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Our Ref: PSM71-107R
Date: 26 November 2010

The Manager
Oceana Gold (New Zealand) Ltd
PO Box 5442
Moray Place, Dunedin
NEW ZEALAND

ATTENTION: BERNIE O'LEARY

Dear Sir,

RE: ROUND HILL EAST & SOUTHERN PITS

We are pleased to submit our report on the predicted behaviour of the west wall and of the plant site as a result of mining the Round Hill East and Southern pits.

We trust this report is in keeping with your requirements but do not hesitate to contact us should you have any queries.

For and on behalf of
PELLS SULLIVAN MEYNINK

Rob

ROBERT BERTUZZI

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Oceana Gold (New Zealand) Ltd

ROUND HILL EAST
& SOUTHERN PITS

Report PSM71-107R November 2010

EXECUTIVE SUMMARY

This report presents the results of geotechnical studies assessing the likely movement of the west wall due to mining the proposed Southern and Round Hill East pits. The main conclusions and recommendations are summarised below.

- It is expected that movement along the FF will be reactivated with the mining of the Southern and Round Hill East pits.
- The proposed mining plans incorporate strategies based on analyses to limit the impact on the west wall such as mining south of approximately 15250 mN and maintaining a minimum 25m offset between the FF and the pits.
- Large displacements along the FF are still predicted to occur as a result of mining. Depending on the analysis, the expected displacements range:
    - from 0.5 to 2.5 m at the plant site
    - in the order of 10 m at the tailings dam embankment.
- If the restriction to mine south of the line at approximately 15250 mN was lifted, it is expected the plant site would see movement of similar magnitude to that at the tailings dam embankment, ie in the order of 10 m.
- Conversely, restricting the mine to a line further south than 15250 mN, would result in less movement at the mine site.
- The bulk of the movement occurs between the years 2015 and 2017. This expected movement will have to be managed to limit the effect on the plant site.
- The risk with Round Hill East is that the west wall movement goes from responding to mining to 'failing'. The recommended triggers are:
    - Generally 50 mm/day limited to 10 mm/day at the plant site
    - Doubling of the daily rate
    - Batter failures or floor heave noticeable during a mining shift
    - Distress within the plant site
    - Change in direction of displacement vectors of 20° or more.
- Monitoring and management of the data is key: the data needs to be plotted and reviewed daily.
- Should the behaviour of the west wall change, such that its failure is predicted, it will be necessary to modify the pit plan. This is likely to entail dividing the pit into either north-south and/or east-west sections; and/or increasing the offset so that the toe of the west wall is further from the FF.
- Slope designs for the Round Hill East pit are provided herein.

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FIGURES

APPENDICES

1. INTRODUCTION

This report presents the results of geotechnical studies carried out by Pells Sullivan Meynink (PSM) of the predicted movement of the west wall due to mining the proposed Southern and Round Hill East pits. The likely impact on the Macraes' Gold Mine's plant site and the soon-to-be disused tailings dam are the key reasons why understanding the predicted movement of the west wall is important.

PSM has carried out a series of studies over the past few months at the request of OceanaGold (for example, Reference 1) to provide the following.

- *Provide guidelines to the magnitude of movement expected as a result of mining the proposed Southern and Round Hill East pits*
- *Address the implications of movement to the plant site but not the tailings dam*
- *Recommendations to reduce the effect on the plant site caused by mining*
- *Measures to be adopted while mining*
- *Assess the stability of the proposed west wall*
- *Provide appropriate pit slope angles.*

This report is structured as a stand-alone report though much of its content has been previously presented in letters and memoranda.

A brief summary of the west wall movement is presented in Sections 2 to 3 before discussing the expected movements caused by mining the Southern and Round Hill East pits in Sections 4 to 0. Pit slope angles are provided in Section 12.

2. BACKGROUND

2.1. Geological Setting

The Macraes Flat area is within the extensively deformed Otago-Haast Schist Belt (Figure 1). The structural geology of the area is dominated by two main orthogonal fault sets, striking to the north and east (1). The Hyde-Macraes Shear Zone (the Shear Zone) is one of the north striking structures with a strike length of at least 25km and is the main ore bearing structure. The Shear Zone dips at about 15 to 20° to the east and is approximately 100m thick being defined by the relatively continuous Hanging Wall Shear (HWS) and Footwall Fault (FF), see Figure 2.

The Shear Zone is largely formed within deformed pelitic schist so that at Macraes Flat the HWS and FF also approximate lithological boundaries. Tectonic displacement of the Shear Zone has been inferred to be hundreds of metres. The strain associated with this displacement was probably concentrated within the intra-shear pelite which could absorb strain more readily than the coarsely grained psammite.

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(1) All directions quoted are relative to Macraes' mine grid, which is 45° west of true north and approximately 67½° west of magnetic north.

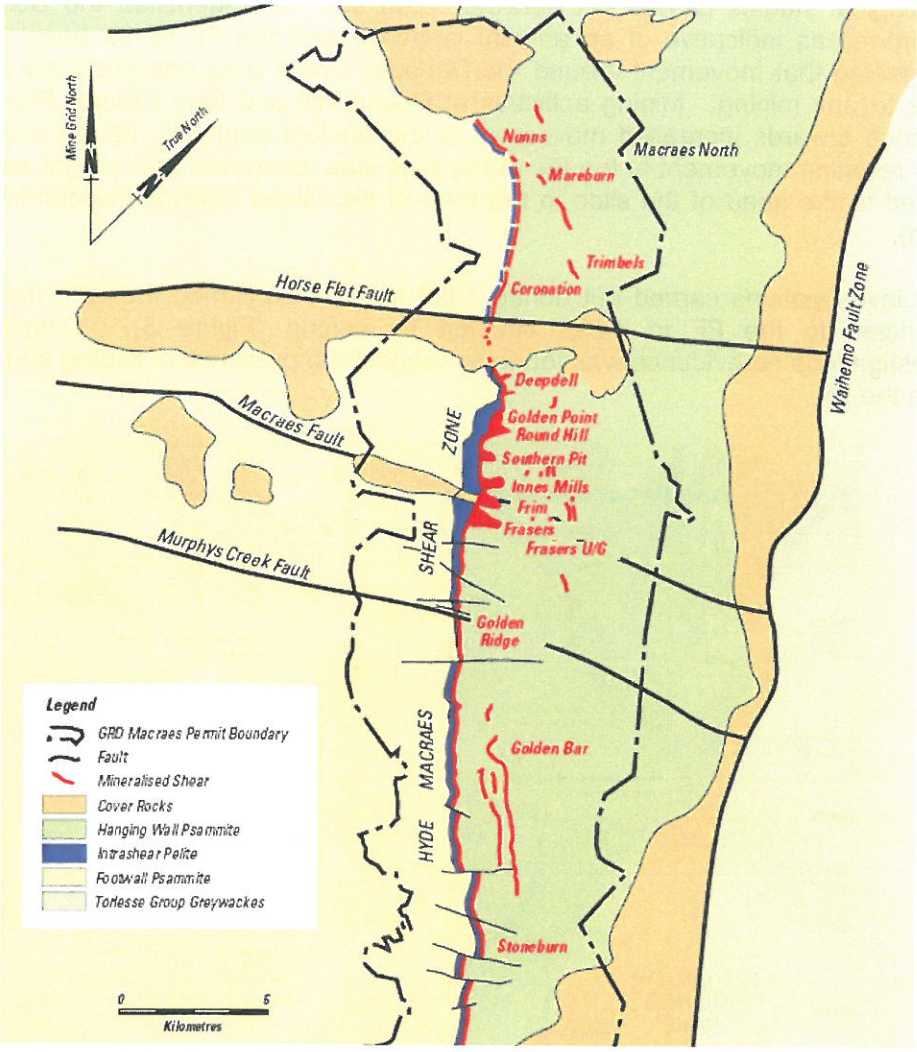

Figure 1: Plan layout of the Macraes' Mine showing the various pits and deposits

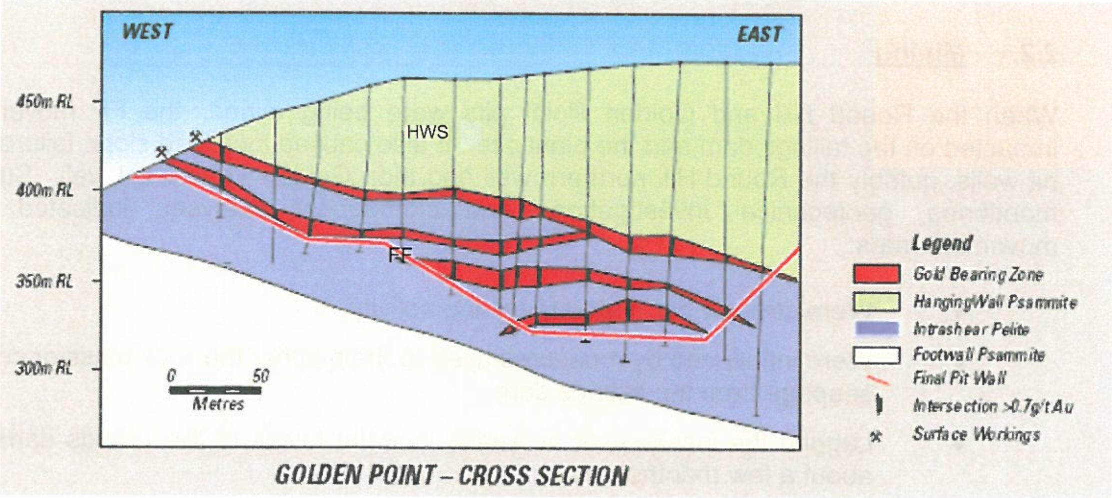

Figure 2: Typical cross section through the Golden Point pit

Geological studies carried out between 1996 and 1999 identified the Deepdell Creek landforms as indicative of an ancient landslide with the FF as its basal plane. This suggested that movement around the Deepdell Creek area had occurred along the FF prior to any mining. Mining activities at Round Hill and then Golden Point tipped the balance towards increased movement of the ancient landslide, as the rock mass that was resisting movement at the toe of the slide was excavated and weight and water was added to the head of the slide in the form of the Mixed Tailings Impoundment (tailings dam).

The investigations carried out during 1996 to 1999 confirmed the land movement was restricted to the FF in areas affected by mining (Figure 3). Despite extensive investigations no evidence was found to suggest the presence of sliding surfaces deeper than the FF.

