Appendix G
Pit Stability

1 Geotechnical Study

The geotechnical investigations into the stability of the open cut were undertaken over a period of over two years. The process and work completed was very detailed, in keeping with a bankable feasibility study. The geotechnical consultants chosen to complete the study had considerable experience with stability modelling and prediction in the underground mine, giving them a good understanding of the local conditions and behaviour of the rock mass. The program covered:

- Review of existing data. This included existing drill core, underground mapping data, and previous studies;
- Planning of the geotechnical program;
- Collection of data and samples;
  - This included an additional 22 drill holes to provide core samples
- Sample testing, including;
  - Soil testing
  - Uniaxial compressive strength (UCS) and Young's Modulus (E)
  - Triaxial
  - Spectrometer tests for clay mineralogy
  - Index testing
  - Direct shear
- Analysis of soil zone stability
  - Modelling was undertaken with a variety of water table level assumptions
- Analysis of rock wall stability, encompassing;
  - Planar failure analysis
  - Wedge failure analysis
  - Rock fall analysis
  - Numerical stress analysis
- Recommendations
  - Inter-ramp slope angles
  - Batter angles, berm widths and intervals
  - Footwall stability management
  - Pit stage scheduling
  - Slope dewatering
  - Interaction with the underground voids

During and upon completion of the draft geotechnical study, it was evident that there were issues that required further work to increase the confidence in the slope analysis. This work was completed in 2004 and early 2005. Thus, the geotechnical study has been thorough, and addresses in detail all of the possible modes of failure.

2 Water Inflows and Pit Instability

The Northern Territory Environment Centre (NTEC) has concerns that large flows of water will be accumulating in the pit, causing instability of the pit walls. The actual water flows and storage strategy needs to be clarified at this point.

The hydrology study identified various sources of water that are likely to flow into the pit, including alluvial aquifers and water-bearing faults in hard rock. Water entering the pit, or trapped in rocks close to the pit walls, is not desirable. It can make drilling and blasting more difficult, cause tyre damage, and reduce wall stability. Hence, a common strategy employed at large open cut mines is to intercept the water in the rocks around the pit using a series of boreholes, and pump it away before it can become a problem. Indeed, this philosophy is recommended at MRM, and is discussed in section 11.9.1 of the EIS.

The particular dewatering strategy proposed for the MRM open cut is to pump water from the bores for use in the concentrator, using surface dams and the underground mine voids as storage facilities. From approximately year 4 of open pit mining, the pit floor would have exposed underground voids. Thus, water cannot accumulate in the pit as suggested; rather, it will flow through cracks in the rock and open voids to the abandoned underground mine workings. Even at the deepest point of the final pit, there is still approximately 2500ML of storage capacity in the underground voids.

Near-horizontal weep holes would also be drilled into select walls of the pit to ensure that no pressurised bodies of water were present within 100m of the pit walls. Gravity would cause the water to flow out of any aquifer and down the weep hole.

As with the NTEC, the Xstrata open pit project team had concerns that flooding the underground mine would affect the stability of the open cut walls. Computer modelling was used to expressly answer this question (refer to the section below on underground voids and computer modelling). It was found that if the level is kept at least 20m below the pit floor, pressures in rocks around the pit walls would not increase, and hence stability would not be affected. As the underground mine extends some 200m below even the bottom of the final pit stage, this is easily achievable.

In conclusion, as correctly identified by the NTEC, water in rocks surrounding an open pit is another issue that must be designed and managed to ensure that its impact on mining operations is controlled. The EIS recognises that there is water that will require management, and presents a strategy for dealing with it.

There are other important geotechnical findings and recommendations that must be managed to successfully mine the MRM open cut. These are discussed in the following sections.

