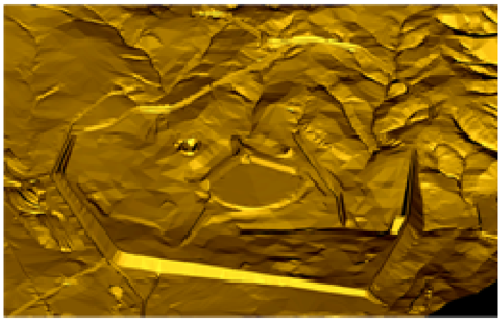
OSBORNE HIGH DENSITY DISCHARGE - AN UPDATE FROM 2004

The trialling of a high density thickened tailings discharge system at Osborne Mine in Queensland Australia was presented at Paste 04. Subsequently full scale operations have proceeded. This paper presents an update on the implementation of high density discharge, operating experiences to date, potential modifications, and the nature of future tailings facility development in light of potential increases in mine life.

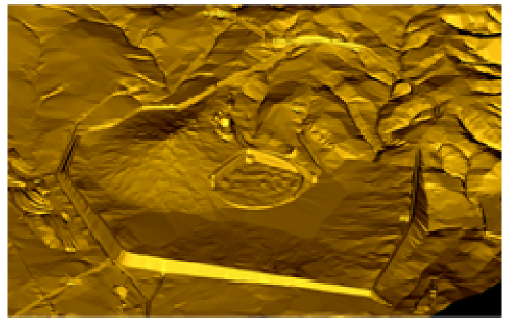
1 INTRODUCTION

Osborne Mine, a copper-gold mining operation located in Northwest Queensland, have converted their conventional tailings storage facility, TSF2 to high density thickened tailings discharge through a process of trial deposition which began almost from the time of commissioning TSF2 in 2002. Initially conventional deposition from a ring main was carried out with tailings at a solids content of 65%. Later, in 2003, as plant modifications made it possible to increase the solids content to 75%, full scale trial depositions were established within the inner parts of TSF2 using an advancing cone methodology whereby a discharge point is progressively extended as the cone develops in front of the discharge. Figure 1 shows a series of renderings of topographical survey data from the start of the trials and illustrates the development of two trials, referred to as the southern and the northern trials. As is evident from Figure 1 the northern trial began in 2004 after the southern trial showed significant promise.

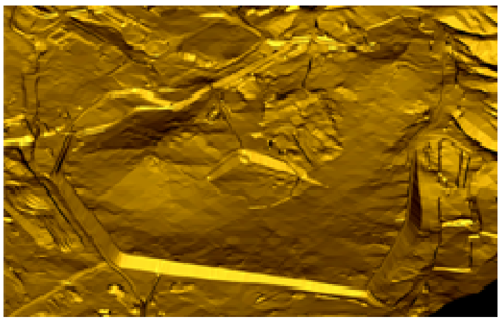
In 2003 detailed geotechnical assessments involving laboratory testing on undisturbed and disturbed samples, in-situ testing using a piezometer cone, and calibration of seepage and stability models calibrated against field measurements were completed. These were documented in a paper by McPhail and Wilkinson entitled *Development and Implementation of Thickened Discharge at Osborne Mine, Queensland Australia* and presented at Paste 04 in Cape Town in 2004. The geotechnical assessments indicated that there were significant merits in pursuing high density thickened discharge in terms of seepage reduction, water savings, reduced wall construction costs and operational convenience. These indications were subsequently confirmed through an extended full scale trial programme.



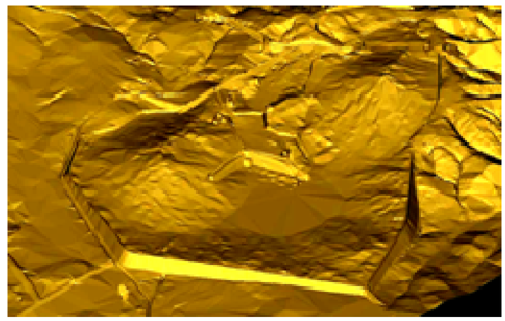
2002 soon after commissioning



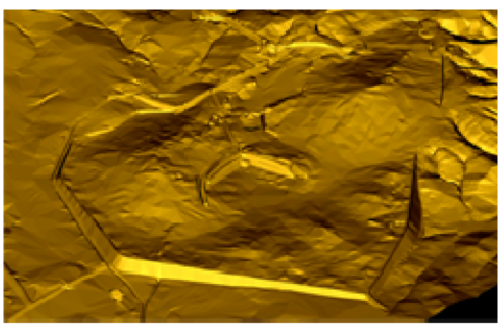
2003 Southern Trial



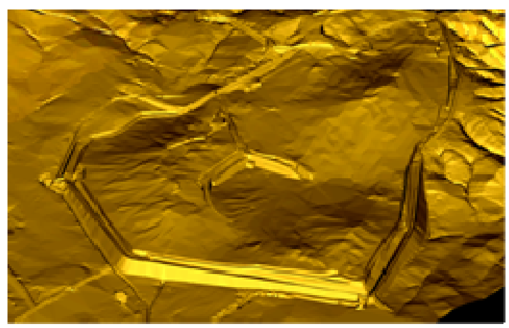
2004 Northern Trial, turn in Southern Trial