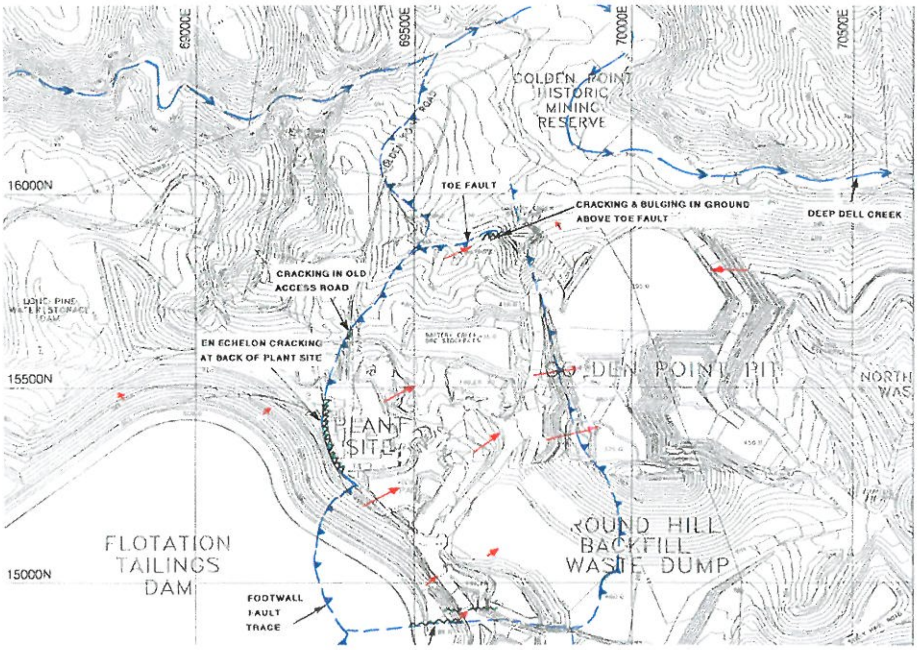

Figure 3: Plan of movement area as it was in 1999

2.2. Mining

When the Round Hill and Golden Point pits were being mined, the FF movement impacted on the tailings dam and the plant site. It also caused localised slope failures on pit walls, notably the Round Hill northern wall and then Golden Point west wall. Survey monitoring, geotechnical investigations and subsequent analyses indicated that movement rates:

- Were strongly correlated to mining activity
- Were influenced by measures used to drain either the rock mass or collect seepage from the tailings dam
- Lagged the increase or decrease in water levels in the tailings dams by about a few months
- Responded to peak rainfall events.

Mining the Round Hill and Golden Point pits was scheduled so that movement rates were maintained initially to less than 2 mm/day and then to less than 10 mm/day. Both pits were successfully mined to completion. In addition, Round Hill West and Round Hill Extension pits were also mined using similar monitoring and a start-stop approach.

Dewatering or, to be technically correct, depressurisation was also part of the approach and horizontal drains and pump wells were installed through the FF. Pump wells continue to intercept water seepage entering the FF from the tailings dam.

The FF movement is currently monitored in the Frasers pit with a network of prisms. As at November 2010 movement is in the order of 2 mm/day in the northern part of Frasers. The trigger movement rate is 50 mm/day adjacent to the active mining area in the southern part of Frasers, though occasionally the rates have reached 100 mm/day and more in localised areas. The impact of the movement is noticed in several ways.

- Cracking along the ground surface above the west wall
- Floor heave (see Photo 1)
- The loss of inclinometers and depressurisation holes (due to shearing)
- Batter failures along the west wall
- Block dislocation and movement along the northern wall (as it is being shunted by the west wall)
- Rehabilitation of the initial few hundred metres of the decline to the underground mine
- The series of bumps along the public Macraes Flat – Dunback Road.

The last three impacts have quietened over the 2010 calendar year as mining concentrates in the Frasers 4C pit which is 200 to 500 m south of the northern wall, the decline and the public road.

It is expected that movement along the FF in the area of the tailings dam and plant site will be reactivated with mining the Southern and Round Hill East pits.

Photo 1: Example of floor heave occurring in the floor of the Frasers pit

2.3. Chronology

2.3.1. Round Hill

Movement of the west wall of Round Hill pit was first observed in late 1995, four years after mining first started. An extensive monitoring programme was implemented:

- To gain an understanding of the behaviour of the movement
- To use as a decision tool to stop / start mining to control the movement rates.

Round Hill pit was completed to design depth of 290 mRL through a combination of stop/start mining and depressurising the slide mass. At this point the minimum perpendicular offset to the FF was approximately 20 m, although it should be noted that the Round Hill pit was essentially a tight cone, unlike the long strip of Golden Pit or the Frasers' pits. The depressurisation included closely spaced, 200 m and longer horizontal drains. Mining would commence when movement rates were below 0.6 mm/day continuing until rates exceeded 1.5 mm/day. When this value was reached all mining activity in the Round Hill pit would cease, until the rates again slowed to less than 0.6mm/day when the next mining cycle would start. The highest deformation rate that was recorded when mining Round Hill was therefore kept to 2 mm/day.

Mining of the Round Hill pit was completed in June 1998 to design depth of 290 mRL. Backfilling of the pit commenced in July 1998. Movement rates on the FF slide surface slowed in the latter half of 1998, and by the beginning of 1999 had effectively stopped; that is they had reduced to a background rate of approximately 1 mm/week (Figure 4).

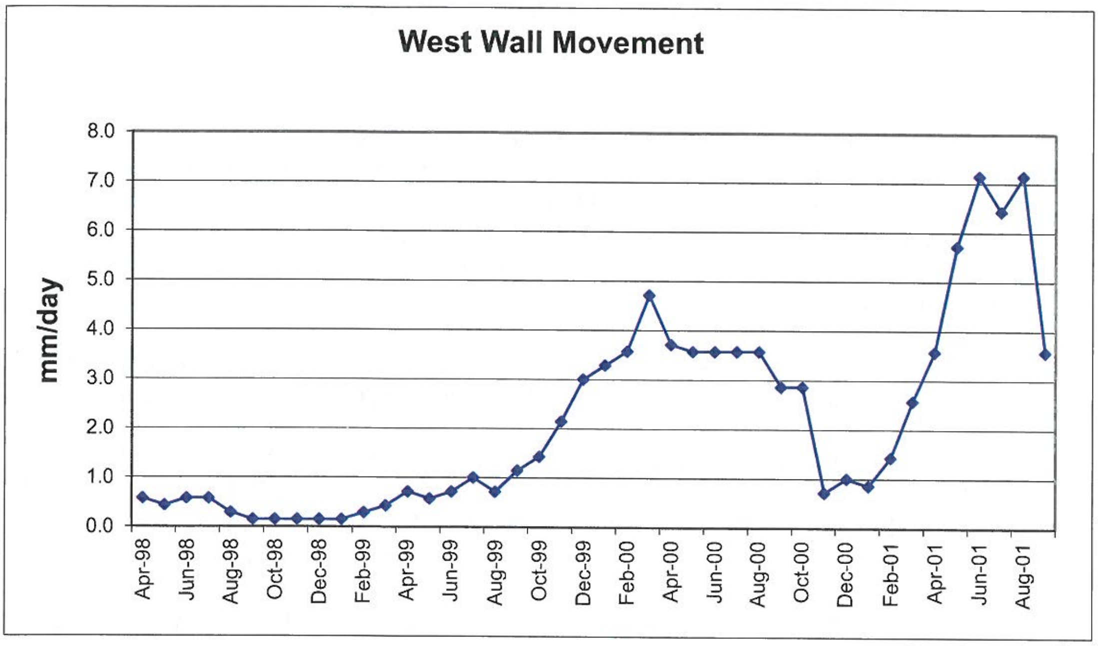

Figure 4: Movement rates during mining Round Hill and initial stages of Golden Point

2.3.2. Golden Point

Movement rates began to increase in February 1999 when mining started in Golden Point and by the end of 1999 had reached approximately 3.5 mm/day (Figure 4). At that time Golden Point stage 1 had been mined to 380 mRL, stage 2 to 400 mRL and stage 3 to 438 mRL. Mining of Golden Point stage 1 was completed (to 370 mRL) in March 2000 and Golden Point stage 2 (to 325 mRL) in October 2000. During this time, it became clear that the west wall movement was not only related to the volume mined but to the mining depth. Rates were approximately 3 to 4 mm/day (Figure 4).

In March 2000, internationally recognised geotechnical and mining experts gathered on site to review the west wall dynamics. Options to isolate the plant site and tailings dam from the mining activities were canvassed but were not economic. It was concluded to manage the slide and mitigate the stability issues with the following.

- Depressurisation – dewatering wells and horizontal drains
- Unloading the crest of the sliding mass by removing low grade ore stockpiles, which were kept close to the processing plant
- Planning to intermittently mine the pits
- Keeping "liquefiable tailings" away from the tailings dam eastern abutment

- Maintaining the vigilant monitoring of a network inclinometers and prisms
- Triggers to immediately cease mining of:
    - A maximum movement rate of 20 mm/day
    - Any doubling of rate
    - A change in direction by more than 20°
    - Cracking in the plant site.

Mining recommenced in Golden Point stage 3 in October 2000 when waste material was used to backfill stage 2. Depressurisation holes were installed along the pit west wall. Most of these holes were declined. Dewatering pumps were maintained in bores on the tailings dam embankment along the FF subcrop. By December 2000, movement rates had reduced to 5 mm/week (Figure 4). Approximately 1 Mm^3 of backfill had been placed in Golden Point stage 2.

As mining progressed in Golden Point stage 3 during 2001, the west wall movement began to increase and by July 2001 when the stage 3 pit had reached a depth of 355mRL, the rates had reached 8 mm/day (Figure 4). Further mining stages were then introduced. The stage 3 pit was divided into a northern (GP3N) and a southern (GP3S) area. GP3N was mined first (to 335 mRL) and then when GP3S was mined its waste was used to backfill GP3N. A target range of 6 to 10 mm/day was adopted to stop / start mining; 10mm/day representing half of the trigger point of 20 mm/day.

The empirical relationship derived in March 2000 proved to be a very good predictor of movement for approximately two years until Golden Point stage 3 was nearing completion, from when it over-predicted displacements. At the time it was thought that the relationship failed to adequately capture the fact that stage 3 mining had initially occurred in the upper benches; benches effectively in the shadow of the previously mined stage 1 and stage 2 pits.

