C.2 Modelling Methodology

C.2.1 Groundwater Modelling

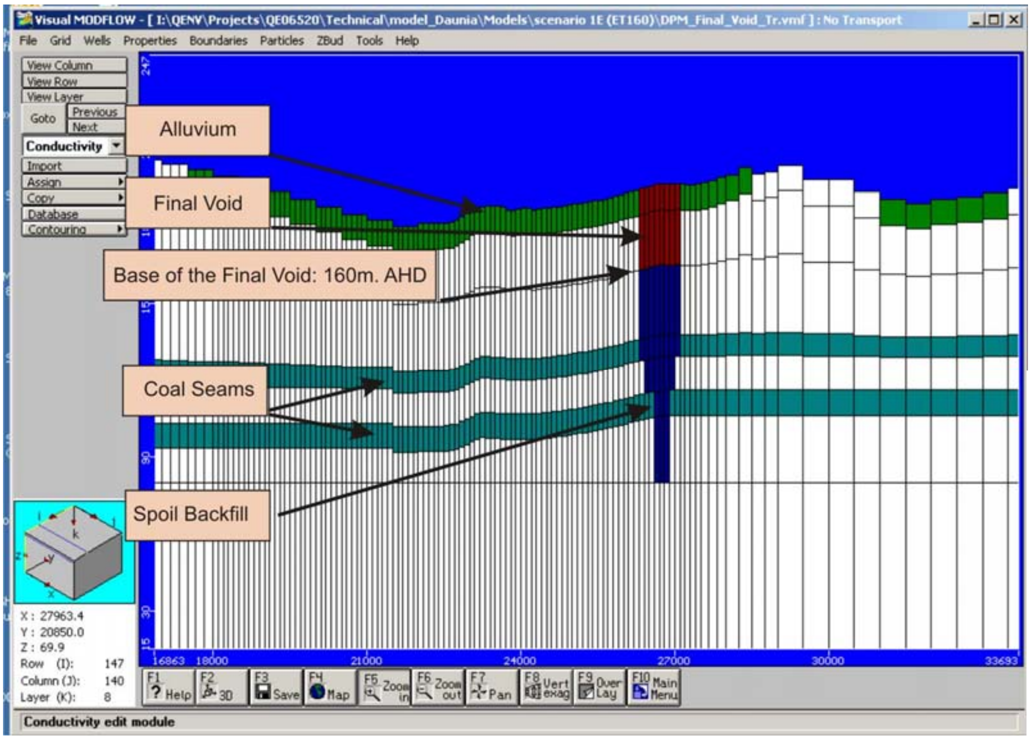
Introduction

In order to address the long term water balance within the final void, predictive scenario runs were conducted using the model developed for the purpose of identifying environmental impact during mining operation. The model was built within Visual MODFLOW Version 4.2 (Waterloo Hydrogeologic Inc.). The process of construction, calibration and sensitivity analyses of the regional groundwater model is detailed in the Appendix A of the Project EIS.

The MODFLOW model features seven layers and includes 203 rows and 186 Columns. Grid cells vary both in width and length from 100 by 100m in the vicinity of the coal mines to 500m by 500m in the corner of the model.

The final void was simulated by attributing a high conductivity (k=9999m/day) to the cells corresponding to the void. For these Cells, the specific yield (unconfined storage parameter) was set to 1.0 (i.e. the entire volume of the cell can be occupied by water). Backfill material (in blue on Figure C.2-1) is assumed to consist of hard sediments (sandstone, siltstone) that are poorly compacted and have a hydraulic conductivity set to 10m/day. All hydraulic parameters are summarised in **Table C.2-1**. In **Figure C.2-1** the blue cells show the location of former DRAIN CELLS that represented the excavated mine pit prior to mine closure in the former Project EIS model runs. The DRAIN CELLS controlled the groundwater level during the mining phase and hence defined the base of the void. This was assumed to be about 90 m AHD (this level is some ten metres above the base of the DRAIN CELLS as shown in **Figure C.2-1**). Following mine closure it is assumed that the cells are back-filled and the DRAIN CELLS turned off. The base of the blue coloured cells in **Figure C.2-1** do not correspond to be base of mine pit because the model layer structure does not allow for this. This perceived discrepancy has an insignificant impact on model results.

