

Mine of the Future™: The automated mine dewatering design module of PBMO™

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Abstract

Rio Tinto and HydroGeoLogic, Inc. have integrated the Physics-Based Management Optimisation (PBMO™) technology into mine dewatering. PBMO™ was pilot tested on the Nammuldi Lens C/D pit in Western Australia. The automated PBMO™ optimal dewatering design strategy produced logical bore placements with sustained utilisation of the bores. The optimisation reduces the number of dewatering bores and total abstraction volume of the initial hydrogeological judgement approach. This test illustrates that PBMO™ can be used as an alternative approach in optimising mine dewatering and/or as a check on the hydrogeological judgement approach. In addition it provides a more defensible approach in environmental management.

Keywords: optimisation, mine operation, dewatering, modelling

Introduction

Rio Tinto's Mine of the Future™ programme is creating the next generation technologies for managing mine operations that achieve greater efficiencies, lower production costs, improved health, safety and environmental performance, and more attractive working conditions. Automation in the dewatering design phase provides the blueprint for a more effective and sustainable development. Co-development of the PBMO™ tool in mine dewatering with HydroGeoLogic Inc. is investing in the future of Western Australia.

Rio Tinto Iron Ore (RTIO) is the largest iron ore producer in Australia and second largest in the world. RTIO operates a network of 14 mines, three port terminals and 1,400 kilometre rail system in Western Australia's Pilbara region. The Nammuldi mine is located in the Pilbara region of Western Australia. The mine consists of 6 lenses (A,B,C,D,E,F) of mineralisation in the Mount Newman Member of the Marra Mamba Iron Formation. A pilot study on the dewatering of Lens CD was tested with PBMO™. The test indicates that PBMO™ is able to optimise the dewatering with less dewatering bores and less abstraction volume compared with the initial hydrogeological judgement approach conducted.

Above water table mining commenced in 2006 and below water table mining is planned to start in 2013. The geology of the region comprises Proterozoic meta-sediments of the Hamersley Group and overlying tertiary age regolith and valley fill sediments (Figure 1). The Nammuldi deposit is located on the south dipping northern limb of the Brockman Syncline. The deposit has a strike length of 14 km and outcrops along the Nammuldi Ridge. The majority of the deposit dips to the south (30 – 45°), however locally they dip to the north (e.g. Lens C). In Lens C

there is a repetition of the stratigraphy caused by intense folding and flat lying faults. Estimation of dewatering requirements in accordance with the mine schedule is necessary in the establishment of dewatering infrastructure and acquiring regulatory approvals.

Mine schedules can be subjected to a variety of uncertainties including changing market demands, variation in ore quality, and hydrogeological responses to abstraction. One specific operational requirement is to ensure the proposed area of the open-cut pit is dry before being blasted and mined. An automated approach means a faster re-optimisation of the dewatering solution.

Various operational constraints can be included in the optimisation e.g. maximum well depths, maximum abstraction rates from individual wells or from sets of wells, maximum total abstraction system flow rates, preferential locations for dewatering bores (ex-pit versus in-pit), exclusion areas for bores and infrastructure, pipeline routing, access to power, and other assorted operational and logistical conflicts to minimise or avoid. PBMO™ incorporates these requirements to produce a sequenced, optimal dewatering strategy - which can span decades for larger mines - based on 1) the resource reserve estimates, 2) the estimated locations and volumes, and 3) an initial or updated mine schedule.

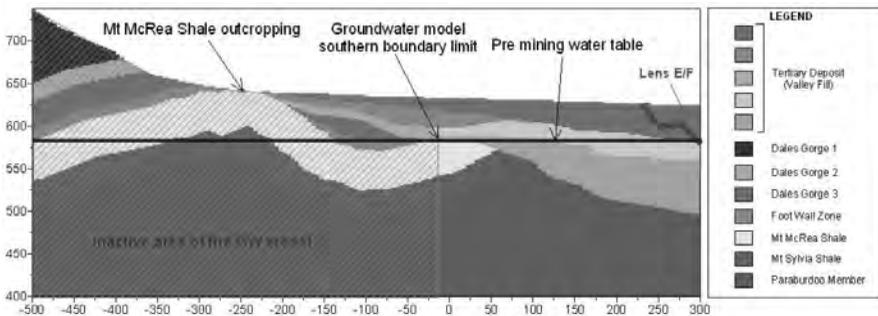


Figure 1 A typical North-South Cross-Section.