Stop/start mining continued in Golden Point until the pit was completed to a depth of 325mRL at the end of June 2002. The minimum perpendicular offset to the FF at this point was approximately 50 m. Movement rates were maintained in the target range.

The pit was backfilled to 360 – 380 mRL to provide a demonstrated minimum Factor of Safety (FoS) of 1.2 to meet the consent conditions for long term stability of pit walls. It was predicted that movement rates would effectively stop sometime before January 2003. In practice, the movement stopped in October/November 2002 (see Figure 5 and Figure 6).

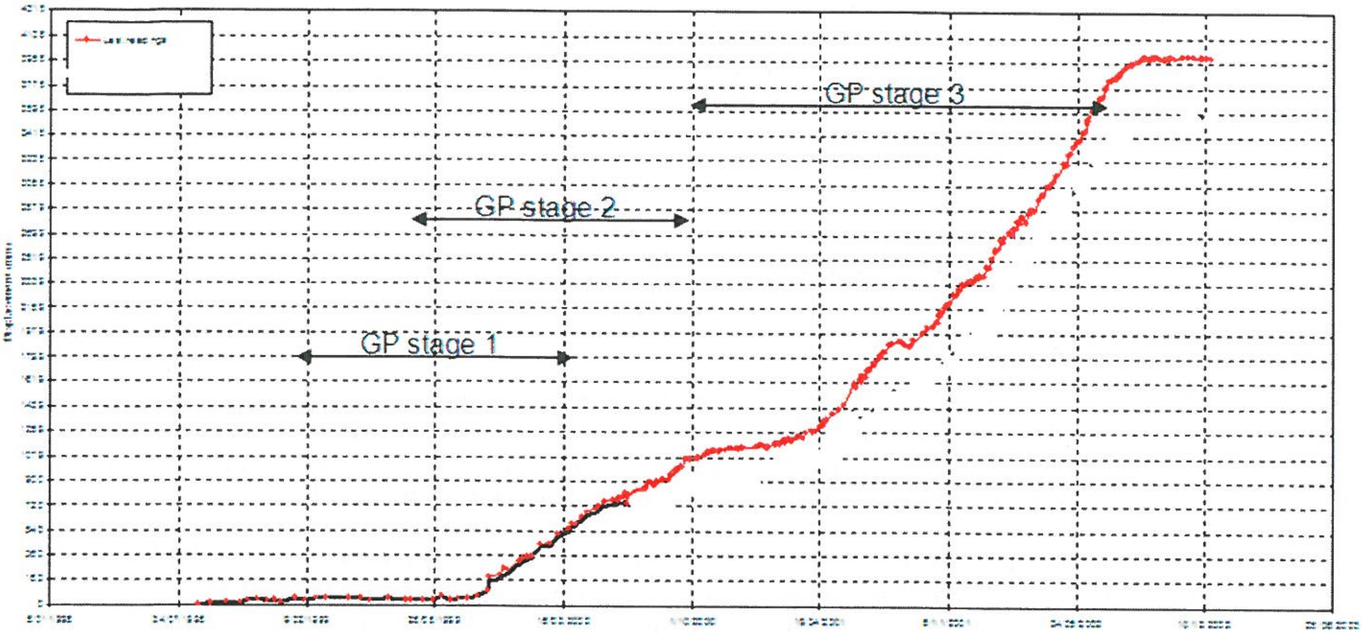

Figure 5: Displacement recorded on the tailings dam's prisms between April 1998 and January 2003 during mining of Golden Point pit (GP). Movement rates effectively stopped in October / November 2002

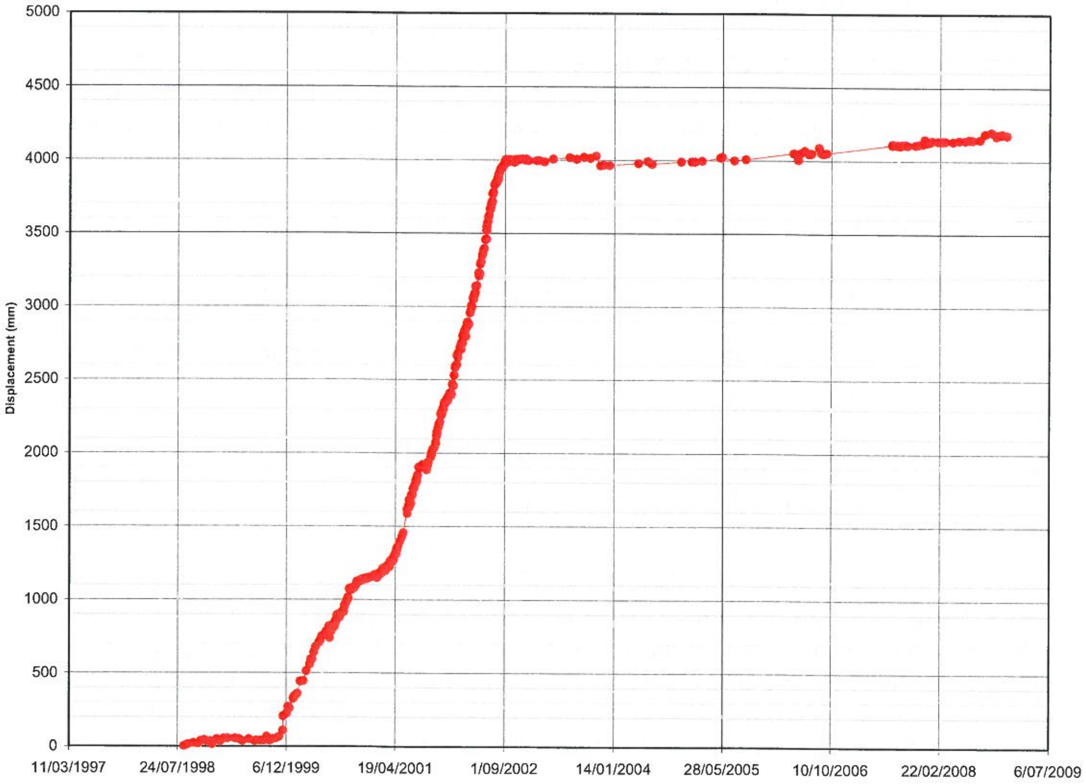

Figure 6: Displacement recorded on the tailings dam's prisms between April 1998 and March 2009. In the 6.5 years from October 2002, the prisms have moved approximately 170 mm, a rate of 0.5 mm/week

2.3.3. NW & RH Extension

During 2001 and 2002 two small pits were excavated to the west of Round Hill and Golden Point; the North West and the Round Hill Extension pits. Both pits mined the oxide ore down to approximately 50 m depth at which point their base was 10 to 15 m above the FF.

3. MODEL OF THE SLIDE

3.1. Parameters

The geometry of the Round Hill and Golden Point west wall was very well understood. The network of survey prisms defined the area of the sliding west wall. The prisms were surveyed regularly, most daily, so that any change in the boundaries of the slide was evident. Inclinometers clearly defined the base of the slide to be the FF.

The groundwater levels were typically well understood. An extensive and intensive network of horizontal drain holes, vertical pump wells and piezometers that had been installed since 1996 provided a good database to assess the groundwater levels.

The rock mass strengths were reasonably understood. The several metres of movement along the FF during mining, not to mention the hundreds of metres over geological time, meant that the FF is at residual shear strength. Hence, the dozen or so ring shear test results available are likely to represent the strength very well. In contrast, the strength of the rock mass at the toe of the west wall has always been the least understood. Estimates of the strength were based on classification of the rock mass, laboratory testing of intact rock samples and shear testing of selected fault surfaces, and back-analyses of failures. The modelling results based on these parameters typically were consistent with the observed movement.

3.2. Summary

The main sliding surface for the west wall was at the top of the FF and is due to:

- Its low residual field strength ($c'=0$ $\phi'=9°$) compared to its dip, ($\alpha=15\text{-}20°$)
- Groundwater pressure
- The weight of the rock mass on the FF
- Mining of the rock mass down dip.

Although a large number of relatively small blocks do occur above the FF, as defined by minor faults and shears, the rock mass essentially moved as a whole block, i.e. with relatively little internal deformation. This was interpreted to be largely due to the relative planarity of the FF. No one particular structure acted as a release surface to the east of the sliding block. Movement occurred in a quite complicated fashion involving movement on both easterly dipping faults and the westerly dipping ramp shears (see Figure 7).

The recorded movement has been in the direction towards the actively mined pit. In the area of the ancient landslide near Deepdell Creek, a component of movement remains down along the dip of the FF (see figures in Appendix E).

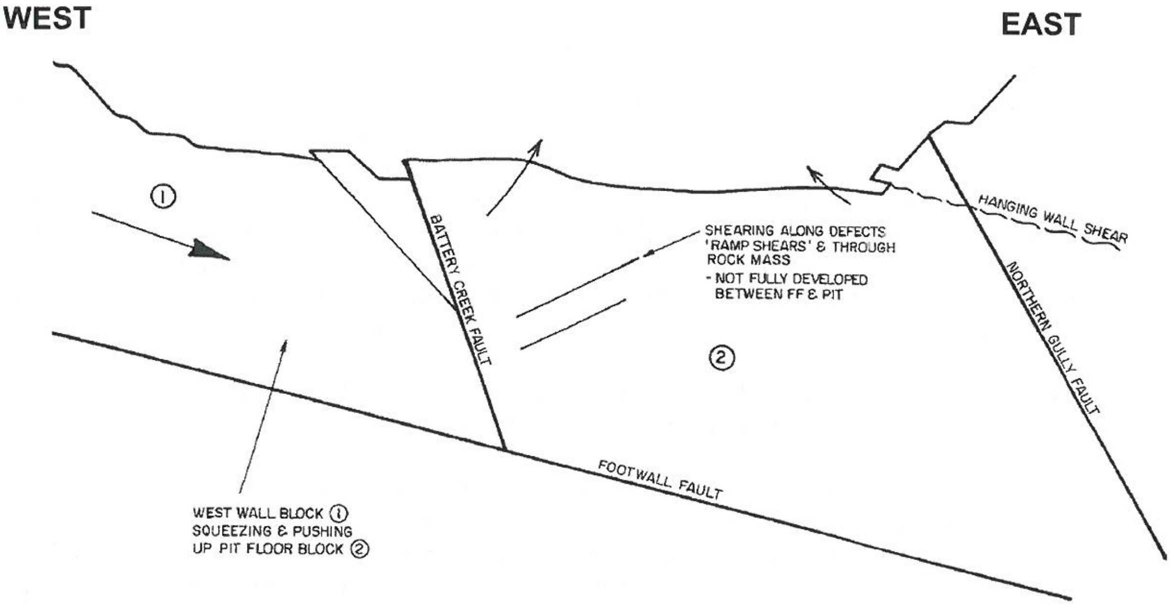

Figure 7: Schematic east-west cross-section of the failure mechanism at the base of the Golden Point pit

4. METHODS

The following methods were used to predict the movement of the west wall due to mining the proposed Southern and Round Hill East pits.