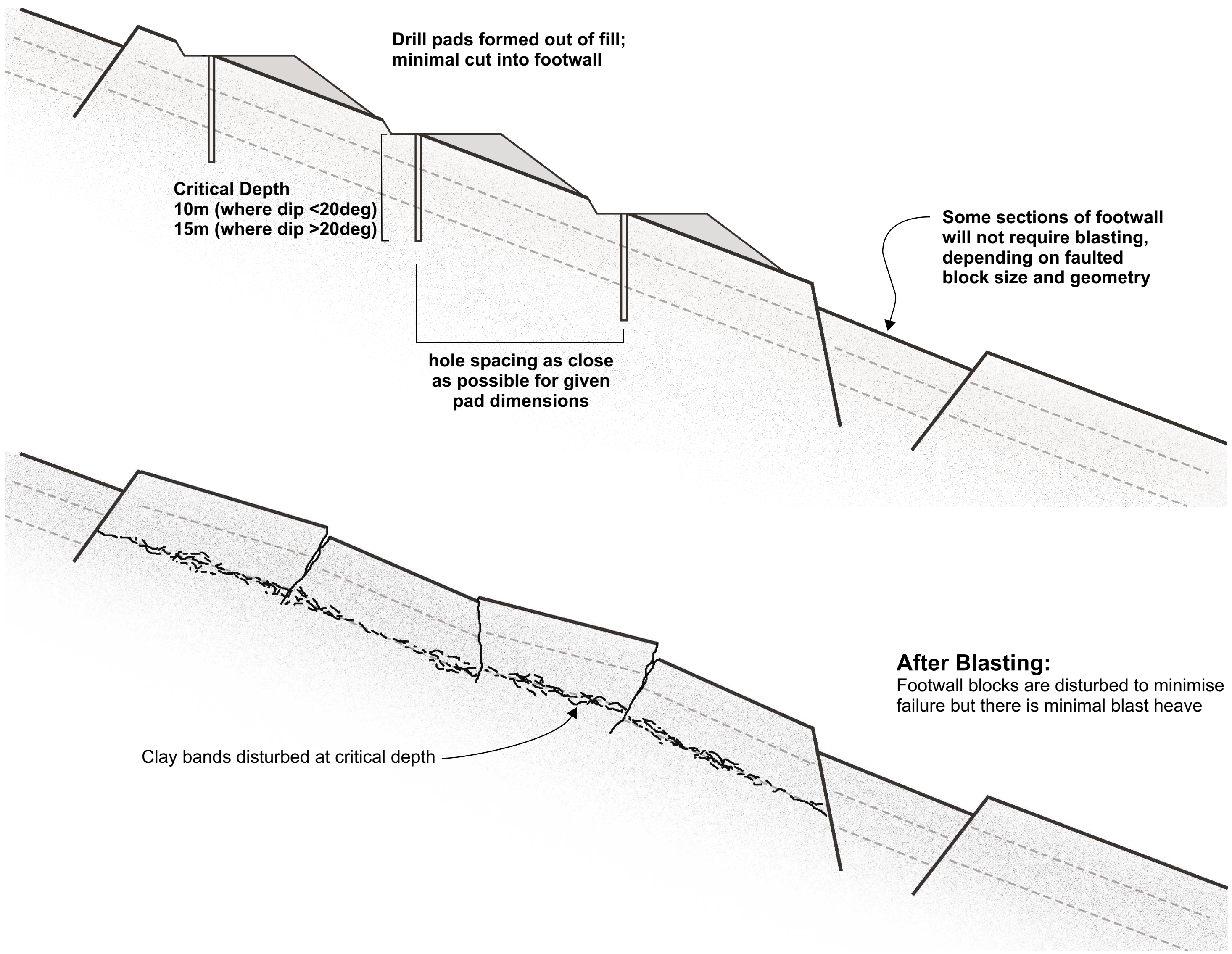
3 Footwall Stability

The study found that the rocks below the ore zone (termed the ‘footwall rocks’) in the main part of the deposit would require special mining practices. The majority of this part of the pit wall would follow the dip of the ore zone (20° to 35°), hence it would have the flattest slope of any of the walls. Despite this flatter slope, the rocks to the footwall of the ore zone could cause instability if the same design principles as used for the other walls were applied to them.

