The Moving Finger Writes – the Value of Hydrographs in Numerical Modelling

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Abstract

Interpretation of hydrographs during dewatering provides an insight into the amount of groundwater that is required to dewater the pit and in predicting the rate of groundwater recovery in mine closure evaluations. Hydrographs can show why sections of the pit are not dewatering at the same rate as the other sections. They may reveal a better place to install dewatering bores and measure the efficiency of the dewatering systems as the dewatering progresses. Historical trends can be used in predicting future water level changes. It is an invaluable tool in providing an insight into the movement and behaviour of the groundwater systems.

Key words: groundwater, numerical modelling, hydrographs, dewatering, modflow

Introduction

Water management is an integral part of any below water table mining operations. Dewatering is often required to enable mining below the water-table. Water is usually used in processing of the ore. Excess water is either discharged to the environment or into evaporation ponds or re-injected back into the aquifer. Shortage of water can determine the viability of the mine.

It is standard practice during mining operations to monitor observation bores located within the orebody to track the progress of dewatering. Monitoring of observation bores outside the orebody is usually treated as secondary as drilling is often restricted to the mineralised zones. Hydrogeologically, however, it is equally important to install and monitor observation bores outside the orebody to gain a wider understanding of the “active” aquifer systems within a wider geographic context.

Hydrographs are aquifer responses to stresses within the aquifer system. Stresses can be a combination of recharge and discharge (stream/creek flows, head/stage in the stream), pumping (in/out) from nearby bores and evapotranspiration from vegetations. In mining, hydrographs are usually used in measuring the efficiency of the dewatering system. In slope stability assessments, they are used to assess the stresses on the pit wall. For mine closure, they define the understanding of the wider aquifer system. In modelling, they determine how the model boundaries boundary conditions should be setup.

Rio Tinto Iron Ore (RTIO) operates the open cut iron ore Yandicoogina Mine (Yandi) in the Pilbara region in the north west of Western Australia. Mining of the iron ore occurs along a palaeochannel known as the Channel Iron Deposit (CID). The CID is up to 70m thick and consists of iron oxide spheroids of which about 70% is saturated. There are four creeks that crossed the CID within the Yandi leases, namely Marillana, Phil’s, Yandicoogina and Weeli Wolli Creeks. Upstream of Yandi Mine, the Marillana Creek flows through active mining leases which discharges groundwater into Marillana Creek. Also, upstream of Yandi the RTIO Hope Downs operations, discharges groundwater into Weeli Wolli Creek. Both operations have plans to increase discharge and their impacts on Yandi need to be assessed. In addition, Yandi has an aquifer re-injection borefield downstream of its mining operations used for disposal of surplus groundwater.

In order to assess the dewatering requirements at Yandi, a numerical model was developed with hydrographs providing an essential insight into the formulation of the conceptual hydrogeological model.

mall abnomalies in hydrographs may go unnoticed or may be incorrectly attributed to measurement or recording error. Depending on the scale of the event recorded by the hydrograph; a small abnomaly linked to a small event may manifest as significant dewatering issue if the event has the potential to increase in scale. A pathway for leakage from a small slow flowing creek can potentially be a conduit for larger flows when the creek gets flooded as can occur during and after a major downpour.

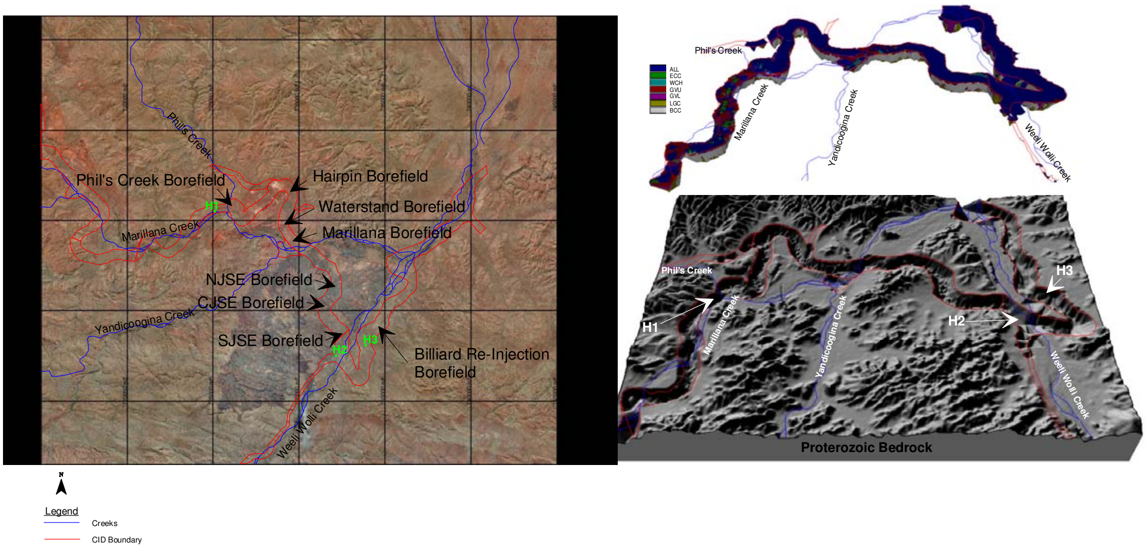
The ability to recognise these abnomalies in the hydrographs and represent them in the numerical model is important in setting up predictive scenarios. Not recognising these events can invalidate the model or resulted in delays or incorrect decisions related to dewatering pumping infrastructure and resultant loss of production.