- Empirical – correlation of past survey data with mining rates
- Comparison with Frasers pit
- Earth Pressure – treating the west wall analogous to a retaining wall
- Numerical
    - Two dimensional (2D) finite element method using the program *Phase*^{2}
    - Three dimensional (3D) finite difference method using the program *FLAC3D*
    - 3D finite element method using the program *Abaqus*.

As each of the above methods relies on a simplified model of the problem, no one method yields the "correct answer". The results from each of the methods are used to improve the understanding of the rock mass behaviour and to educate engineering judgement to form a solution.

The following sections describe each of the methods used.

5. EMPIRICAL

The monitoring data during the period of mining the Round Hill and Golden Point pits was re-assessed as part of these studies. Such relationships were developed at the time the pits were mined and led to the mining approach detailed in Section 2. Appendix E reproduces plans that show the movement vectors at key points during Round Hill mining. Figure 8 to Figure 10 present graphs showing the relationships between average weekly movement rates and the volumes mined. It can be seen that substantial volumes were mined in the Round Hill and Golden Point pits before movement of the west wall was noticed. Further, the graphs show that relatively small mining volumes towards the end of mining in the pits caused the largest increases in movements.

Overall movement recorded was approximately 5m at rates up to 40-90 mm/week, although it must be noted that the rates were used as a control for stop/start mining.

It is apparent that the west wall movement is dependent upon the proximity of the material mined to the FF. This can be readily seen in Appendix A which presents four east-west cross sections at 14950, 15150, 15500 and 15700 mN showing the HWS and FF together with the pre-mining topography, “current pit”, backfill and the potential future pits.

Figure 11 shows the level above which mining is not expected to adversely impact on the west wall movement based on the empirical data from Round Hill / Golden Point. Broadly, the data shows that mining above 390 – 400 mRL did not increase movement. Movement rates began to increase as mining advanced between 390 – 400 mRL and 350mRL. The current experience at Frasers is similar; movement increased when mining went below approximately 415-400 mRL (Reference 2).

The mining level suggested in Figure 11 is approximately 350 mRL. Below this movement rates increased significantly with ongoing mining.

In addition, mining of the proposed pit south of approximately 15250 mN is not expected to adversely impact on the plant site (Figure 12). This line at approximately 15250mN (2) is based on the observed behaviour of the plant site whilst mining Round Hill and then when mining developed north into Golden Point. The recent performance of the Frasers pit has also educated this line. The comparison between the two mining areas is discussed further in Section 6.

While east-west trending faults do occur throughout the HMSZ, such as those indicated in Figure 1, no continuous east-west fault was mapped at the time of mining Round Hill and Golden Point that passed through or adjacent to the plant site. Figure 3 shows the large scale structures identified at that time.

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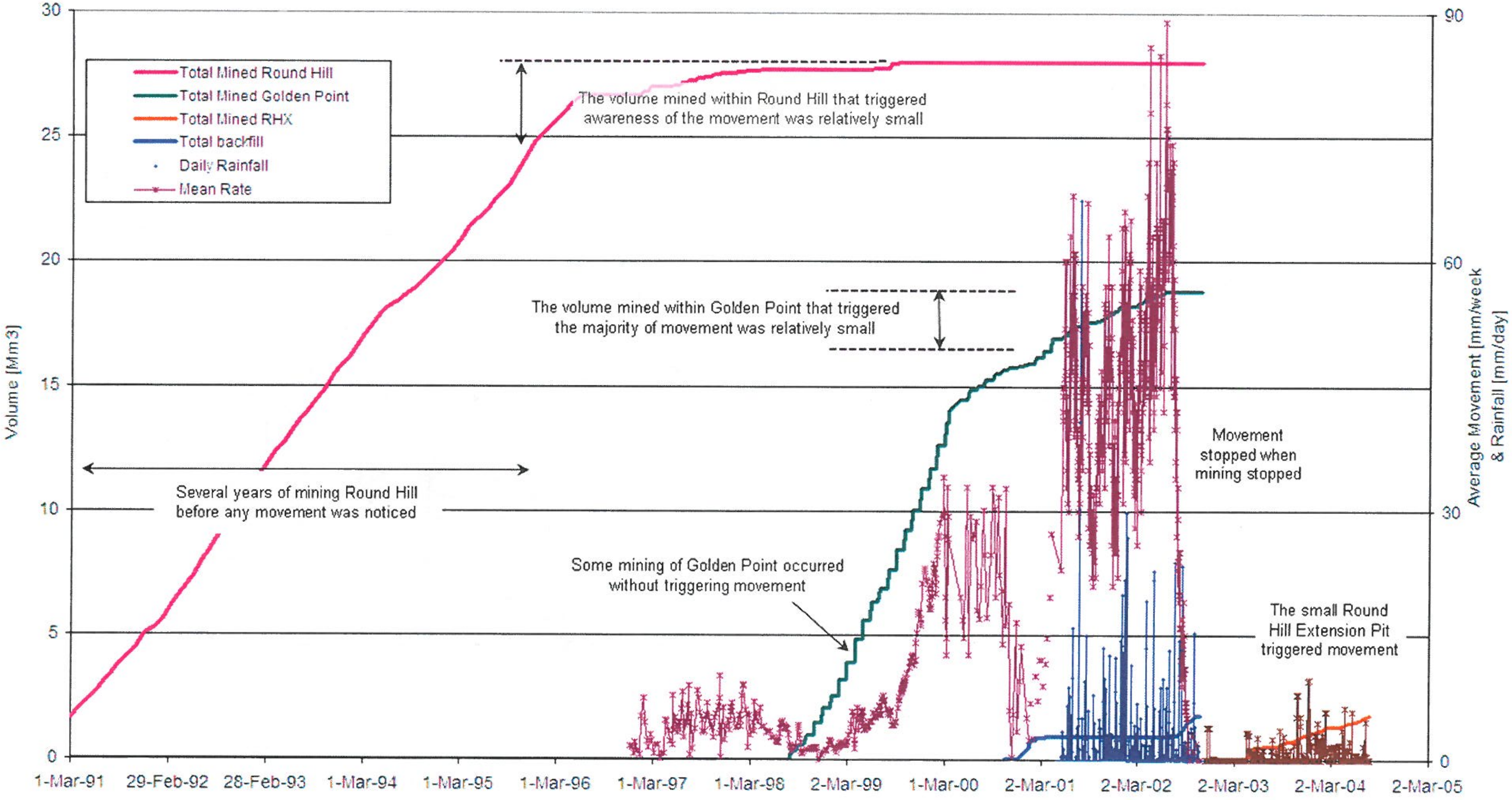
(2) the line passes approximately through the points [69500mE, 15250mN] and [70000mE, 15450mN]



The volume mined within Round Hill that triggered awareness of the movement was relatively small

The volume mined within Golden Point that triggered the majority of movement was relatively small

Several years of mining Round Hill before any movement was noticed

Some mining of Golden Point occurred without triggering movement

Movement stopped when mining stopped

The small Round Hill Extension Pit triggered movement

Figure 8: Summary of available mining and monitoring data in relation to the movement of the plant site. Key points are noted on the figure