The footwall rocks themselves are as strong as most of the other rocks in the pit. However, there are weaker planes of clayey ‘tuff’ that lie in between the bands of stronger rock. This could cause instability in certain circumstances, if the strong rocks ‘slid off’ the rocks below. This is termed planar failure.

If the footwall rocks were all perfectly parallel to each other with a constant dip (at an angle steep enough to cause sliding), then the geotechnical study showed that planar failures could occur in the open pit. However, the deposit at MRM does not display these homogenous characteristics. The deposit is criss-crossed by a myriad of faults that move the blocks of rock up and down relative to each other. Also, local folds and twists are present. All of these features are well-known from the 10 years of mining in the underground operation. Thus, the clay bands are not continuous. Rather, they are broken up typically into 30-60m long and wide blocks, each tilted and folded relative to each other. Indeed, it was this disrupted nature of the orebodies that made underground mining of the deposit quite challenging. However, what was detrimental to the underground mine is of great benefit to the open pit, as the faults and tilting disrupts the continuity of the planes of weakness. This causes the blocks to be interlocked to a degree, increasing the stability.

Despite this, some simple operational and design strategies could be used to further enhance the stability of the footwall. Figure 1 shows how 10-15m deep holes drilled in rows would be used to



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Footwall Stabilisation Blasting - Concept

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FIG. 1

blast the footwall rocks, further disturbing the failure planes. Also, haul roads would be a combination of cut and fill to limit the exposure of the tuff bands in any cut batter above a haul road.

4 South-west Domain 2

The south-west portion of the open pit, termed Domain 2, was identified as an area that required specific design and operational recommendations to ensure successful wall formation. The rocks in this portion of the pit also contain the weaker clay 'tuff' beds as the footwall. However, their dip is steeper than in the main zone of the pit, thereby increasing the risk of sliding into the pit excavation. Fortunately, this portion of the pit wall is in the shallowest part of the deposit, with a depth of 70-120m below the surface.

A strategy was devised to manage this section of wall:
1) The inter-ramp-slope-angle (IRSA) was reduced from 51° to 33°.
2) Weep holes at least 100m long would be required to ensure that no water was building up pressure behind the wall.
3) No haul ramp should be constructed in this area of the pit (referring to Figure 4.2 in the EIS, note how the ramp on the western wall does not extend all the way to the southern end of the pit).
4) Design of the pit stages should ensure that the wall could be cut-back further to a flatter angle if instability was noted. Again, Figure 4.2 illustrates how the haul road, which is the only infrastructure planned in that area, is located well back from the pit crest.
5) Monitoring would be required to detect movement of the wall.

The pit staging in Figure 4.3 of the EIS shows how the stages have been designed to delay mining in this area. This enables the new information that would be gathered from the mining of the other pit stages to be used to verify the findings of the geotechnical study before any mining takes place in this area. This will enable the optimal design and mining sequence to be developed before any activity takes place.

5 Underground Voids

The NTEC claims that "Question marks remain over the stability of the proposed open cut in proximity to underground workings". This is an incorrect statement. The behaviour of the pit slopes and floors around the underground mine have been modelled extensively.

The geotechnical consultants used were particularly strong in the area of modelling of the underground and open cut interaction, and have a long association with providing geotechnical expertise to the underground mine. Computer models using numerical stress analysis were used to predict the behaviour of the rock mass for various mining scenarios. The computer models were run with the existing underground mine only to enable the modelled rock behaviour to be calibrated to the actual performance of the underground mine. This ensured that the model was appropriate for this purpose and would give reliable results.

Many model runs were then completed to investigate the impact of several variables:

- Underground void geometry;
- Varying fault sets;
- Groundwater pressures;
- Open pit mining sequence; and
- Open pit wall slope angles.

