Mine flooding prognosis making use of EPANET

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Abstract Flooding and associated decanting of many South African underground and opencast mines has been reported from a number of areas within South Africa. The South African government has stressed the urgency of implementing intervention measures as many of these mines are located close to densely populated areas. However before intervention actions can be taken, these systems have to be investigated and understood. This paper demonstrates that EPANET can be used to obtain a first estimate of the flooding prognosis before a detailed mine flooding model like the DMT BoxModel is implemented. A case study is used to compare model results.

Keywords Mine flooding prognosis, EPANET, DMT BoxModel

Introduction

Flooding and associated decanting of many South African underground and opencast mines has been reported from a number of areas within South Africa. Mine flooding needs to be managed and appropriate measures should be in place, in instances where mine decant can take place (Wolkersdorfer 2008). The South African government has stressed the urgency of implementing intervention measures. However before any intervention can be successful these flooding mine systems have to be understood.

There are numerous tools available to assist in this regard including numerical models. In fact some of the models have been specifically developed for the simulation of mine flooding. The BoxModel used by Deutsche Montan Technologie GmbH (DMT) is such an example.

Methodology

Linear interpolation of rising water levels can both lead to an over or under estimation of the date when a mine is 100 % flooded. This is due to the fact that this method cannot account for the variability and interconnection between different mine voids and also does not consider the change in the hydraulic gradient over time which is an important factor (Banks 2001). The use of porous flow models for mine flooding simulations are also incorrect under certain conditions due to the fact that the nature of the governing hydraulics are more related to pipe flow than porous medium flow.

Modelling has become a tool commonly used to analyze, estimate and predict associated impacts associated with mine flooding and decanting. Water inflow in the vicinity of open pits or underground mines is three-dimensional; consequently, 3-D numerical flow models must be based on 3-D hydrogeological data if they are to become reliable predictive tools for resolving issues listed above (Martinez and Ugorets 2010).

Two 3-D numerical models were applied in this study. The first model, namely the DMT BoxModel developed by Deutsche Montan

Technologie GmbH (DMT) has been employed as the numerical tool of choice and has been further developed to cope with the features of extensively exploited large coal fields (Eckart *et al.* 2004).

The BoxModel is a 3D finite volume program for modelling the flow of groundwater and mine water, heat transport and multi-component mass transport including sorption, microbial degradation and the reactions with minerals. A special feature is the highly flexible discretization to model geological structures such as layers and faults as well as structural mining elements and mine excavations (DMT 2011).

The model supports multiple boxes in a free structure with multiple connections between boxes of various types. Turbulent, laminar and time dependent flow functions between boxes are supported, to name a few, as shown in Fig. 1.

The second model, namely EPANET (developed by the United States Environmental Protection Agency) was actually developed for the simulation of water distribution in piping systems. For the purpose of this paper, components of EPANET are used in a fixed configuration to represent the mine voids with head dependent inflows. The configuration is shown in Fig. 2. The purpose of the check valve is to ensure flow in only one direction and the