The Site

The Yandi mine site is located in the paths of cyclones and every year between January to April there are concerns that mining operations will come to halt when the pits get flooded. A numerical groundwater model was considered essential and was setup to estimate dewatering requirements for the CID mining operations, better understand the impacts of cyclonic downpours i.e. recharge to the CID and provide contingency requirements in preparation for a cyclonic event.

Plate 1 shows the meanders of the CID incised into the Proterozoic bedrock. The orebody consists of an upper and lower Vitreous Geothite, underlain by Geothite Clay Conglomerate which is vuggy and highly permeable and in turn underlain by less permeable Basal Clay Conglomerate. Overlying the CID is recent alluvium.

Plate 1 *(a) Location of dewatering borefields within Yandi Mining Leases and location of observation bores, (b) Channel Iron Deposit incised into Proterozoic Bedrock*



Climate

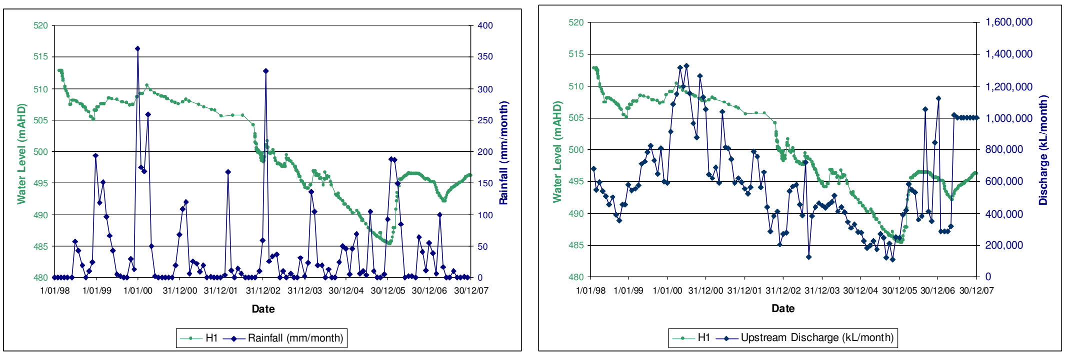
In general, the region is classified as arid-tropical with two distinct seasons; a hot summer extending from October to April and a mild winter from May to September. Average annual rainfall for 1998 to 2007 was 534 mm. Rainfall is episodic and highly variable between years. The majority of rainfall occurs during the hottest months from cyclonic lows. Winter rains are light and falls in June/July. Due to the low rainfall and brief wet season, watercourses flow, if at all, for only brief periods.

Hydrographs

Figures 1a and 1b show the hydrograph of observation bore H1, located in the CID close to Marillana Creek, plotted against recorded rainfall and discharges from the upstream operations. The hydrograph shows water level rose when recorded rainfall was greater than 50 mm a month (Figure 1a). The gradual declined in the hydrograph can be attributed to reduction in upstream discharge (Figure 1b) and abstraction from the nearby Phil's Creek borefield. In February 2006, cyclonic downpours in the area caused the water level to rise due to increase dewatering and discharge from the upstream operations. As the water level peaked, it slowly declined due to abstraction from Phil's Creek borefield. In May 2007, it rebounded and with no significant rain event during that period, the rebound can be attributed to increase discharged from the upstream operations. These responses from the hydrograph show that Marillana Creek is in good hydraulic connection with the water table and affects dewatering at the Phil's Creek borefield.

These show that discharge from the upstream operations is an important consideration when setting the model up. Prediction of cyclonic activities in the area has to be incorporated into the model as it had influenced the discharge pattern of the upstream operations in predicting the dewatering requirements at Yandi.

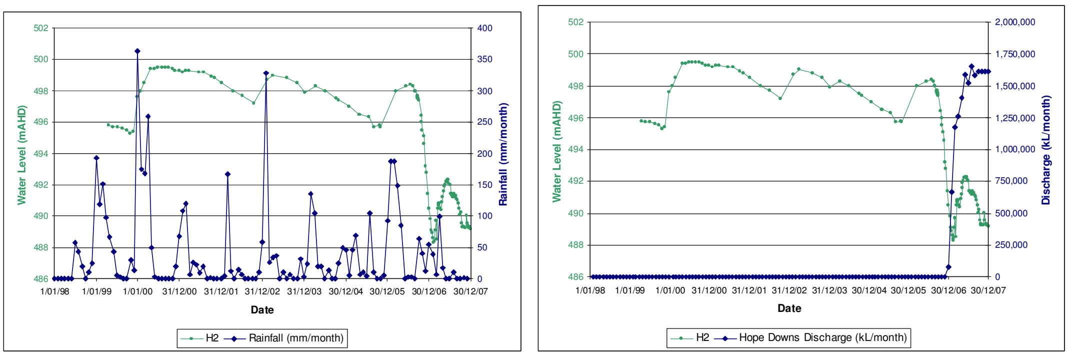
Figure 1 *(a) Correlation of bore H1 hydrograph with recorded rainfall, (b) correlation of bore H1 hydrograph with discharges from upstream operations*