Feb 2005



Oct 2005 beach filling to push pond onto drain pad



Aug 2006 beach extension of Southern and establishment of South Eastern mounds

Figure 1: Progression of high density trials

In 2005 a decision was made by Osborne to commit fully to high density thickened tailings deposition using the advancing cone methodology. Relevant submissions were made to the regulator and have been successful in obtaining the necessary permissions to officially convert TSF2 to high density thickened tailings discharge.

This paper describes the development and conversion process from 2004 to the present day and sets out the benefits as well as learning points gained along the way. The paper describes life of mine tailings management proposals and also sets out a number of challenges that will have to be met over the remaining operational period when ores from satellite operations are processed on an increased scale as the Osborne Mine ores are steadily exhausted.

2 STATUS IN APRIL 2004

The main conclusions reached through the initial trials as presented at Paste 04 were:

- High density thickened tailings discharge using the advancing cone methodology is practical at Osborne and can be reliably established using existing available plant equipment ie without the need to move to positive displacement pumps.
- Solids contents of up to 78% are achievable and the slurry can still be pumped at this consistency using centripetal pumps (the solids SG is 3.6).
- There is a negligible risk of spontaneous liquefaction as at these high solids contents the material deposits above the steady state line and remains so with loading.
- Seepage rates are of the order of 1% of the volume of water contained in the slurry. The remainder of the water either evaporates or is retained by the tailings mass as interstitial water.
- Water savings of 40% are feasible due to the reduced losses achieved by recirculating water from the thickener thus keeping the supernatant water in the processing plant.
- Beach angles of 4% are achievable

- Since the reliability of generating thickened discharge was of the order of 65% and there were concerns about the impact of flushing operations on the beach it was considered prudent to retain part of TSF2 as a conventional tailings storage area. "Out of specification" thickened tailings could be deposited in this area and flushing operations managed so that the majority of the delivery line could be flushed without discharging on to the high density beach.
- Beach surveys within the conventional area indicated that the "out of specification" thickened tailings beaches at approximately 2.5% or 1:40. This is comparable with cone profiles achieved in earlier trials on TSF1.

3 STATUS AS AT NOVEMBER 2006

3.1 RAISING THE CREST ELEVATION HYDRAULICALLY

Since TSF2 is a conventional tailings site converted to high density thickened discharge it has been necessary to ensure that supernatant water and stormwater is able to reach the decant area. To maximise the advantages of the advancing cone it was decided to raise the crest of the dam using hydraulically-placed tailings. This has been achieved by setting up a third advancing cone working from the south eastern corner and progressing northwards. Planning for this cone is indicated in Figure 2