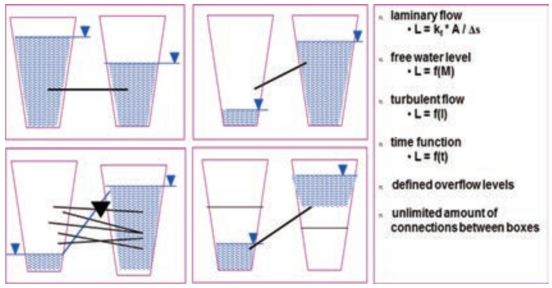

Fig. 1 *Various interconnection types between boxes (DMT 2011).*

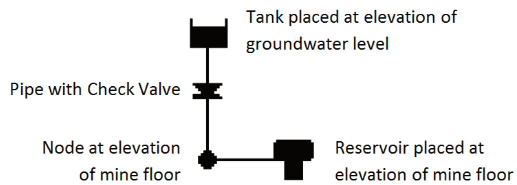

Fig. 2 *Head dependent inflow mine void configuration.*

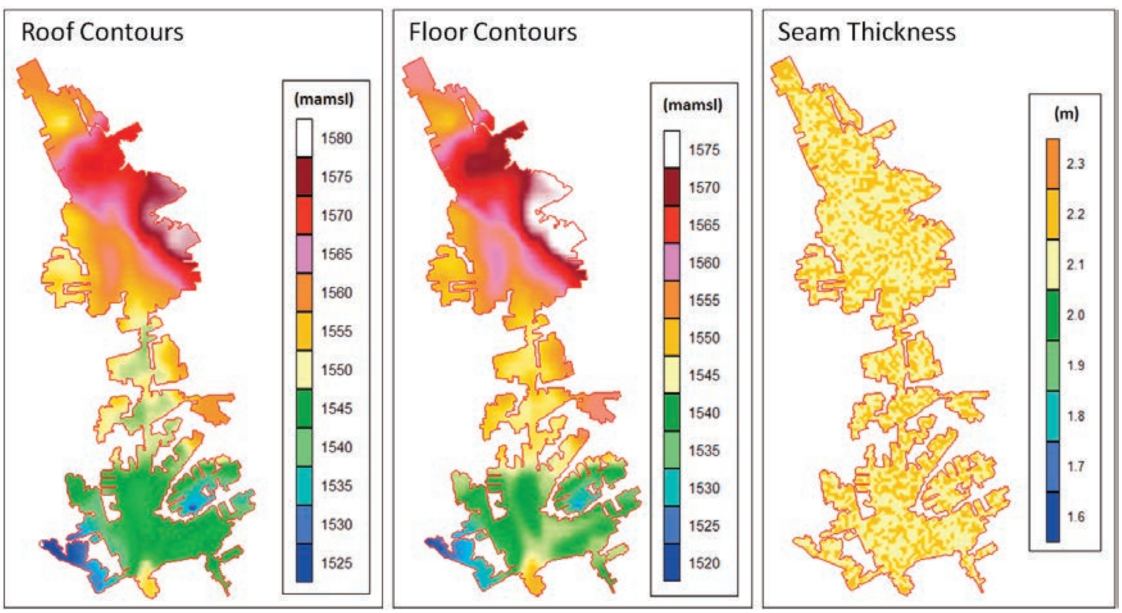

Fig. 3 *Roof, floor and seam thickness of coal mine.*

nodes are used to connect the various mine voids to a network.

Both models were used to simulate the same case thereby comparing the results and testing the hypothesis that EPANET can be used as a first approximation for mine flooding scenarios.

Case Study

An underground coal mine in the Mpumalanga province in South Africa is used in the case study. The mine closed in 1996 and since then water levels in the mine have been slowly rising. The roof and floor contours of the mine are shown in Fig. 3. A uniform seam thickness of 2.1 m was assumed for modelling purposes.

DMT Box Model Approach

In the DMT Box Model a box was created for each of the 668 mined-out areas and each of the boxes were connected with one another as shown in Fig. 4.

Recharge to the mine was applied based on the mining activity which resulted in 15 % recharge over fully stooped areas and 3 % recharge over the remainder of the area. Pumps were introduced into the model to sim-

