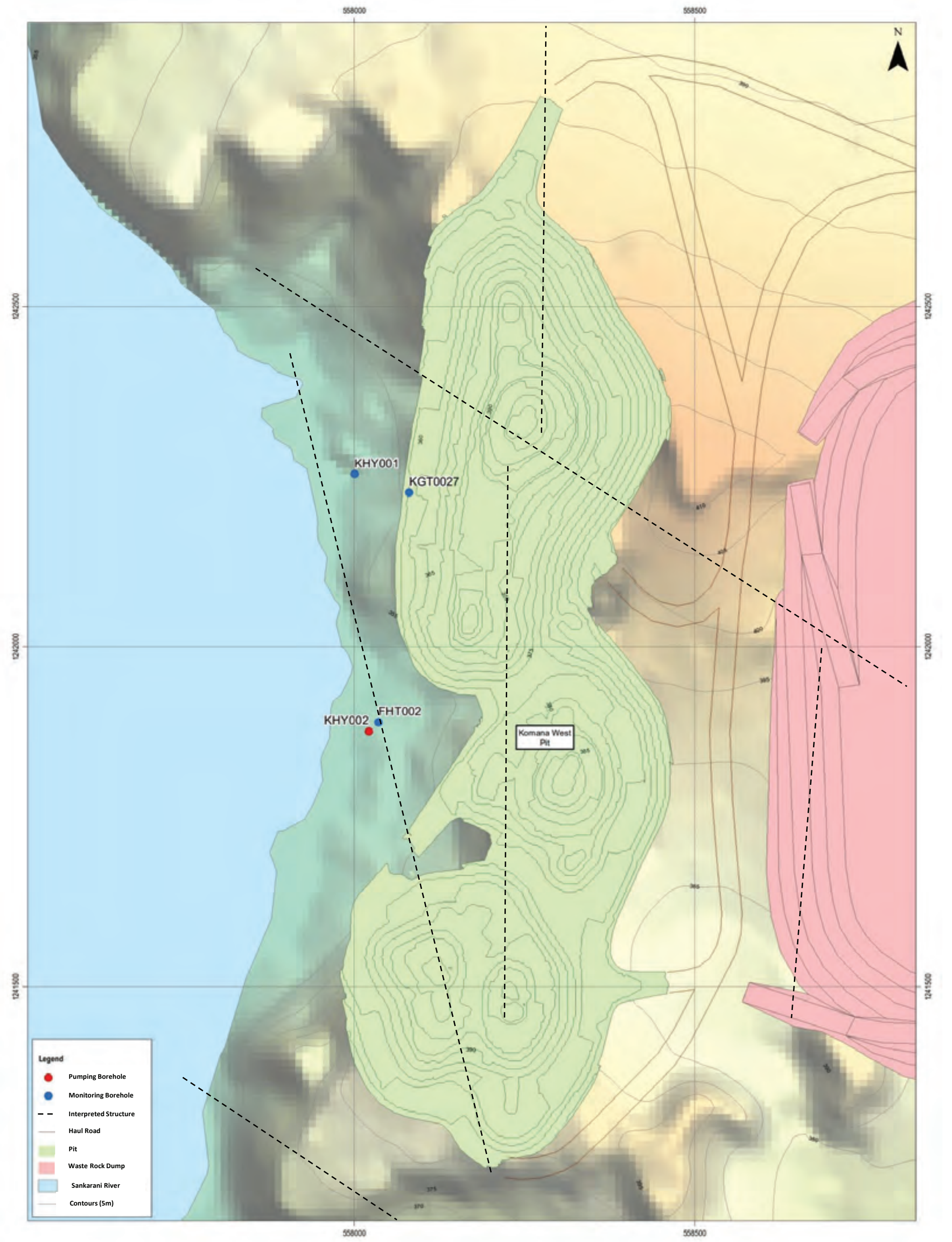

Figure 1: *Location of pump testing boreholes relative to Komana West pit and Sankarani River.*

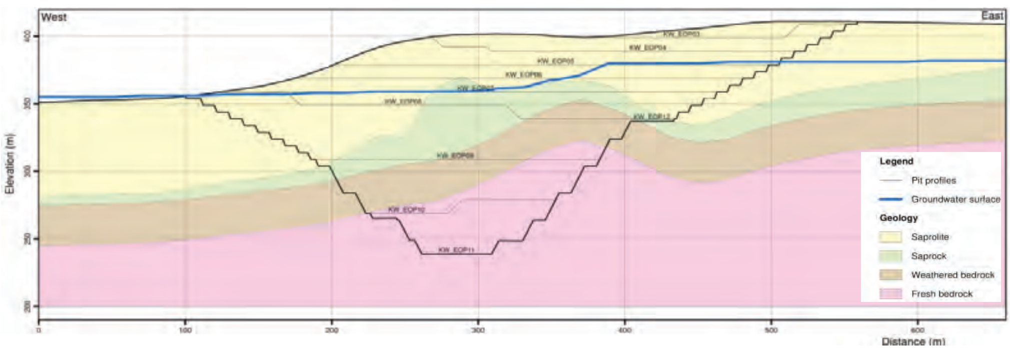

Figure 2: *West-East cross section through the Komana West Pit*

- Determine whether the approximately 60 meter thick saprolite layer could be successfully depressurised through dewatering the underlying fractured rock aquifer, effectively under-draining the saprolite; and
- Use the information gathered to design and implement a network of peripheral dewatering boreholes around the perimeter of the two pits.