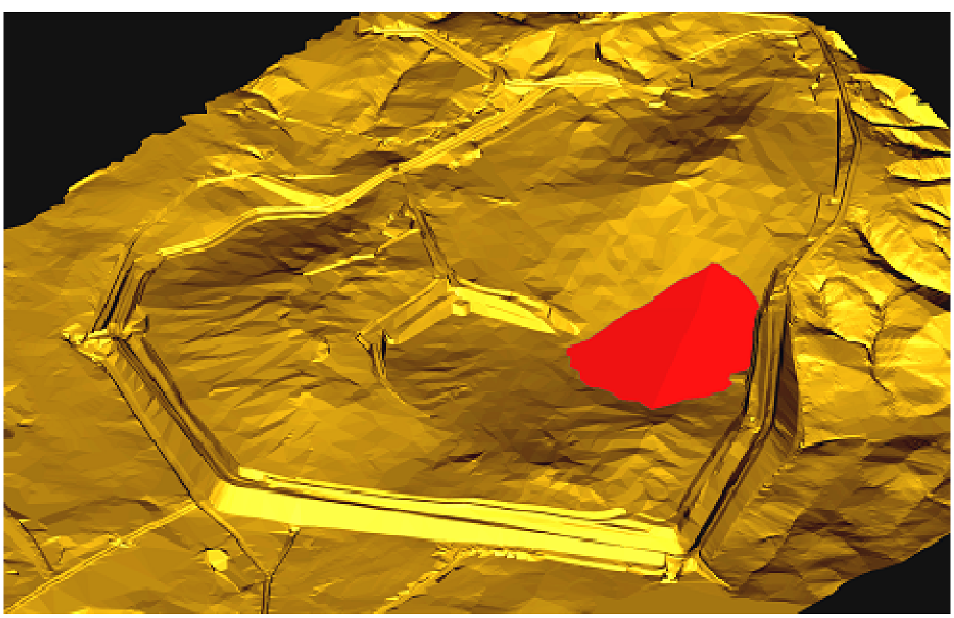


Figure 2: Southeastern advancing cone

By extending the southern cone as indicated in Figure 3 it has been possible to effectively raise the crest elevation of the dam while ensuring that there is sufficient pond volume available at all times.

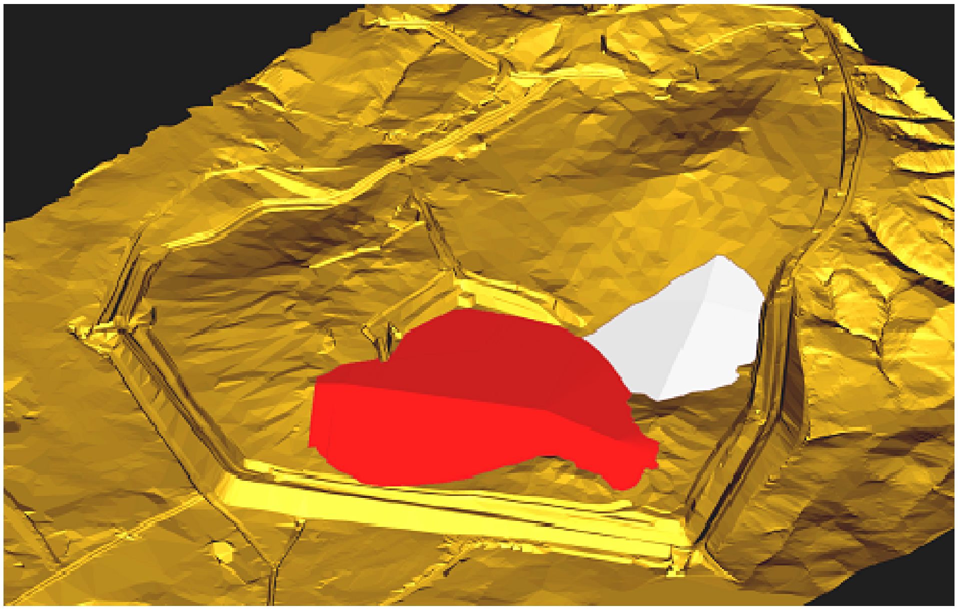


Figure 3: Extension of the southern advancing cone

3.2 STORM MANAGEMENT

Raising the embankments hydraulically using advancing cones introduces storm water management issues since there is runoff from the slope face to the outer parts of the TSF. To accommodate and control this storm water storm water control trenches were constructed along and on the inside of the existing toe starter embankments as indicate in Figure 4 which also shows the locations of spillways which enable the water to be discharged at ground level and directed to the reclaim pond. Figure 5 shows photos of the trenches and spillway in the south eastern corner as at November 2006.