Figures 2a and 2b show the hydrograph of observation bore H2, located in the CID close to Weeli Wolli Creek, plotted against recorded rainfall and discharges from RTIO Hope Downs operations. The hydrograph, generally rose when the recorded rainfall exceeds 190 mm a month (Figure 2a). The declined in the hydrographs in July 2006 can be attributed to dewatering from the nearby SJSE borefield. In December 2006, 23 km upstream, the Hope Downs operations started dewatering and discharge groundwater into Weeli Wolli Creek. In February 2007, water level in bore H2 started to rise, indicating a time-lag of about one and a half months. The rise continued until June 2007 when the initial pulse of inflow reached a new equilibrium and started to decline when the dewatering from SJSE borefield started to make an impact.

These show that there is leakage from Weeli Wolli Creek and there is a time-lag of about one and half months from when the discharge occurs at the discharge point.

Figure 2 *(a) Correlation of bore H2 hydrograph with recorded rainfall and (b) correlation of bore H2 hydrograph with RTIO Hope Downs discharges*

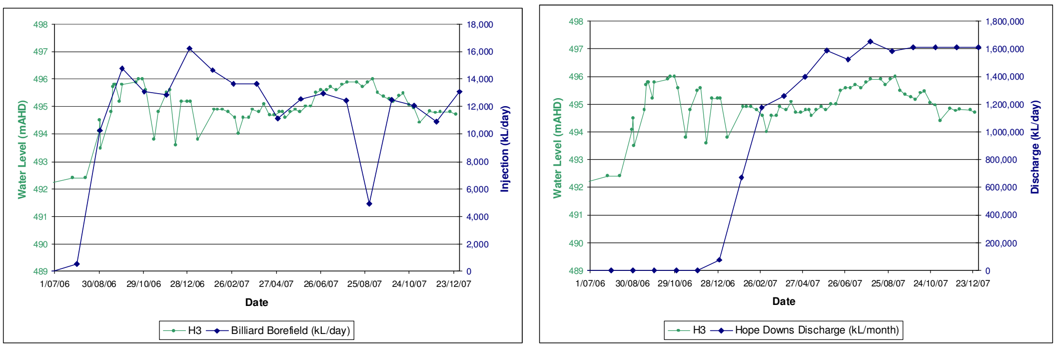


Figures 3a and 3b show the hydrograph of observation bore H3, located in the CID in the aquifer re-injection borefield. When re-injection started in July 2006, the hydrograph responded very quickly. When the re-injection rate declined, water level in bore H3 also decline. In March 2007, the hydrograph rebound showing that the discharge from the Hope Downs dewatering has reached this bore and gradually decline after the initial pulse of inflow.

These show that there is good hydraulic connection to the re-injection borefield and that the inflow from Hope Downs discharge is substantial enough to cause further rise on top of the re-injection rise.

Understanding and assessing the events that have major implication on the predictive outcomes of the numerical model is crucial before the development of the numerical model. The Yandi model is an example where dewatering requirements for the mine is influenced by discharges into the creeks which flows through the mine. In order to model leakage from the creeks, MODFLOW stream cells were used and the discharge rates upstream were assigned to the most upstream inflow cell in the model. The function of the stream cells was to account for the amount of flow in streams and simulate the interaction between surface water and groundwater.

Figure 3 *(a) Correlation of bore H3 hydrograph with injection from Billiard re-injection borefield and (b) correlation of bore H3 hydrograph with RTIO Hope Downs discharges*



Conclusions

The ability to capture events that are critical to the model should be realised at the conceptualisation of the model by understanding the responses of hydrographs. A model setup for predictive investigations should include all stresses that have the potential in deciding the final outcomes. Boundary conditions selected should be appropriately represented in the model. Hydrographs are hydrogeologist "eyes" into the subsurface and should be well interrogated before a numerical is setup. Small abnormalies in hydrograph may not be an error in recording.

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References

McDonald, M.G., and A.W. Harbaugh, (1988), A modular three-dimensional finite-difference ground-water flow model, Techniques of Water-Resources Investigations 06-A1, USGS, 576 p.

Prudic, D.E., (1989), Documentation of a computer program to simulate stream-aquifer relation using a modular finite-difference ground-water flow model, USGS, Open-File Report 88-729, 113 p.