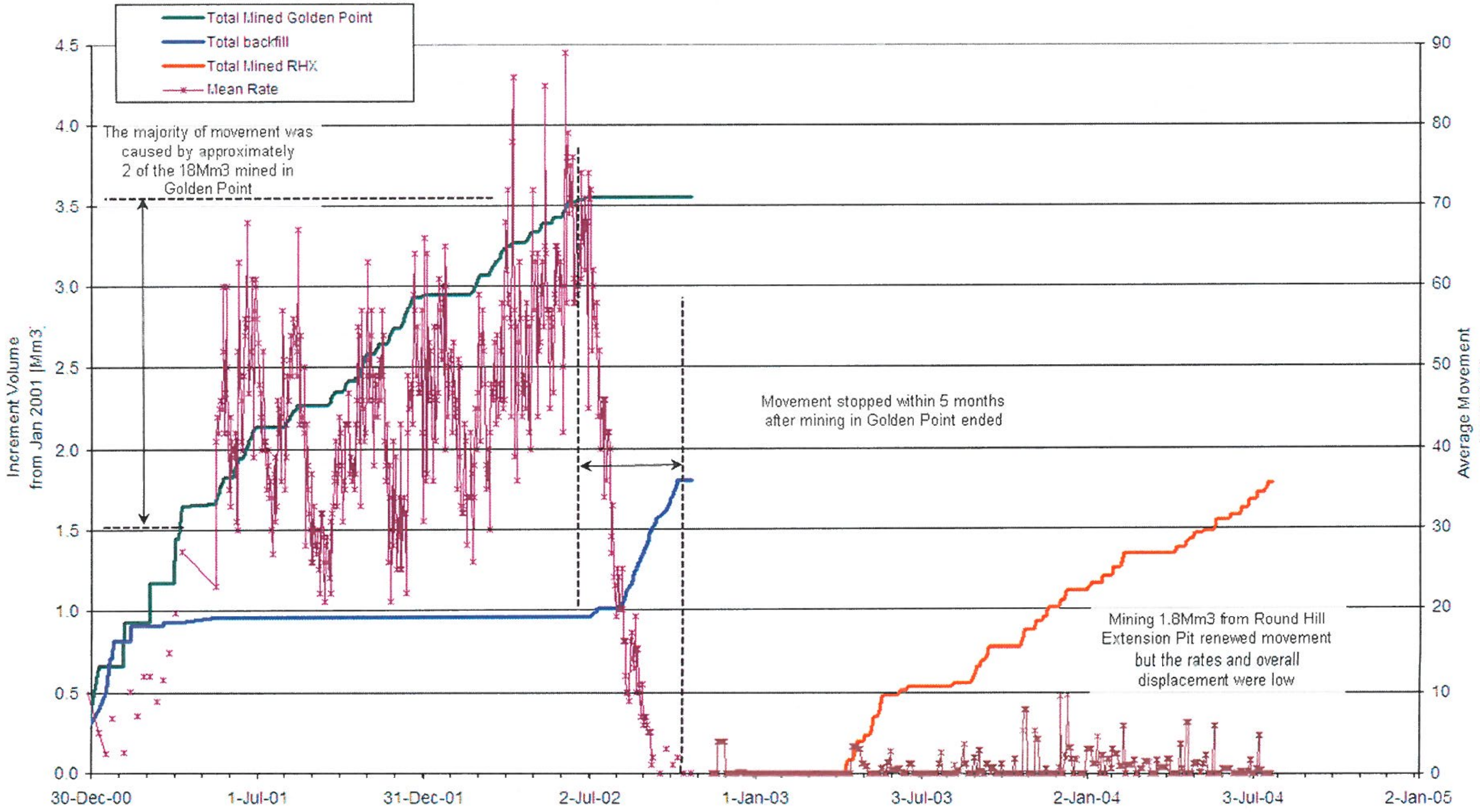
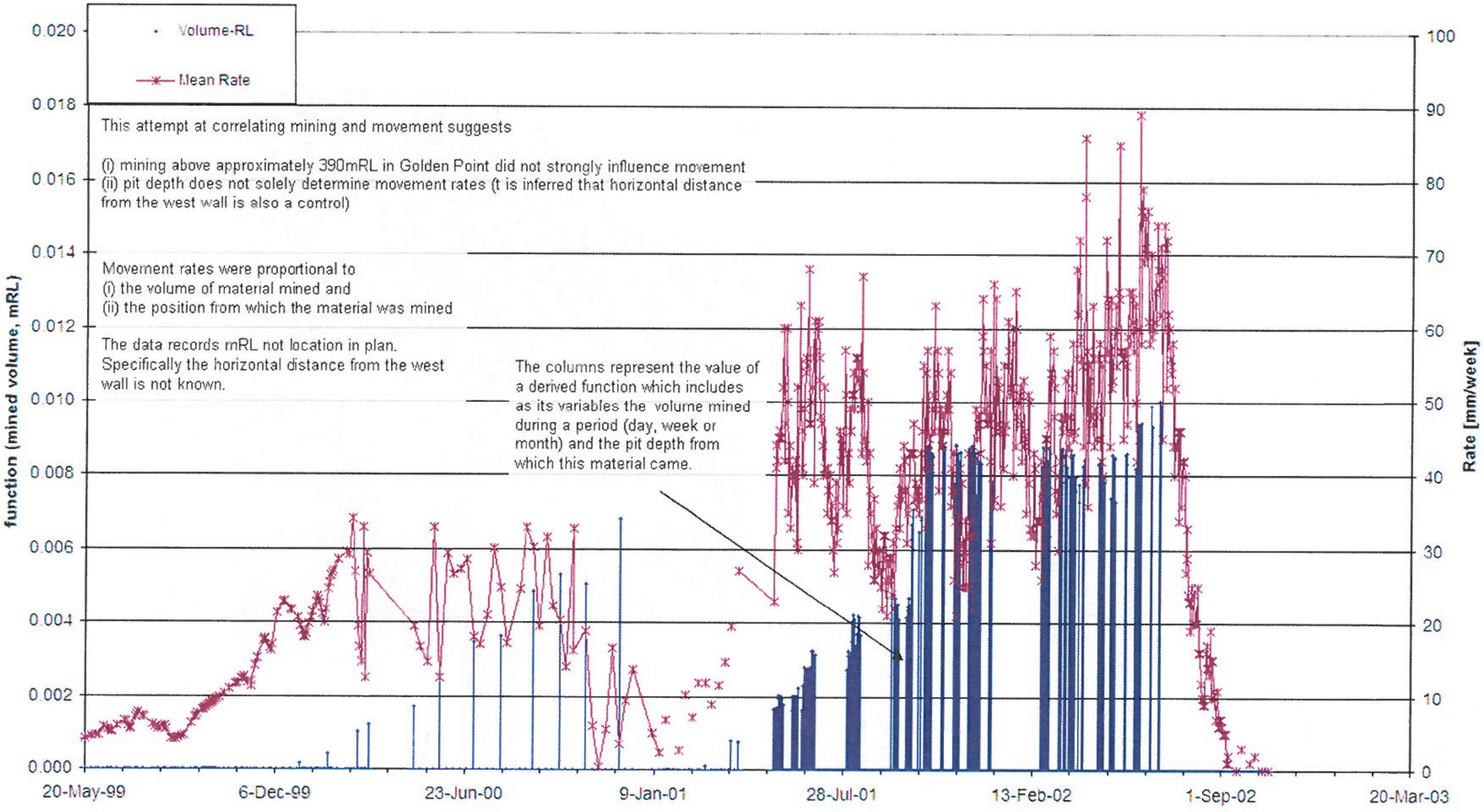


Figure 9: Summary of Golden Point mining and monitoring data in relation to the movement of the plant site. Key points are noted on the figure



This attempt at correlating mining and movement suggests

(i) mining above approximately 390mRL in Golden Point did not strongly influence movement
(ii) pit depth does not solely determine movement rates (t is inferred that horizontal distance from the west wall is also a control)

Movement rates were proportional to
(i) the volume of material mined and
(ii) the position from which the material was mined

The data records mRL not location in plan. Specifically the horizontal distance from the west wall is not known.

The columns represent the value of a derived function which includes as its variables the volume mined during a period (day, week or month) and the pit depth from which this material came.

Figure 10: Correlation between movement rates and a function of the volume mined and the depth of mining. Key points are noted on the figure

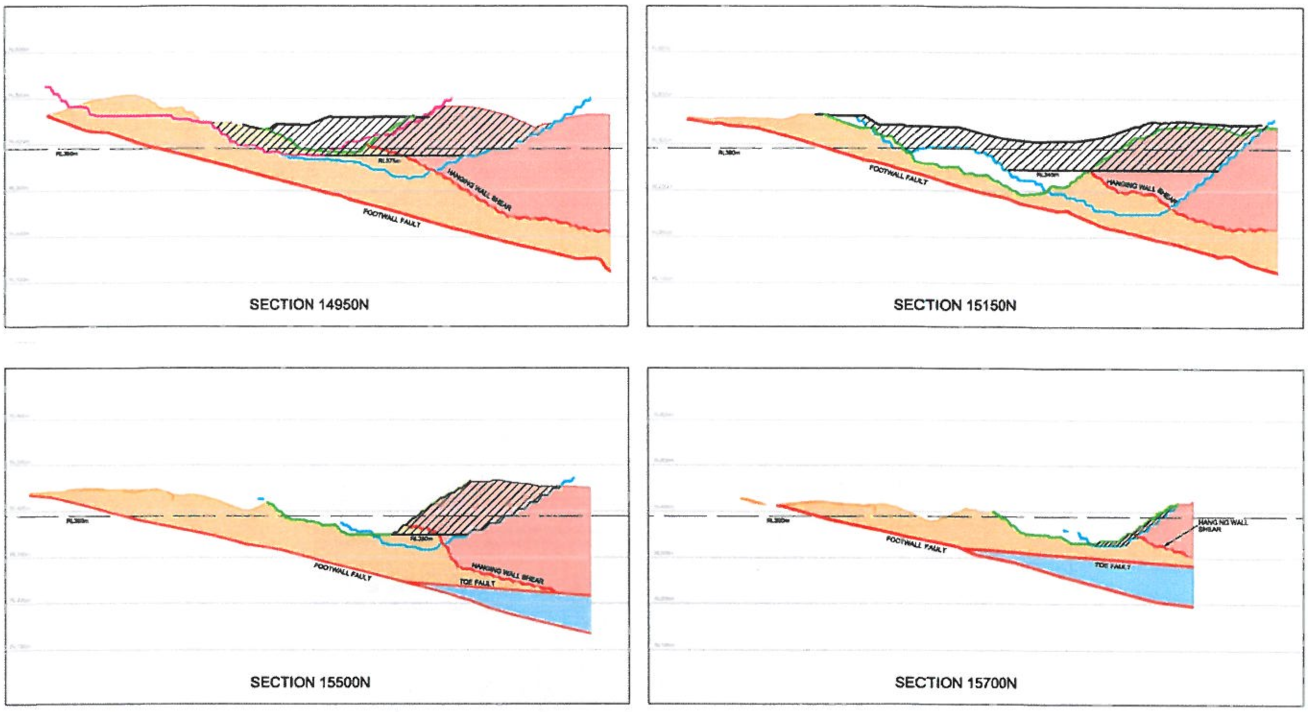


Figure 11: Conceptual level(s) above which mining the proposed Southern and Round Hill East pits should not adversely impact on the west wall movements (shaded areas in the above figure). Overall this level is approximately 350 mRL.

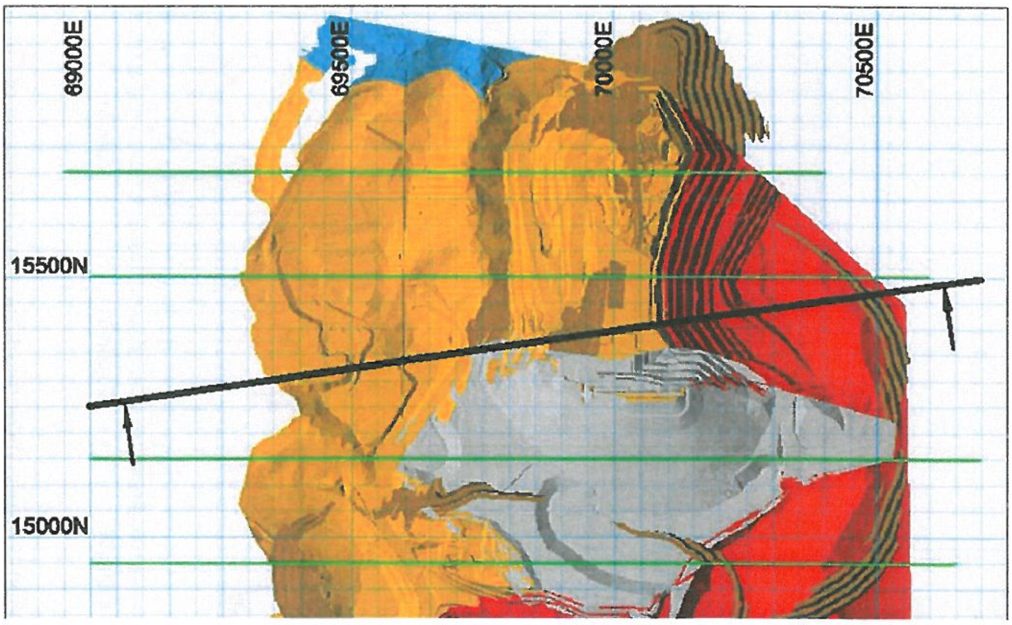


Figure 12: Conceptual boundary south of which mining the proposed Southern and Round Hill East pits should not adversely impact on the plant site

6. COMPARISON WITH FRASERS

The proposed mining of Southern and Round Hill pits is similar to that at Frasers, particularly noting the relative positions between:

- the plant site and the proposed Southern and Round Hill pits and
- the site offices at Frasers.