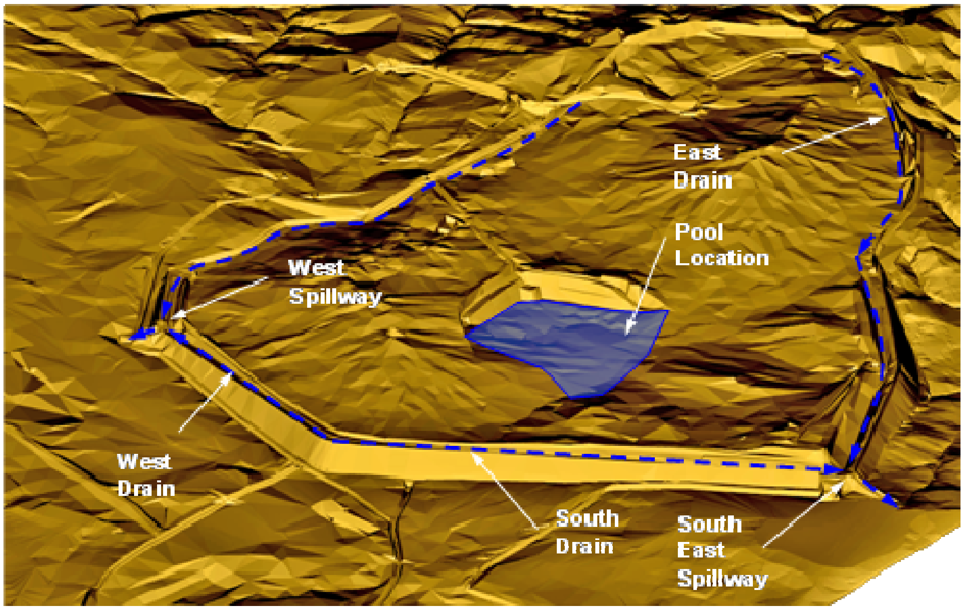


Figure 4: Location of storm management trenches and spillways

Southeast Spillway

South Drain

East Drain looking north

East Drain looking south

Figure 5: Photos showing the storm trenches and spillway

3.3 NORTHERN EXTENSION OF PERIMETER EMBANKMENT

While toe wall raises have been eliminated through adoption of high density thickened discharge during construction of TSF2 in 2001 only the lower southern of the toe wall was constructed. To fully enclose the site with a toe wall it been necessary to construct an extension of the original starter embankment around the northern perimeter of the TSF site. This is indicated in Figure 6. A significant advantage of the advancing cone methodology is that the height of the toe wall may be a nominal 1.5m over all of its length except for the area in the saddle at the northernmost extremity. At this location the toe wall is higher in order to enable an advancing cone to be established. From this point the cone is advanced in a southerly direction as indicated in Figure 7. By progressively raising the discharge point with each pipe extension the advancing cone crest rises as the cone is advanced. This continues until the design elevation is reached where the maximum allowable spread between the toe walls achieved.