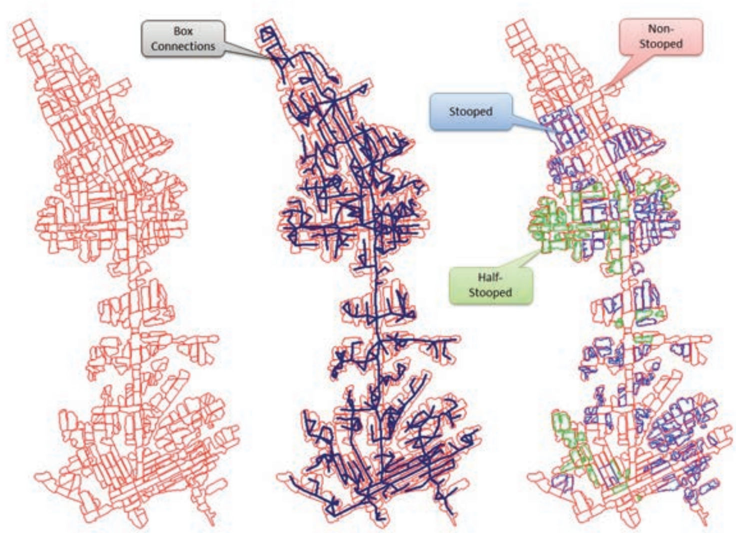

Fig. 4 *Mined-out and stooped areas.*

Fig. 5 *Virtual pumps and control points introduced into the model.*

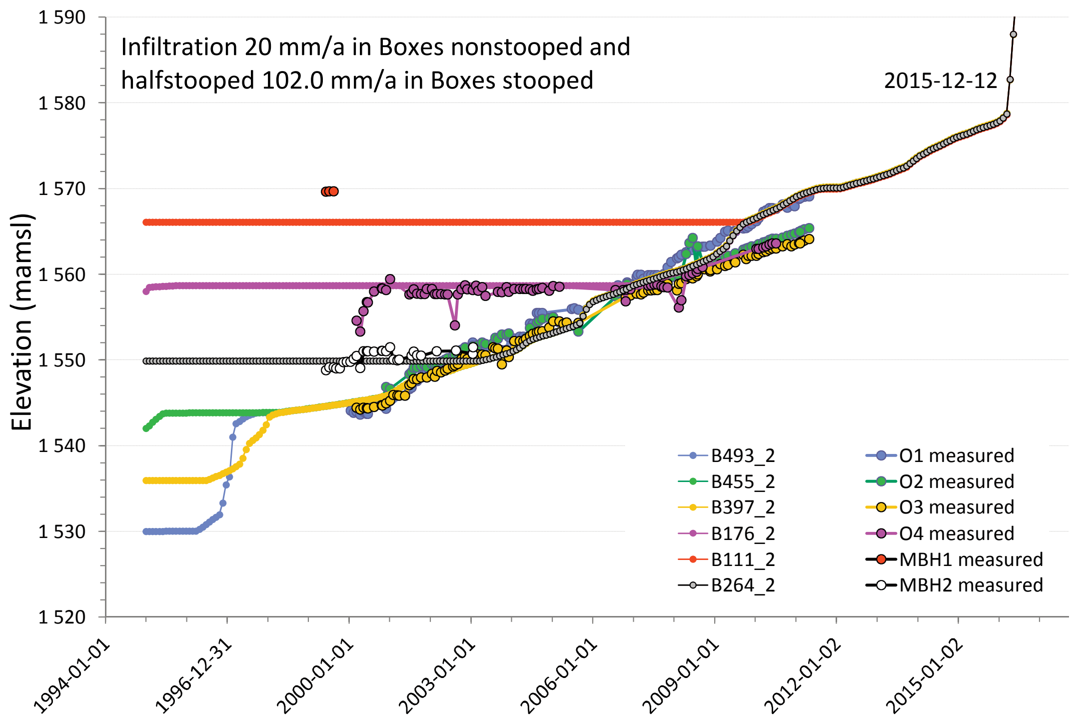

Fig. 6 *Simulated versus observed values of the DMT BoxModel*

ulate the hydrological conditions while the mine was in production. Control points were introduced in the model that coincides with monitoring boreholes intersecting the mine void as shown in Fig. 5.

Simulated versus observed values for the DMT BoxModel is shown in Fig. 6. Note the date of 100 % flooding is predicted to be December 2015.

EPANET Approach

The EPANET was used to setup an equivalent model to that of the DMT BoxModel. All parameters were kept exactly the same except for the delineation of the boxes. A coarse delineation based on floor elevations resulted in 43 mine voids (6 % of the total BoxModel voids) to be simulated with the EPANET configuration discussed earlier. The resultant floor elevations and equivalent EPANET model is shown in Fig. 7.

The comparison of the EPANET model versus the DMT BoxModel is shown in Fig. 8. The EPANET model is more conservative with the prediction of the flooding date which is 6 months earlier than that predicted by the DMT BoxModel. This behavior is contributed to the fact that the EPANET model assigns a fixed head condition to each defined void space which in turn is inter-connected through the node network. The step-wise nature of the EPANET curve is a result of the discretization of 668 boxes to 43.

Conclusions

Based on this information, and given the urgency of the situation of the mine flooding situation in South Africa, EPANET may be a solution to obtain a conservative mine flooding curve and expected time of decant. The advantage of EPANET is that it only takes a fraction of the time necessary for a complex 3-D model such as the BoxModel. However a word of caution is offered, in order to ensure accurate predictions on the sensitive mining areas, detailed field investigations are necessary,