Figure 13 summarises the recorded movement that has occurred along the west wall of the Frasers pit since January 2010. It is clear that the bulk of the movement has occurred over a 400 m length of wall, approximately between 12000 and 12400 mN. This is adjacent to the actively mined area of the pit, which is called Frasers 4C.

It is also clear from Figure 13 that the movement of the west wall quickly diminishes to the north of the actively mined pit, such that within 200 m of the active pit, displacements are approximately a tenth. The fuel farm which is approximately 100 m north of the active pit site has seen approximately 0.5 m of movement and the offices which are 200 to 400 m north of the active pit have seen only 5 mm movement over the past two years.

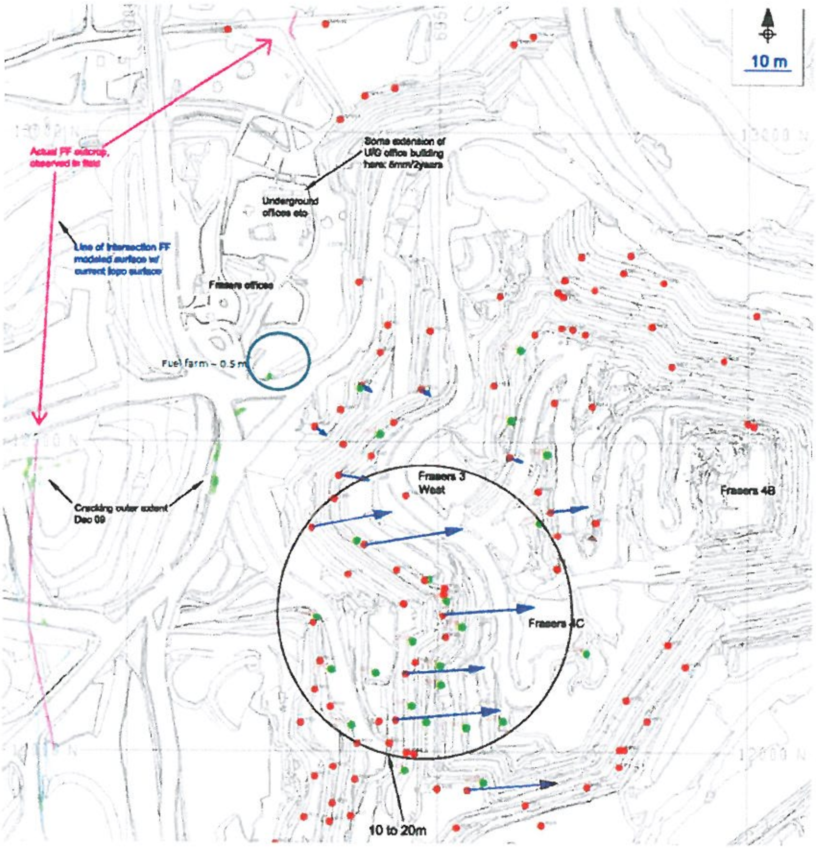


Figure 13: Location of the Frasers pit and site offices. The movement vectors recorded since January 2010 show the bulk of movement – the maximum being approximately 10 to 20 m – has occurred directly adjacent to the mining area. Immediately north of the mining area, the vectors show approximately a tenth of this movement. All vectors are towards the active mining area.

The similarity with the proposed Southern and Round Hill pits can be seen in Figure 14. By inspection, the bulk of the movement initiated by mining is expected to occur along the west wall between 14500 and 15250 mN.

It is expected that movements will quickly diminish moving to the north of the active mining area. Based on the experience at Frasers, the movements at the plant site, which is 50 to 300 m north of the mining area, could potentially be as low as 10% of the main movements.

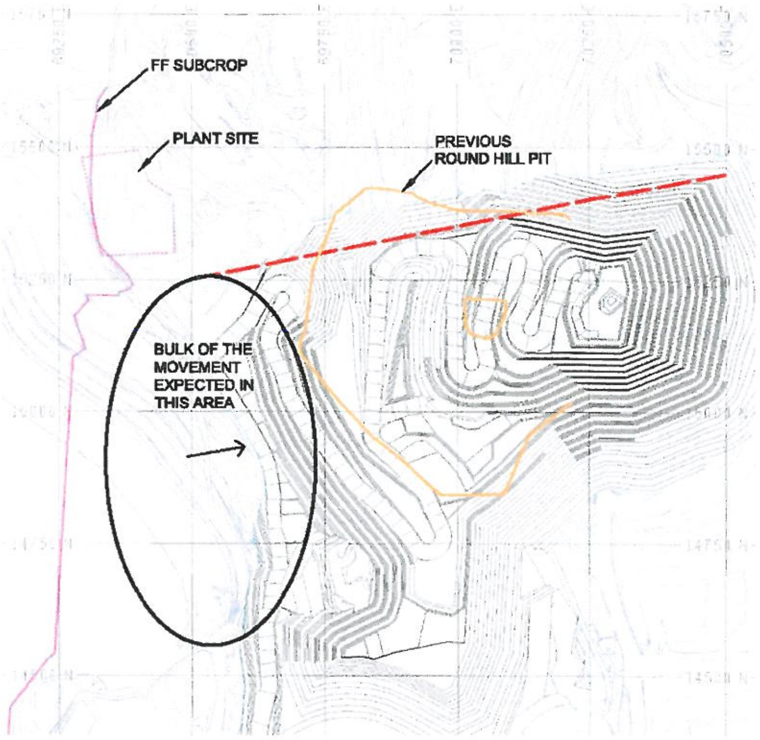
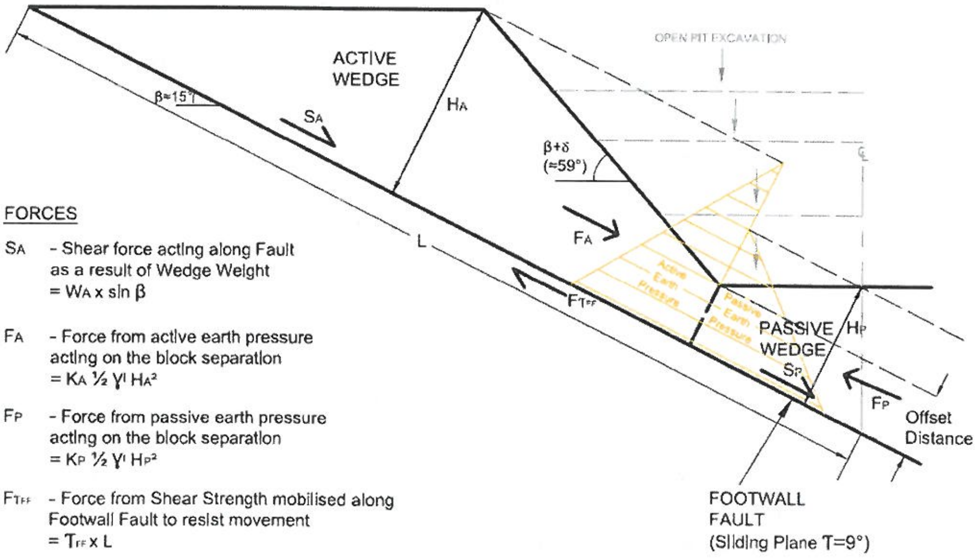


Figure 14: Location of the proposed Southern and Round Hill pits relative to the plant site. The crest of the previous Round Hill pit is shown.

7. EARTH PRESSURE

7.1. Model

The analogy of a retaining wall is used to develop a simple model of the west wall. Figure 15 illustrates this model schematically.



FORCES

S_A - Shear force acting along Fault as a result of Wedge Weight $= W_A \times \sin\beta$

F_A - Force from active earth pressure acting on the block separation $= K_A\ \frac{1}{2}\ \gamma'\ H_A^2$

F_P - Force from passive earth pressure acting on the block separation $= K_P\ \frac{1}{2}\ \gamma'\ H_P^2$

F_{TFF} - Force from Shear Strength mobilised along Footwall Fault to resist movement $= T_{FF} \times L$

Figure 15: Retaining wall model of the west wall

The west wall moves when the active earth pressure is greater than the passive earth pressure generated at the toe of the open pit. The movement of the "virtual retaining wall" is along the base of the wall; that is along the FF (Figure 16).

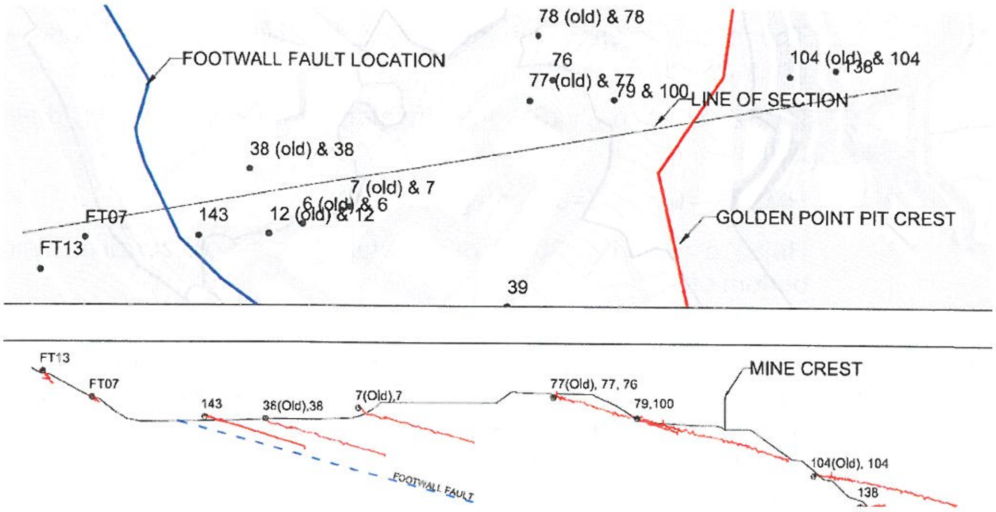


Figure 16: The clear trend of total prism movement, which is shown by the red vectors, is as a block parallel to the FF

As the pit is excavated, the passive wedge reduces in size, tipping the balance in favour of the active wedge which results in its movement. The active wedge continues to move until sufficient material is transferred from the active to the passive wedge at the base of the pit to reach equilibrium again and movement ceases.