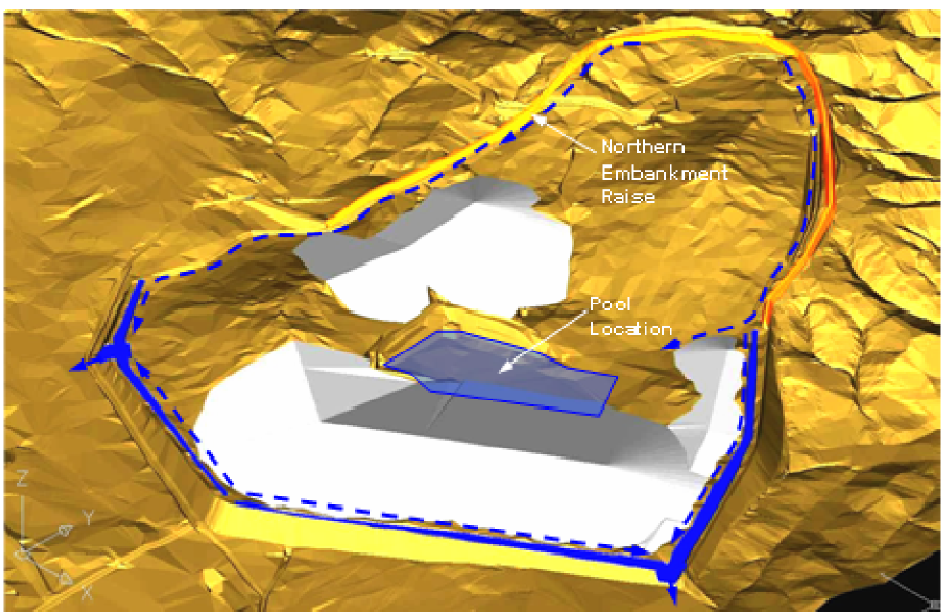


Figure 6: Extension of the northern perimeter

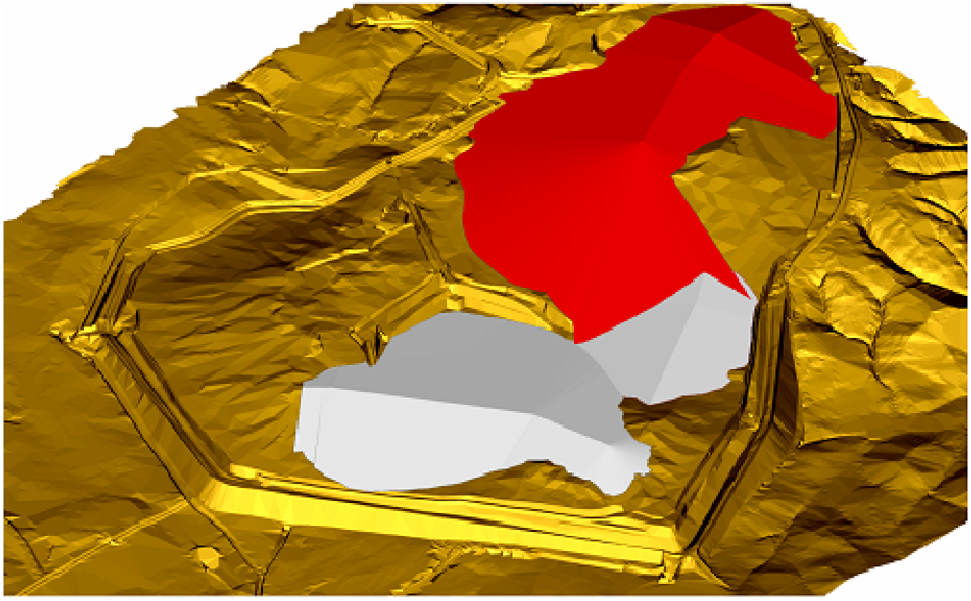


Figure 7: Final northern advancing cone

3.4 OBSERVATIONS

Over the past 3 years of operation a number of useful observations have been made and some lessons learned. These are set out below.

3.4.1 Beach slopes to 5%

Beach modelling suggested that beach slopes could be steepened by incorporating a bend at the discharge end of the pipe such that the tailings would be flowing near vertical on discharge. Modifications were made to the discharge and it was found that beach slopes steepened to 5%. Figure 8 shows a photograph of the up-turned pipe.

Figure 8: Photograph showing the “up-turned” pipe discharge

3.4.2 Reliability of high density slurry generation

By setting meaningful incentives and managing performance through key performance indicators (KPI’s) negotiated with the operators, combined with a number of minor plant modifications, it has been feasible to increase the reliability of high density tailings delivery from 65% to 80%. At this level of reliability, combined with the use of up-turned discharge points and careful management of flushing times, it has proved practical to deposit all tailings on the advancing cones without significantly impacting on the averaged beach angle. There is some scouring by the “out of specification” thickened tailings as well as by the flushing but the resulting gulleys are quickly “healed” when deposition at the correct consistency resumes.

3.4.3 Water savings and seepage loss

Water savings in excess of 40% have consistently been achieved and have resulted in considerable improvement in sustainability reporting. As importantly, the lower volume of water available on the TSF means that there is less water available for seepage loss. As a consequence groundwater monitoring bores around TSF2 have shown no change since commissioning of the TSF.

3.4.4 Operation

The advancing cone methodology has proved exceedingly simple to operate. An operator visits the dam four times a day to check on beaching and the condition of the discharge point.

However, the ease of operation has, in the context of the need to retro-fit thickened discharge to a TSF geometry designed for conventional deposition, been somewhat of a trap. A number of factors now dictate that an increase in the level of attention to the operations is warranted to ensure that toe wall elevations around the perimeter of the TSF are not exceeded. This is particularly the case where two advancing cones meet. Figure 9 shows ponding occurring against the toe wall area as a result of beaching towards an advancing cone. The remedy in this case simply requires a discharge at the low area and progressive build-up of the tailings by advancing this discharge into the TSF, however, this requires an increased level of input from the operators both to establish the discharge point as well as manage the deposition.

Figure 9: Ponding against the toe wall at the intersection of two advancing cones

The use of HDPE delivery piping is vital for ease of management as an operator is able to move or extend this piping with ease. However, the pipe expands and contracts and sags between supports. Supporting the pipe requires the use of tyres which are able to steady the pipe and accommodate movement. However, remains difficult to ensure that the elevation of the advancing cone is level and consistent. Figure 10 shows a typical delivery point and illustrates the issues.

Figure 10: Typical delivery point showing HDPE pipe issues

While beaching to the sides, against toe walls, it is essential to maintain a careful watch on the tailings build-up and to move the discharge point either to re-direct flow or to lower the discharge elevation (and in so doing reduce the lateral spread of the beached tailings) in order to ensure that the required level of tailings at the toe wall is not exceeded.

Flushing of delivery pipes requires careful control. Inevitably, flushing results in the scour of a channel from the discharge to the toe of the beach. The depth of scour is related to the total volume of water used in the flushing process. This needs to be just sufficient to ensure that the pipe is clear and no more. Moreover, it is vital to observe the direction of flow during flushing to ensure that this is not to and along a toe wall where it may cause scouring of the toe wall. Figure 11 shows a typical flushing scour at Osborne.