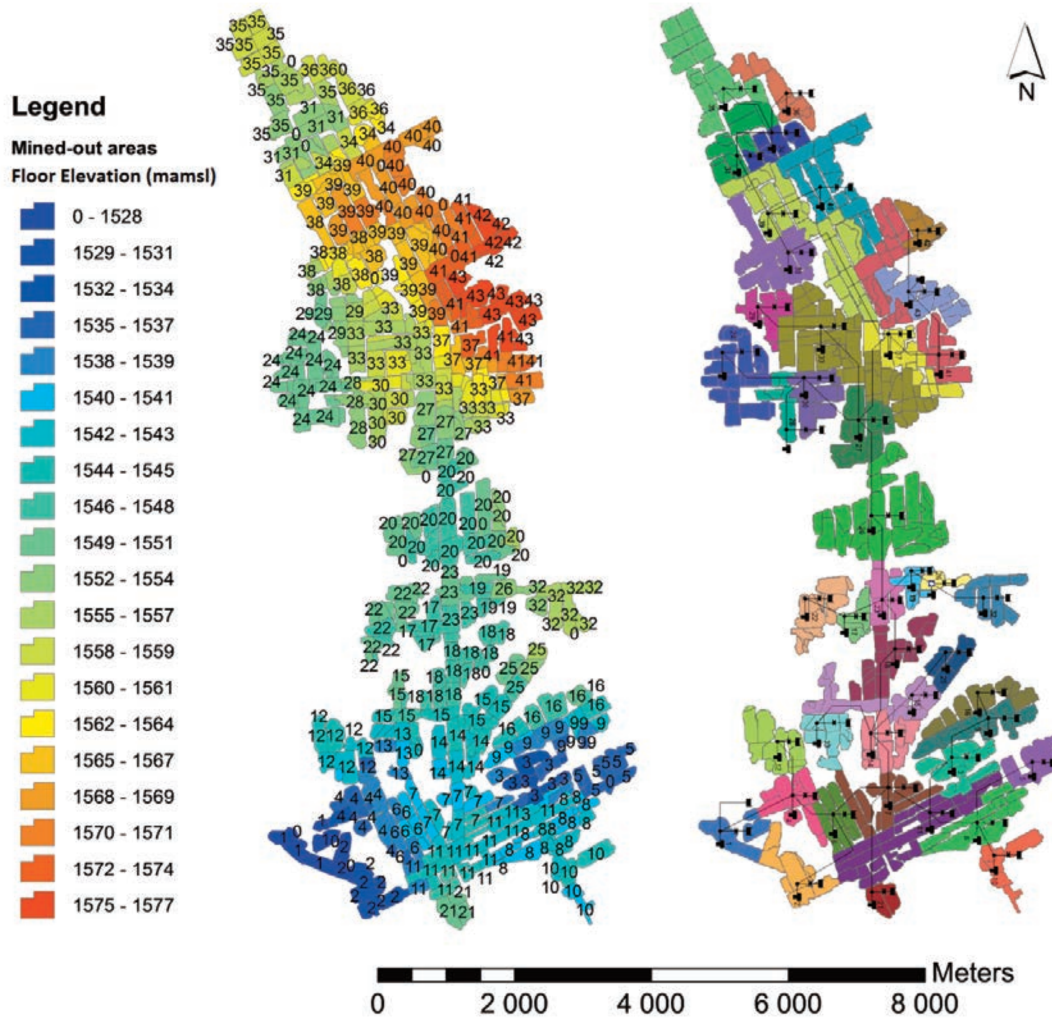

Fig. 7 *Equivalent EPANET model.*

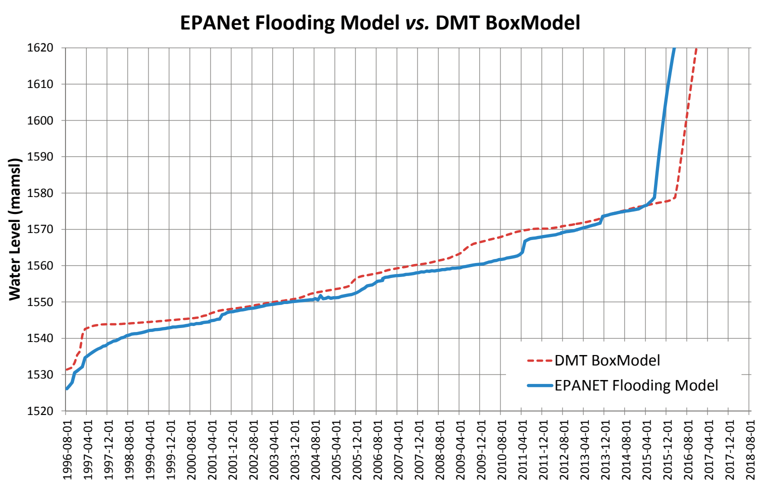

Fig. 8 *EPANET model results compared to the DMT Box-Model.*

including extensive data collection and monitoring to minimize uncertainty and to identify and investigate long-term solutions that would reduce the requirement for pumping and treating of poor quality water.

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