The pressure coefficients (K_a *and* K_p) can account for the slope of the wall and the slope of the crest as shown in the following equations.

Active force on the wall = $F_a = \frac{1}{2} K_a \gamma H_A^2$

Passive force on the wall = $F_p = \frac{1}{2} K_p \gamma H_P^2$

Where

$$K_a = \frac{\sin^2(\phi^* - \alpha)}{\sin^2(\alpha)\sin(\alpha + \delta)\left(1 + \sqrt{\dfrac{\sin(\phi^* + \delta)\sin(\phi^* - \beta)}{\sin(\alpha + \delta_w^*)\sin(\alpha - \beta)}}\right)^2}$$

$$K_a = \frac{\sin^2(\phi^* - \alpha)}{\sin^2(\alpha)\sin(\alpha + \delta)\left(1 + \sqrt{\dfrac{\sin(\phi^* + \delta)\sin(\phi^* - \beta)}{\sin(\alpha + \delta_w^*)\sin(\alpha - \beta)}}\right)^2}$$

ϕ^* = shear strength of wall material
δ_w^* = side wall – soil friction angle
α = slope of wall from horizontal
β = slope of crest from horizontal
γ = unit weight of soil behind wall
H_A *and* H_P = height of soil behind and in front of wall, respectively

7.2. Analysis

The following four load cases were considered.

1. The shear strength of the HMSZ is defined as c'=0 and ϕ'=45°, no groundwater
1. HMSZ c'=0 and ϕ'=45°, groundwater at 5m below surface, draining to the bottom of the pit
2. HMSZ c'=0 and ϕ'=30°, no groundwater
3. HMSZ c'=0 and ϕ'=30°, groundwater at 5m below surface, draining to the bottom of the pit

The results are presented in Appendix B and summarised in Figure 17 as FoS and imbalanced force versus excavation depth. The results shows that there is a force imbalance (FoS<1) once the fault offset, ie the perpendicular distance from the FF, is less than approximately 25 to 50 m, depending on assumptions in relation to material strength and groundwater pressures.

The observed behaviour at the Frasers pit suggests that the appropriate offset distance is 25 m.

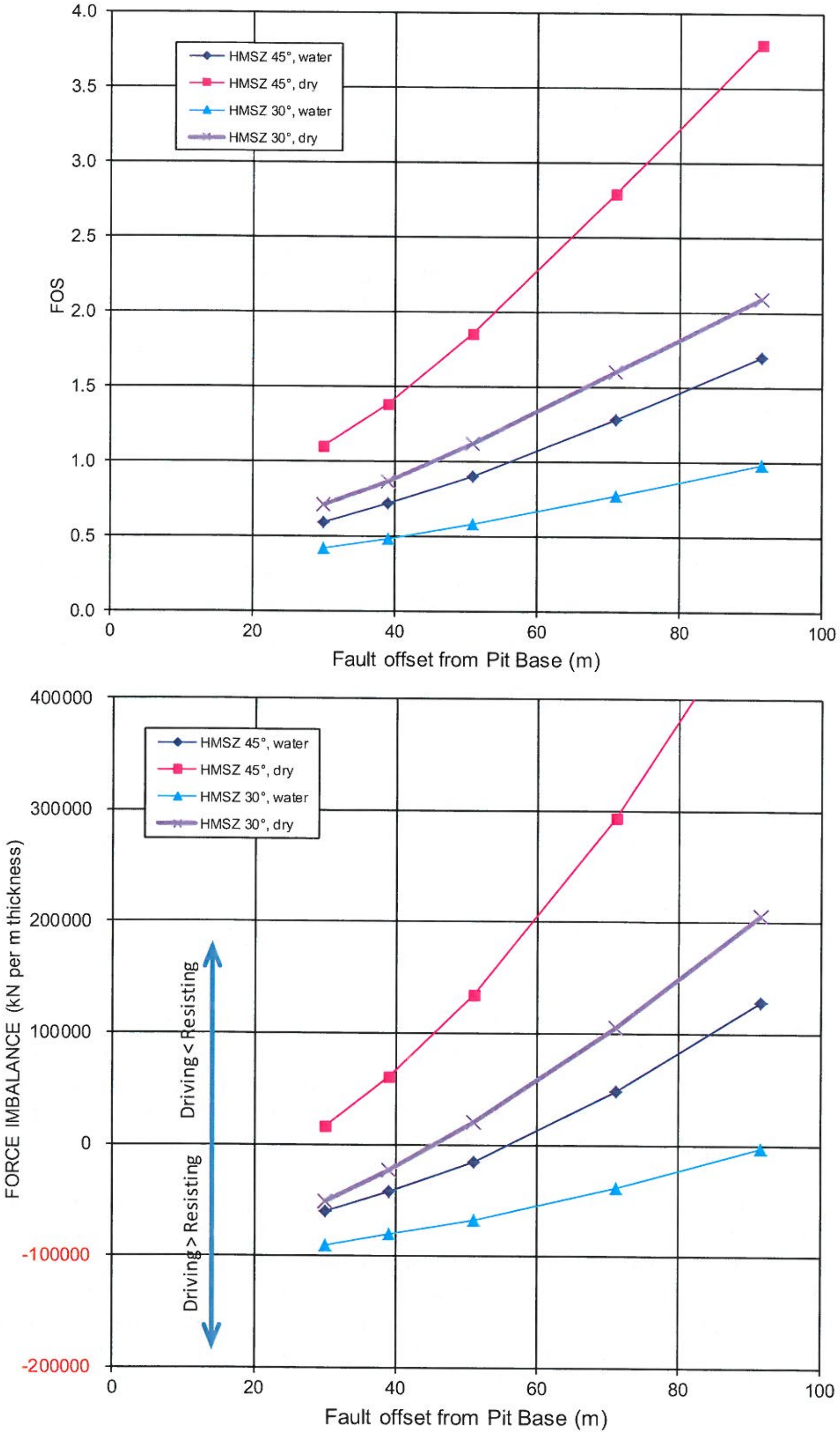


Figure 17: Results of retaining wall analysis. FoS (top) and imbalanced force (bottom) versus distance between pit and FF

8. 2D MODELLING

Finite element analyses using the program *Phase*^{2} (3) were carried out to assess the stability of the west wall; similar to the work that was completed for the Frasers pit in 2007 (Reference 4). Two east-west sections were created – one at 15177mN and the other at 15403mN – to bound the expected behaviour through the centre of the existing Round Hill pit and through the plant site (Figure 18).

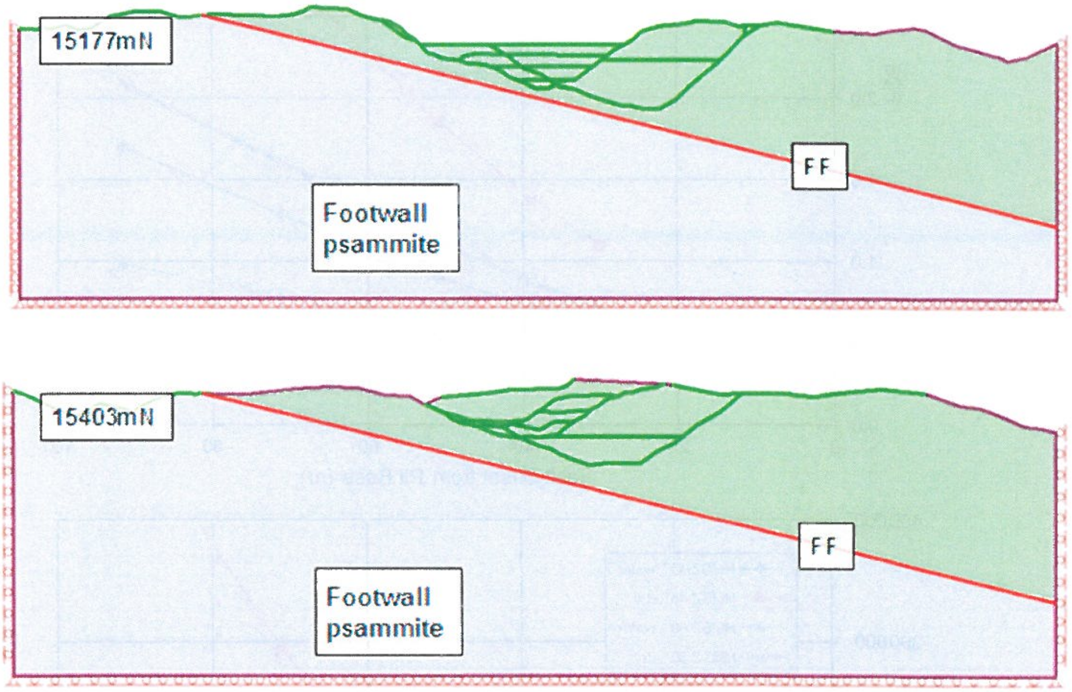


Figure 18: *Phase*^{2} model sections through the Round Hill pit (top) and plant site (bottom). The green lines represent the various mining stages used in the model

Table 8.1 summarises the material properties used, which are those developed over the past several years (References 4 and 5). It is assumed that insitu stresses are $\sigma_H = \sigma_h = \sigma_v = \gamma z$ where z= depth [m] and γ = 26kN/m^3. The models were run assuming either no groundwater pressures or the full pre-mining groundwater pressure is exerted on the FF. These two conditions were chosen to again bound the expected behaviour.