Figure C.2-1: Daunia Final Void groundwater model. Detail of the model structure in the surrounding of the mine pit.



Visual MODFLOW - [I:\QENV\Projects\QE06520\Technical\model_Daunia\Models\scenario 1E (ET160)\DPM_Final_Void_Tr.vmf] : No Transport

X : 27963.4
Y : 20850.0
Z : 69.9
Row (I): 147
Column (J): 140
Layer (K): 8

Conductivity edit module

Table C.2-1 Hydraulic conductivity and Storage coefficients used in the model.

Geological Unit	Model Layer	K model	K Sources	Ss model (1/m)	Sy model	Ss/Sy Sources
Quaternary age Alluvium Unit	Layer 1	10 m/day	No known pumping tests have been conducted in the Alluvium unit in the proximity of the site, and hence, measured hydraulic conductivity values are not available. The range of hydraulic conductivity values for silty sands of between 1 m/day and 90 m/day as reported by Freeze & Cherry (1979) has been adopted.	N/A	0.26	No known pumping tests have been conducted in the Alluvium unit in the proximity of the site, and hence, storativity values are not available. The range of storativity values for a medium sand of between 0.15 and 0.26 as reported by Fetter (1994).
Sandstone component of the Permian age Blackwater Group	Layer 2,4,5 and 6	0.1 m/day	No known pumping tests have been conducted in the sandstone unit in the proximity of the site, and hence, measured K values are not available. The absence of moisture in these units during drilling (D. McManus, pers.comm., January 6, 2005) indicates the sandstone to be largely impermeable. Freeze & Cherry (1979) reports the hydraulic conductivity of sandstone to range between 0.00001 m/day and 1 m/day. A number of 0.1 m/day has been assumed for the model after K sensitivity analysis during model calibration	0.000005.	0.05	This aquifer would typically be confined within the groundwater model and therefore the specific storage was assumed to be 0.000005.

Coal seam component of the Permian age Blackwater Group	Layer 3, 5	5 m/day	The representative and lower limit range of hydraulic conductivity results was sourced from BHP Billiton Mitsubishi Alliance pump tests conducted on similar coal seams at Goonyella. A conservative upper K value was selected from a range of pump test results conducted in Blackwater. Selected exploration holes at Poitrel (nearby Daunia) were subject to yield testing. Typically, yields of less than 2 L/s were measured. Yields as low as 0.08 L/s and up to 15 L/s were however recorded. To this end, the range of K values adopted from the pump tests conducted in Blackwater are considered to be a satisfactory representation of the yields measured at Poitrel.	0.000005.	0.05	Typical storativity value reported from BHP Billiton Mitsubishi Alliance pump tests conducted on similar coal seams at Goonyella and Blackwater
Mine Refill	Some cells in layer 2,3,4,5,6	10 m/day	Represents the spoil backfill deposited in the void - assumed to be similar to alluvial material.	0.000005.	0.26	Assumed to be similar to alluvial material.
Void	Some cells in Layer 1 & 2	9999m/day		N/A	01	

Where:

Conductivity (K) Property of a medium expressing the relative ease with which fluids can pass through.

Specific Storage (Ss) is defined as the volume of water that a unit volume of aquifer releases from storage under a unit decline in hydraulic head due to aquifer compaction and water expansion.

Specific Yield (Sy) is known as the storage term for an unconfined aquifer. It is defined as the volume of water that an unconfined aquifer releases from storage per unit surface area per unit decline in the water table.

With the exception of the final void, recharge was applied across the model domain as a percentage of average rainfall according to the rates detailed in the Project EIS. Thus, a recharge of 5mm/year was applied along the alluvial deposit and 1 mm/yr in areas of the sandstone unit outcrop. This recharge is as a result of precipitation percolating into the groundwater system. The different rates are due to the different conductivities of the aquifers.

For the final mine pit void, the applied recharge was estimated from the historical rainfall time series applying eight different scenarios with varying catchment area and climatic condition. These scenarios are summarised in the Table C.2-2.