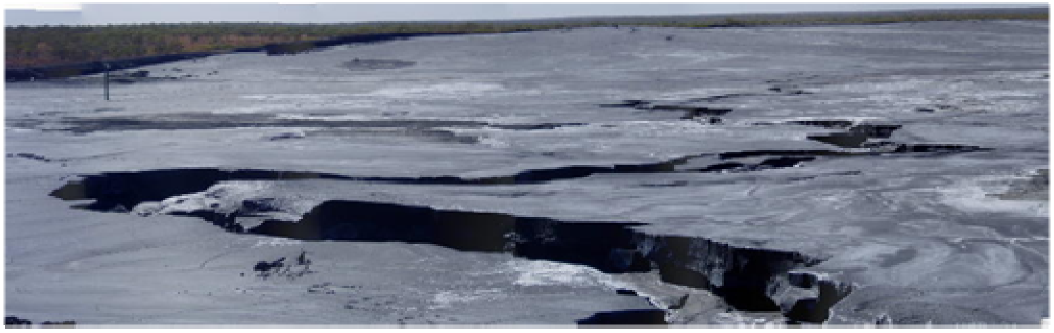


Figure 11: Typical flushing scour at Osborne

3.4.5 Opportunities to improve reliability

A number of opportunities have been identified and trialled that will improve the reliability of generation of high density thickened tailings. At the time of writing these are about to be implemented. The overall objective is to get the consistency of the tailings high enough that it is feasible to control the density delivered to the TSF by adding water. This is regarded as preferable to simply thickening to the required density since it will result in more a consistent slurry. The opportunities include:

- Improved regulation of pressures to the bank of hydrocyclones that separate the tailings into coarse and fine fractions ahead of the thickener. While it is generally appreciated that cyclones require constant pressure to operate optimally it is not always appreciated that the level of improvement is very significant. While regulation of the pressure requires specific instrumentation and control, the effort in incorporating these is easily justified.
- Reduction of surges in the milling circuit through improved instrumentation and control
- Application of mechanical seals in the first stage of the slurry pump so as to reduce gland service water
- Increasing automated control. This is feasible as a result of implementing the above measures since it comes down to controlled water addition.

3.5 Closure

During 2005 conceptual evaluations of closure options for the tailings storage facilities at Osborne were completed based on a closure date of October 2008.

The geometry of TSF2 at that stage will be as indicated in Figure 12. On closure the slopes of the mounds would be dozed through and over the existing toe walls, to form a continuous slope to ground level, and then the entire slope covered.

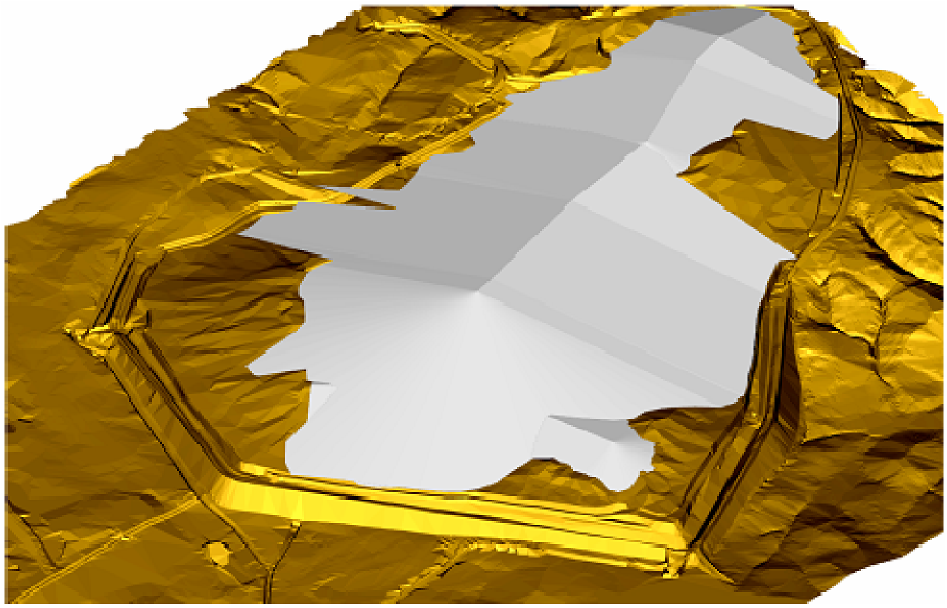


Figure 12: Geometry of TSF2 per the current closure plan (2008) prior to dozing

It was evident from comparison of the closure measures for the conventional facility, TSF1, with the measures for the high density thickened facility, TSF2, that TSF2 would be considerably simpler to close. The reasons for this may be summarised as follows:

3.5.1 Shedding mound

There is no pond area and consequently no restrictions on access anywhere on the facility. Moreover, the gentle slopes that characterise the high density mounds make it easy to access the facility to re-grade, dress and cover the tailings. Most importantly, however, is the fact that storm water will not accumulate on the top surface of the TSF so that it is never necessary to manage a pond.