Methodology

A long-term pump test was conducted on borehole KHY002, shown in Figure 1, located between the Sankarani River and the Komana West pit footprint, over a period of 14 days at a constant rate of 3.7 litres per second. Water levels in the pumping borehole were monitored throughout the pump test in order to determine whether steady state flow conditions were reached, which would indicate water being drawn into the borehole from the Sanakarani River. Throughout the pumping test, pH and electrical conductivity (EC) measurements were taken simultaneously in both the borehole discharge water and in the Sankarani River at the closest possible location upstream of KHY002. The two sets of pH and EC values were compared against each other in order to determine whether the groundwater abstracted from KHY002 displayed any hydrochemical affinity to that of the river water, as might be anticipated under circumstances in which drawdown of water at KHY002 induced ingress or increased recharge from the river.

Water levels in three monitoring boreholes; FHT002, KGT0027 and KHY001, also shown in Figure 1, were also measured throughout the pump test. The monitoring boreholes were located between 15 and 380 meters from the pumping borehole, and were drilled into both the saprolite (FHT002 and KGT0027) and saprock (KHY001). The aim of monitoring the water levels in these three boreholes was to determine the efficacy of pumping from the fractured rock aquifer to depressurise the overlying saprolite.

Final dewatering borehole locations were selected in order to intercept structural features in the fractured rock aquifer identified through geological mapping and geophysical investigations. Preference was given to areas with lower basal saprock elevation in order to target potential local groundwater 'sumps', enabling the dewatering boreholes to under-drain a larger portion of saturated saprolite and saprock.

Results and Discussion

Table 1 provides a summary of the boreholes used during the pump test, the lithology into which they were drilled, the maximum drawdown achieved and their distance from the KHY0002 pumping well. Table 2 provides the hydraulic conductivity and storativity of the saprolite and saprock units, as calculated from the aquifer testing conducted. The drawdown observed in all boreholes is shown graphically in Figure 3, with the EC data recorded throughout the test at both KHY002 and in the Sankarani River shown in Figure 4.

Table 1: Summary of pump test data

Borehole ID	Maximum Drawdown (m)	Distance from KHY002 (m)	Lithology
KHY002	12.77	0	Fractured rock
KHY001	4.43	380	Saprock
FHT002	6.18	15	Saprolite
KGT0027	0.70	360	Saprolite

Table 2: Summary hydraulic properties of saprolite and saprock

Lithological Unit	Hydraulic Conductivity (K – m/s)	Storativity (S)
Saprolite	4.78 x 10-8	1.21 x 10-2
Saprock	8.89x 10-7	5.76 x 10-6

From the data presented in Table 1 and Figure 3 it is evident that substantial (and continuous) drawdown was achieved both at KHY002 and in all monitoring wells, with no steady state flow-recharge condition observed. No excursions from the drawdown curve were noted, which may potentially indicate the presence of a recharge boundary. The lack of any obvious recharge boundary indicates limited hydraulic connection of the Sankarani River to the underlying aquifer. Figure 4 shows that the EC profiles of KHY002 and the Sankarani River water remained markedly different throughout the test, with minimal variability in the KHY002 conductivity measurements observed over the period of the test. Furthermore, no geological structures were detected linking the River to the Pit (Figure 1). This supports the interpretation that no tangible ingress of water from the river towards the KHY002 borehole occurred in response to the drawdown induced by pumping.

The drawdown observed in the monitoring boreholes indicates that dewatering within the fractured rock aquifer can have a laterally extensive impact on local water levels, with water levels in the saprolite showing a relatively rapid response to dewatering. It can thus be concluded that dewatering in the fractured rock aquifer can be effectively used to lower water levels and thus reduce pore pressures in the saprolite across the mining area by underdraining the saprolite. Consequently, the open pits can be designed with 'dry slopes', allowing for steeper slope angles and thus minimised stripping ratios, which will result in improved overall profit margins, as well as reduced risk of collapse within the pits.