Simulation and Optimisation Methods

Optimal mine dewatering design requires a physically based and calibrated groundwater flow model to simulate drawdowns, the objective function, well defined management and technical constraint specifications, and an optimization approach. Groundwater drawdown simulation gives us the ability to test various design options for improvement. The objective function and the degree to which constraints are satisfied quantify the fitness of a trial solution. Optimisation allows us to efficiently compare alternative trial outcomes, thereby narrowing our choices to the very best among feasible options. Finally, probability and (geo)statistics enable us to measure the risk and level of confidence associated with each solution, fully examine the data to identify valuable connections, gain insights, test conclusions, and make reliable forecasts.

RTIO developed and calibrated a groundwater flow model of the Nammuldi Mine for use in the optimal dewatering design. Calibration was limited to pre-

dewatering data. Dewatering calculations are implemented using the physics-based numerical simulator MODFLOW-SURFACT™ (HGL 2012a). This code was selected as it accurately and robustly represents variably saturated groundwater flow under the high gradients resulting from deep mine dewatering. PBMOTM (HGL 2012b) was selected as the optimisation tool as it was specifically designed to handle highly non-linear systems (such as found in mine dewatering simulation) and is compatible with MODFLOW-SURFACT™.

The optimisation engine on which PBMOTM is based consists of a suite of global and local linear and non-linear optimisation methods within an integrating framework which synergistically provide a reliable numerical estimate of the globally optimal solution. The core global optimiser employs a mild assumption of Lipschitz continuity, which allows an efficient and robust search for a global optimal value through a systematic partitioning and exploration of the entire problem with the Brand and Bound approach.

Nammuldi Mine Groundwater Flow Model

A fully three-dimensional (3-D) numerical variably saturated flow model was constructed using the Visual Modflow Graphical User Interface (GUI) Version 4.3 Pro to prepare input files and run the numerical simulation code MODFLOW-SURFACT™ Version 3.0 (HGL, 2012a). Figure 2 shows the numerical model domain for the proposed Nammuldi below water table mine. The model domain extends 5 km in the north-south direction including the Nammuldi and Brockman ridges, and extends 25.8 km in the east-west direction to cover the proposed pit areas and minimise drawdown at the distant hydraulic boundaries. The 25.8 km by 5 km (129 square kilometres) domain is discretised into a numerical (finite-difference) grid consisting of 52 rows, 287 columns and 14 horizontal layers (208,936 model cells) of varying thickness. The top of layer 1 of the model follows the surface topography and its base is set to 560 mRL. The tops and the bottoms of the remaining layers are set at uniform elevations with increasing thickness with depth.

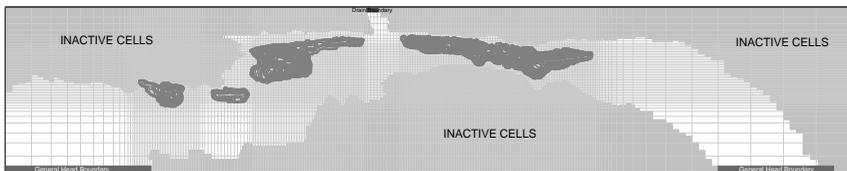


Figure 2 *Model Domain and Boundary Conditions.*

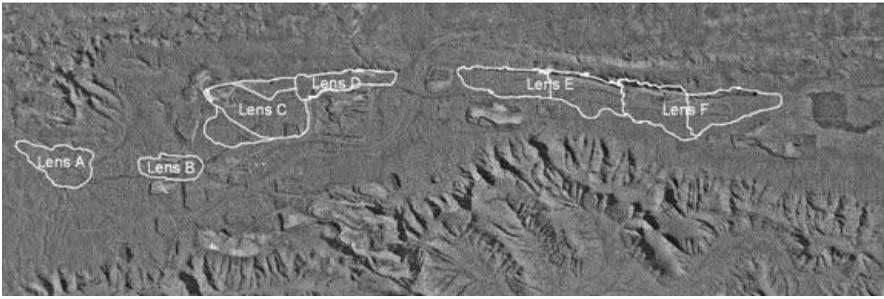


Figure 3 Aerial View of Proposed Nammuldi Mine. Lense C/D is the optimisation pit.

The base of the model is at 150 mRL. Recharge to groundwater is predominantly from the outcropping Mount Newman Member in the north and valley-fill in the south.