3.5.2 Covers

A range of covers for the TSF have been evaluated such that they will meet criteria relating to:

- Long term erosion
- Net percolation through the cover
- Salt migration and the extent to which this could affect vegetation.

Covers incorporating a range of layers have been evaluated. Layer combinations have included:

- An erosion resistant surface layer that will support vegetation
- A capillary break to prevent salt migration into the cover
- A clay layer in contact with the tailings to reduce infiltration during the cyclone-dominated wet season of 4 months.

In modelling the potential cover arrangements it was found that for TSF2:

- The shedding profile that prevents ponding of water at any time significantly reduces the potential net percolation.
- Thinner covers without the clay layer performed better from the perspective of net percolation. This is because the thinner covers allow greater exfiltration during the hot dry months.
- As the cover thickness reduces, however, suctions increase to below wilting pressures for vegetation and salt migration increases.

A trial area is to be established on TSF2 to test and monitor the performance of the cover combinations. The data from the test areas will enable calibration of the cover models and assist in progressing the design from conceptual to final design.

3.5.3 Progressive rehabilitation

The advancing cone geometry enables progressive rehabilitation as deposition advances. It is proposed to allow exposure of the tailings only long enough for exfiltration to reduce the water content of the tailings such that salt migration into the cover will be minimised.

4 PLANNING FOR AN EXTENDED LIFE OF MINE

The prevailing high metal prices have significantly increased viable ore reserves and have made it economical to consider transporting ore from satellite ore bodies. Planning for the additional tailings that would arise from extended operations has been carried out to meet the following requirements:

- The design should permit termination of operations at a range of junctures which will be dependent prevailing economics.
- The design should, as far as practicable, be confined to the current footprint areas defined by TSF2 and its associated reclaim pond.

Accordingly three tonnage scenarios were identified by Osborne, namely, “base” case, “target” case and “optimistic” case and planning for high density thickened discharge has been completed for each scenario. Figure 13 below shows how the dam geometry as at 2008 can be progressively extended to address these three scenarios.

Notable features of Figure 13 are:

- Advancement of the cone into the area below TSF2 and into the reclaim pond area visible to the south of the TSF
- Deposition of the “fillets” outside of the existing southern and eastern toe walls. This is to prevent scour and improve control during the cresting of these toe walls.
- Re-alignment of the storm control trench around the west side of the TSF and reclaim pond
- The reducing reclaim pond volume which is feasible because of the potential for progressive rehabilitation to enable shedding of storm water from the rehabilitated areas without entering the reclaim pond. This will reduce the catchment area to be accommodated by the reclaim pond.