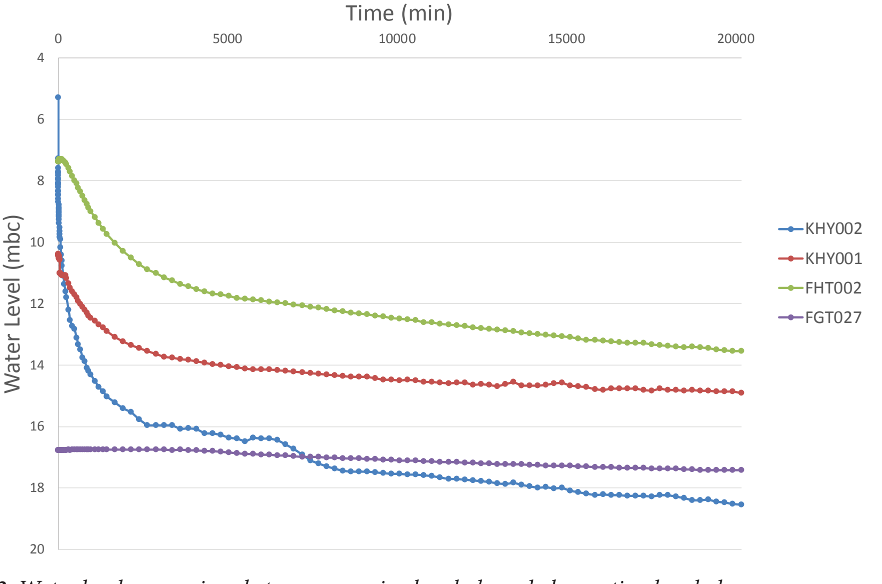

Figure 3: Water level comparison between pumping borehole and observation boreholes.

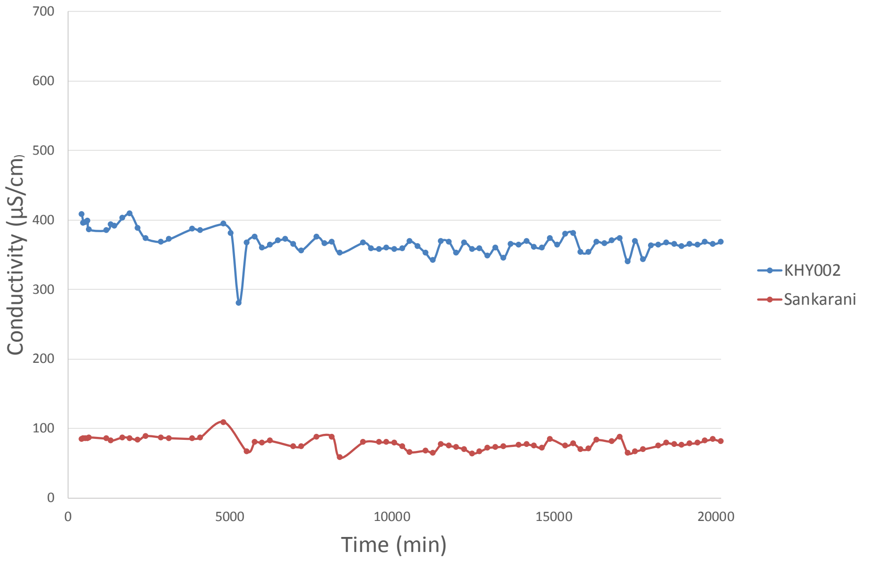

Figure 4: *Electrical conductivity comparisons between pump test borehole and Sankarani River water.*

Following the initial investigations, a network of 27 dewatering boreholes were drilled across the site, 13 at Komana East and 14 at Komana West. Pump tests were carried out on all boreholes in order to recommend optimal dewatering rates for each borehole in order to achieve sufficient dewatering and slope depressurisation across each pit.

Conclusions

The following key findings were made:

- Significant drawdown was achieved and sustained over pumping for the duration of the pump test at borehole KHY002. This drawdown extended through both the saprolite and saprock units and was observed to propagate to boreholes located up to 380 m from the pumping well;
- No evidence of steady state pumping conditions or recharge was observed throughout the testing period, with water levels in the pumping borehole continuing to draw down for the duration of the test;
- No evidence of hydrochemical modification of the abstracted water from KHY002 was observed throughout the testing period. At all times, abstracted water appeared distinct from that of the Sankarani River with respect to EC, with no evidence of any ingress of river water through the saprolite or saprock units;
- Theseresults indicate that there is unlikely to be any significant hydraulic connection between the Sankarani River and the groundwater system in the Komana Pit area.

The lack of hydraulic connectivity between the Sankarani River and the underlying aquifer results in a low risk of water ingress from the River into the Komana West pit. Additionally, the pump testing indicated that dewatering of the fractured rock unit can effectively underdrain the above lying saprolite.

Active dewatering through the use of boreholes completed in the fractured rock will likely be effective as both a dewatering and upper slope depressurization method for both the Komana East and Komana West pits. As a result, a network of 27 dewatering boreholes were drilled into the fractured rock aquifer across the Yanfolila site.

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