Dewatering Optimisation Strategy Specification

The pool of candidate locations for abstraction bores are provided in Figure 4. These are the locations permissible for testing various abstraction strategies with PBMO™. There are 100 ex-pit and 13 in-pit candidate locations. The in-pit candidate locations are on 520 mRL bench area which is accessible only after January 2017. In addition, sumps may be used to dewater local areas, if warranted.

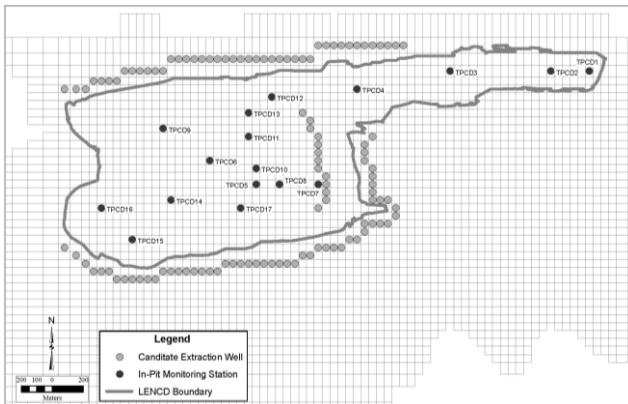


Figure 4 Location of Candidate Wells and Tracking Points - Lens C/D. RTIO has provided the locations for candidate water abstraction bores and exclusion zones. Lens C/D has an area of approximately 2.4 km². There are 100 ex-pit candidate locations and 13 in-pit locations. The allowable in-pit bore locations are available for dewatering use only after January 2017.

Dewatering Design via PBMO™

PBMO™ was used to develop an independent optimal dewatering strategy for Lens C/D. The solution was developed without apriori knowledge of RTIO initial dewatering strategy based on hydrogeological judgement. The RTIO design

solutions were intentionally withheld as a means of independently testing and verifying PBMO™. Thus, RTIO purposely withheld the initial dewatering strategy until after the optimal PBMO™ strategy was submitted. The PBMO™ search strategy for optimal mine dewatering is discussed in the PBMO™ Users Guide (HGL, 2012b). The optimal strategy is provided on Figure 5.

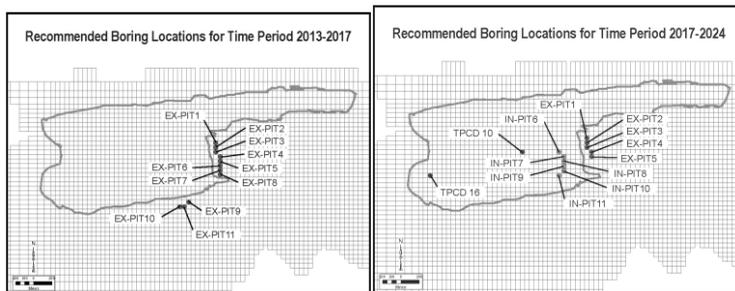


Figure 5 PBMO™ Optimal Solution for Dewatering Lens C/D – Abstraction Bore Locations. PBMO™ developed a dewatering solution to completely meet Mine Schedule 7. The solution for Lens C/D consisted of a total of 17 abstraction bores: 11 ex-pit bores, 6 in-pit bores and 2 low flow sumps.

PBMO™ Optimal Design

The PBMO™ optimal dewatering strategy requires 17 bores (11 ex-pit and 6 in-pit) with as many as 11 bores operating at any one time. All PBMO™ bore locations comply with restrictions on available locations, and all groundwater levels comply with mine schedule requirements. The PBMO™ solution reduces the number of dewatering bores and total abstraction volume of the initial hydrogeological judgement approach.

Conclusions

The pilot study conducted on Nammuldi Lens C/D demonstrates that PBMO™ can be applied to mine dewatering. The independent optimisation with PBMO™ demonstrated that the Lens C/D can be dewatered with less dewatering bores and less abstraction volume compared with the initial hydrogeological judgement approach. Additionally, the PBMO™ formal optimization approach is adaptive; it has the capability to incorporate new information such as refinements to mine shell pit progression and can readily incorporate enhancement or recalibration of groundwater flow models such that efficient and effective dewatering strategies can be readily produced; thereby avoiding mine scheduling impacts resulting from the time required to manually adjust dewatering strategy plans. Notably, PBMO™ supports the RTIO Mine of the Future™ programme by reducing impediments to mining production planning and operations that result from human-directed design's inability to quickly adapt dewatering strategies to dynamic and complex needs.

The approach is mathematically constrained and repeatable providing a more robust and defensible approach in environmental management.

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