The modelling presented many valuable findings.

The underground mining already completed was predicted to generate tensile yield zones in the rocks above. These tensile zones were not predicted to result in large-scale movement with surface expression of open tension cracks; rather, the tensile forces are released through small movements between rock structures, such as bedding planes and joints. This agrees with observations to date: there are no large cracks in the strata overlying the underground mine.

When the open pit progressed through these pre-weakened zones, there was an impact on the behaviour of the rock. Some pit walls were predicted to exhibit some slow 'creep' before the forces again came to equilibrium, stopping the movement. There were no wall failures predicted: all the walls moved a little before settling down. Maximum predicted movements were in the order of 60-140 cm.

The recommendations resulting from the computer modelling were:

1) The Inter-Ramp-Slope-Angles (IRSA) should be reduced from 55° to 45° in the ore zone;
2) Open pit stages should mined in a sequence that does not result in a single full height slope;
3) Water in the underground mine should be kept at least 20m from the pit bottom whilst open cut mining is in progress;
4) No open pit walls should come closer than 60m to any active underground mining areas;
5) The flood protection bund should be constructed at least 100m from the final pit crest; and
6) Stope crowns are likely to be stable above a thickness of 20m.

In order to satisfy these recommendations, the following has been incorporated into the mine plan:

- The pit designs use the recommended flatter slope in the ore zone;
- The scheduling of the open pit is such that the next pit stage has commenced mining before the previous stage has been completed;
- The underground mine dewatering system will be used to maintain adequate clearances between the bottom of the pit and the water level;
- The underground mine will be closed before the open pit proceeds to full production;
- The bund has been located significantly further away from the pit crest than 100m; and
- Voids management procedures will be used to manage pit operations in close proximity to the underground voids.

5.1 Working around Voids

The management of open cut operations in the vicinity of old underground workings will require diligence to ensure the safety of personnel working in the pit. Unlike most open pit operations with voids present, MRM has precise models of all the underground workings as of 2005. This makes management of voids relatively straightforward, as there are no unexpected voids. However, the possibility of changes to the voids since the closure of the underground mine must be built into the mine operation practices.

The voids will be identified in mine plans, which will trigger Safe Work Procedures (SWP's) that must be followed when work is undertaken in these identified areas. Such practices can include:

- Restricted access of various levels to match the risk:
  - Lower risk areas may allow equipment with rollover protected operator cabins (ROPS) fitted to access the area;
  - Higher risk areas would be inaccessible to all vehicles and personnel;
- Geotechnical analysis of known structures, rock types and ground conditions would be made to determine a safe crown pillar thickness for each void;
- Probe drilling from safe ground to confirm the dimensions and location of the voids at that time; and
- Risk assessment to determine the safest and most effective way to make the area safe, including;
  - Drilling of large diameter holes into the void, followed by filling with crushed material

- Drilling of long holes through the stable crown pillar to enable it to be blasted into the void.

The procedures developed for the MRM open cut will be based on those employed successfully for many years at the Fimiston open cut (the ‘Superpit’) in Kalgoorlie, Western Australia.

6 Conclusions

An extensive and detailed study was completed as part of the feasibility study into open pit mining at MRM. This addressed all aspects of pit stability, including local scale and slope scale failures.

This study addressed issues such as the effects of groundwater and existing underground voids on the wall stability. Recommendations ranging from design guidelines to operational constraints and requirements were made to manage these issues. This enabled a pit design and mine schedule to be developed that would be stable over its operational life, throughout the varying rocks to be encountered in a pit at MRM.

Areas of higher risk of failures were specifically identified and modelled. These have been discussed in this document. Control strategies were devised to maintain a safe and efficient operation of a pit at MRM. Xstrata have confidence that the mine designs, schedules, and operational strategies devised in the feasibility study, and presented in the EIS, will provide a safe work environment over the life of the open cut mine.