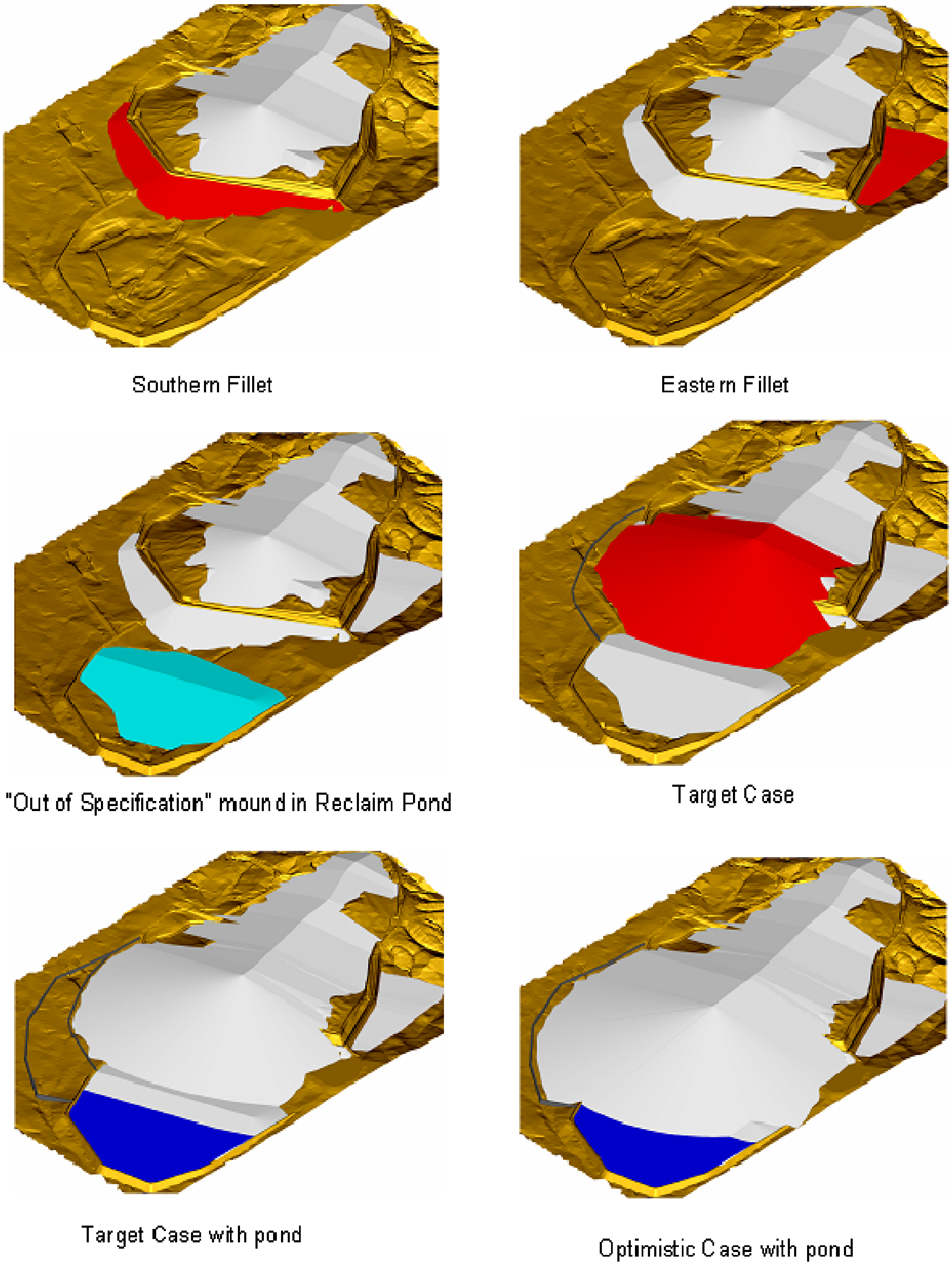


Figure 13: Increased life of mine TSF2 development scenarios

5 FORTHCOMING CHALLENGE

Ores from satellite ore bodies have the potential to produce tailings whose depositional behaviour may be significantly different from the current tailings. This may result from mineralogical differences between ore types which will introduce variability in grind, rheological properties of the slurry, thickening characteristics and, from these, variability in the beaching behaviour of the slurry. Moreover, since all but one of the satellite deposits are to be developed using open cast operations the initial ores mined will be oxidised and of differing characteristics to the hard rock ore.

Large scale bulk samples from the satellite deposits are to be processed in the existing plant over the next year. As each bulk sample is processed it will be possible to obtain samples and assess beaching properties. Ultimately, however, there will be blends of the ores and the slurry behaviour will depend on the blend. It is therefore evident that a methodology for predicting and monitoring the depositional behaviour will be required if risks are to be managed. Methods for predicting and monitoring that are being evaluated are:

- Measurement of rheology and incorporation of this into predictive beaching models
- Establishment of pilot-scale trial paddocks into which limited depositions can be conducted, beaching models calibrated, and comparisons made against the existing product.
- Maintenance of an area where full scale depositions can be conducted and behaviour verified prior to deposition on the advancing cone.

Options for minimising the effect of ore variations have been identified at this stage as entailing:

- Separate disposal of the majority of the oxide ores into available capacity at TSF1
- Further optimisation of units within the thickening circuit to improve the performance of cyclones and the thickener
- Increased monitoring and surveillance of tailings operations.

Conceptual planning is underway at the time of writing to evaluate the extent to which:

- It will be possible to develop the reclaim pond to accept “out of specification” high density tailings
- It will be feasible to convert the reclaim pond to a conventional facility. This is seen as a backup option that needs to be “on the shelf” in the event that the slurry behaviour becomes such that high density thickened discharge proves no longer possible.

6 CONCLUSIONS

Experience with high density thickened discharge using an advancing cone approach on TSF2 at Osborne has been sufficiently good for Osborne to commit fully to this method of operation and to implement measures that will further enhance the reliability of high density slurry generation. There have been quantum reductions in water losses and on capital expenditure on wall raisings as a result. In addition, there are significant benefits in terms of closure of TSF2 since the final geometry of TSF2 is that of a shedding mound with no ponding.

Potential extensions to the life of mine that entail the treatment of ores from satellite pits introduce a new challenge in respect of slurry deposition characteristics. This challenge will need to be met through a combination of prediction, monitoring and back-up plans which are currently under development and will no doubt form the topic of a future publication on experience with high density thickened tailings at Osborne.