As emphasized in the model limitations, the pit geometry and in particular the regrading is not represented in the model. The effect of the various regradings is incorporated indirectly in the model from the impact on catchment areas.

The modelled pit is composed by a juxtaposition of 100*100m grid cells. The bottom of the deeper pit cell is set up at about 126mAHD. The modelled pit is a coarse schematic representation of the real pit as geometric features smaller than the grid cell cannot be accurately represented in the model.

The model provides an understanding of the hydraulic exchange and equilibrium between the pit and the surrounding aquifer. To represent the volume stored within the pit lake, it is more accurate to use an independent calculation sheet which associate the Final void lake level (calculated by mudflow) with the corresponding volume of the lake.

In general we believe that the regrading of the pit profile will only impact on the base level of the void. For regrading to be important in preventing the formation of a pit lake that becomes saline with time it would be necessary to back fill the void to a level close to the regional groundwater level.

Table C.2-2 Summary of the 8 climatic and catchment area cases runs

				Catchment Area (km^2)	
Cases	**Climate**	**Rainfall Change**	**Catchment Case**	**Void**	**Catchment**
1a	Historical Monthly Data	0%	Minimum	3.88	0.8
1b	Historical Monthly Data	0%	Large	3.88	4.1
2a	Climate Change - Dry Case = -30 % Rainfall	-30%	Minimum	3.88	0.8
2b	Climate Change - Dry Case = -30 % Rainfall	-30%	Large	3.88	4.1
3a	Climate Change - Median Case = -7.5 % Rainfall	-8%	Minimum	3.88	0.8
3b	Climate Change - Median Case = -7.5 % Rainfall	-8%	Large	3.88	4.1
4a	Climate Change - Wet Case = +15 % Rainfall	15%	Minimum	3.88	0.8
4b	Climate Change - Wet Case = +15 % Rainfall	15%	Large	3.88	4.1

Initial Heads

In order to overcome model stability issues, the output of a model simulating one year after the end of mining operations has been used as initial conditions for all the eight cases runs. The one year model initial conditions were the water level output for “Daunia-Tr20 - best estimate scenario” reflecting operational phase of the project between year 15 and 20.

Model Sensitivity

A sensitivity analysis was conducted in the initial construction of the model. It is described in detail in the Chapter 2.4.4 of the Annexe A of the Project EIS. The sensitivity analysis was conducted on the key aquifer hydraulic parameters (hydraulic conductivity and storage parameters).

The eight scenarios described here are providing a sensitivity of the modal to rainfall.

An additional two sensitive runs have been conducted to address the sensitivity of the model in regards to the Evaporation parameter.

Model Limitations

In addition to the model limitations mentioned in the Project EIS, it should be noted that the model was set up as a regional flow model to explore large scale impacts on a regional scale. It has not been calibrated to accurately predict groundwater behaviour on a local scale. The level of detail included in the model around the pit does not support the investigation of detailed groundwater processes occurring in the local scale around the mine. In particular, the model does not adequately reflect the effect on pit inflows that may result from different pit geometries. However, the pit geometry have very little impact on groundwater hydrology. Groundwater hydrology is driven by regional aquifer pressures, the parameters of the aquifer and the recharge/evaporation on the void. The final void profile is accommodated by the interaction between the surface water and groundwater modelling (i.e the GoldSim model).

C.2.2 Surface Water Modelling

Hydrology

The hydrology for the final void modelling was determined based on an annual runoff coefficient. The annual volume of runoff was determined based on the runoff coefficient and the catchment area. The runoff was generated for a range of scenarios to assess the impacts due to changes in catchment area and to capture the potential variation in rainfall due to climate change. The scenarios considered are presented in table above.

Rainfall recorded and runoff calculations were supplied to be in included in the groundwater modelling.

Solute Balance

The solute balance was completed using a excel spreadsheet to account for the movement of both water and solute on an annual basis through the final void. The solute loads were determined using the following parameters:

void – 750 µS/cm;

rehabilitated – 250 µS/cm; and

groundwater – 15,000 µS/cm

The solute and water balance were conceptualised as shown in figure below. The balance included the results of the groundwater modelling including the starting water volume, the groundwater inflows and outflows.