The results are presented as figures in Appendix C showing model predicted displacements and an equivalent FoS called the strength reduction factor (SRF) and are summarised in Table 8.2. It must be remembered that the values in Table 8.2 relate to two dimensional sections and groundwater conditions which are considered to bound the problem. In practice, the problem is expected to lie between these bounds and hence 'average' values are also quoted. Further, the absolute values are not that important, rather it is the differences which need to be considered.

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TABLE 8.1
SUMMARY OF MATERIAL PARAMETERS

MATERIAL	COHESION c' [kPa]	FRICTION ANGLE ϕ' [°]	TENSILE STRENGTH [kPa]	YOUNG'S MODULUS E [MPa]	STIFFNESS [MPa/m]
Hyde-Macraes Shear Zone (HMSZ)	180	45	10	3000	-
Footwall Psammite	180	45	10	10000	-
FF	0	9	0	-	k_n = 100 k_s = 10
Backfill	0	35	0	100	-

The results replicate the observed behaviour of the west wall – the HMSZ sliding in response to mining, stopping when mining ceased and the pit backfilled. The results also suggest that the proposed mining of the Southern and Round Hill East pits down to 350 mRL will not adversely affect west wall movement. However, mining below 350mRL is expected to re-initiate movement. The 2D analyses suggest that movement could be more than that observed in the past.

The models predict movement of between 2.5 m and more than 10 m at the tailings dam (Figure C5) and up to 2.5 m at the plant site (Figure C8).

TABLE 8.2
SUMMARY OF *PHASE*^{2} RESULTS
FoS

STAGE	ROUND HILL PIT		PLANT SITE		'AVERAGE'	CHANGE FROM 1998
	Dry	Pre-mining Groundwater	Dry	Pre-mining Groundwater		
1998	0.9	<0.01	>4	>4	≈ 2.2	Base case
Now	>4	>4	>4	>4	>4	Better
Down to 350mRL	2.3	1.3	>4	2.5	≈ 2.5	Same
Final pit	1.0	<0.01	2.0	1.1	1.0	Worse

9. 3D MODELLING

9.1. Methodology

A predictive model was developed based on parameters calibrated from back-analysis, or a retrospective model, that comprised the following.

- 3D surfaces of the pre-mining ground surface and previous mine development works interpreted by OceanaGold from survey
- Geological conditions interpreted by PSM from borehole logs and face mapping
- A model boundary based on the magnitude and direction of observed movements
- Material properties interpreted by PSM from laboratory testing, logging and back analysis
- Pore pressures
- Insitu stress field based on experience and sensitivity analysis.

The model was numerically solved for displacements and stresses at the end of each mining stage and the resulting displacements compared to the recorded survey.

The retrospective modelling revealed several issues.

- Limited knowledge of water pressure distribution
- Difficulties importing the digital terrain data into the numerical models
- Inability of the numerical simulation software (*FLAC3D*) to deal with the specified conditions.

The inability for *FLAC3D* to produce a reliable solution was realised after thorough and extensive investigation and analyses. Consequently an alternative numerical simulator was trialled to resolve this issue. After significant testing, the finite element software, *Abaqus* was selected for future analyses.

9.2. Retrospective

9.2.1. Solid

Abaqus was used to model observed behaviour at Round Hill and Golden Point pits prior to 2002. The modelling process is divided into two separate phases, solid model development and numerical analysis.

The direct use of survey data proved difficult to use in the numerical model and restricted the numerical efficiency of the software. To improve this situation, an idealised surface that contained the general site design criteria was fitted to site survey data, which included bench widths of 10m and inter-ramp angles of about 41° to 43°. Two 15m high batters were combined into 30m heights to improve computational efficiency without comprising analysis results. A comparison of survey and final solid model are shown in Figure 19 and Figure D1 in Appendix D.

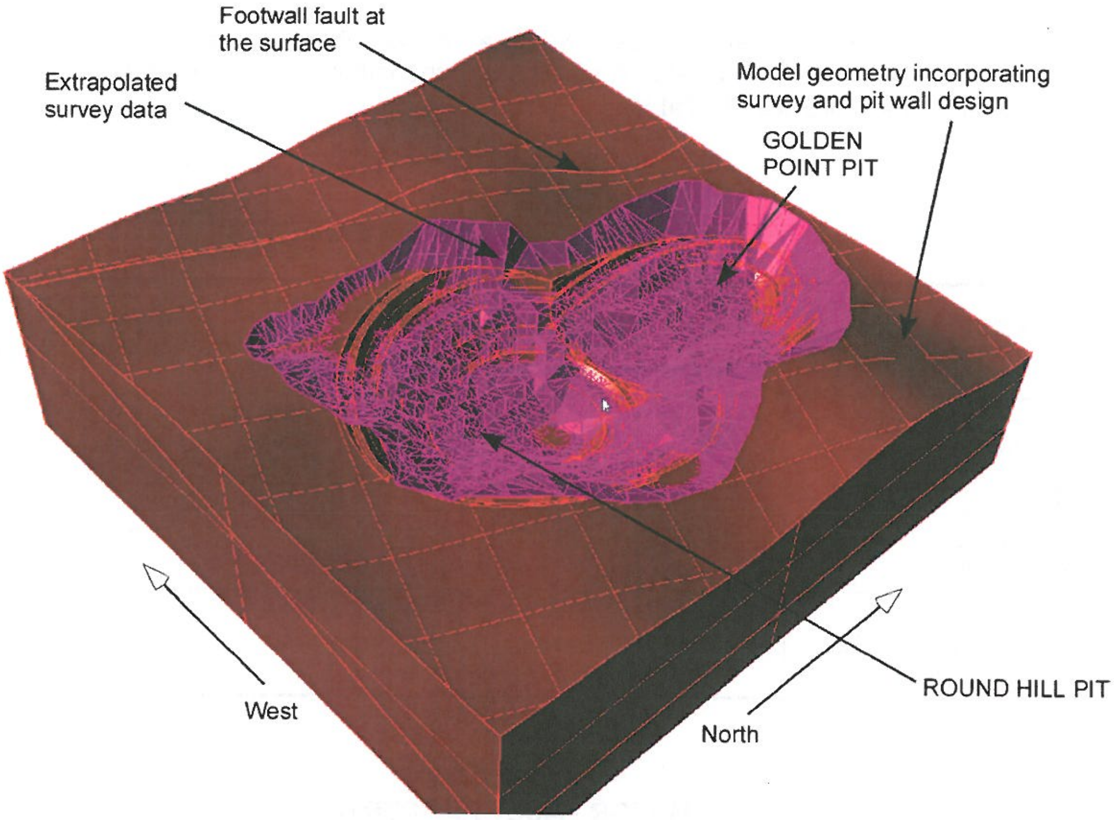


Figure 19: Calibration geometry for pit development from 1996 to 2001

9.2.2. Mesh

The mesh used in the numerical analysis was created by the following process.

- Development of a unified surface topography from OceanaGold's data that covered the model area
- Removal of geological conditions considered extraneous to the principal mechanism of movement, this being sliding along the FF
- Development of unified surfaces defining pit development and backfill from OceanaGold's data.

Alternate mesh densities were analysed comprising 50,000 to 100,000 tetrahedral elements ranging in volume from about 10 to 400,000 m^3. Larger elements are constrained to the extremities of the model and to the material below the FF. The model comprised ten components that were used to simulate yearly changes in pit profile including backfill.

The mesh extent is significantly smaller than that typically used to model pit interactions. In this application only the movement of the material above and up dip of the footwall is under consideration (i.e. the west wall). This allows the model to be more computational efficient as element density is higher in this area of interest.

9.2.3. Material Properties

Material properties were defined from a combination of testing, borehole log interpretation and back analysis. A summary of the initial material properties used in the back-analysis is provided in Tables 8.1 and 8.2.

TABLE 8.1
MATERIAL PROPERTIES

MATERIAL TYPES	DENSITY (kg/m^3)	COHESION (kPa)	FRICTION (°)	DILATION (°)	YOUNGS MODULUS (GPa)	POISSON'S RATIO	TENSILE (kPa)
Backfill	2200	0	30	0	0.05	0.35	0
Rock below backfill	2600	180	45	0.5	1	0.3	90
Base rock (Modelled elastically)	2600	-	-	-	10	0.3	-

TABLE 8.2
MAJOR FAULT PROPERTIES

FAULT	COHESION (kPa)	FRICTION (°)	TENSILE (kPa)	NORMAL STIFFNESS (MPa/m)	SHEAR STIFFNESS (MPa/m)
FF	0	9	0	100	100

9.2.4. Insitu Field Stress

Data on initial stress conditions at Macraes Mine is limited. Consequently a sensitivity analysis was undertaken to provide an estimate of insitu stress conditions, which concluded that hydrostatic stress state is reasonable for the modelled problem whereby:

- Vertical stress is equal to overburden
- Horizontal stress in both directions equals the vertical stress.

9.2.5. Development Stages

A total of ten model steps were adopted for the calibration model including stress initialisation (Step 0) and nine development stages (Steps 1 to 9) comprising:

1. Round Hill excavation during 1996
2. Round Hill excavation during 1997
3. Round Hill excavation during 1998
4. Round Hill backfill during 1998
5. Round Hill backfill during 1999
6. Golden Point excavation during 1999
7. Golden Point excavation during 2000
8. Golden Point excavation to mid 2001
9. Golden Point excavation to late 2001.

Figures D2 to D6 in Appendix D graphically depict these model stages.

9.2.6. Parameter Sensitivity

The west wall of Round Hill and Golden Point pits is in a meta-stable condition and strongly dependent on the rate of mining, the presence of backfill and on the following parameters.

- Rock mass strength and stiffness
- FF strength and stiffness
- Geometry of the pit surface and subsurface features
- Water pressure.

Of these factors geometry has the highest confidence as it is based on extensive survey and borehole logs. Strengths and stiffness have greater variability and were, therefore, the main focus of sensitivity studies.

9.2.7. Calibration

A series of sensitivity analyses were undertaken to model the pit development between 1996 and 2001. Analyses were undertaken to assess appropriate values for:

- Rock mass strength
- Strain softening of the rock mass
- Rock mass modulus.

Groundwater was omitted in the sensitivity analyses due to the large uncertainty concerning pore pressure magnitude and distribution. This reduces model complexity but also effectively reduces rock mass strengths and stiffness derived from back analysis. If groundwater pressures were included the strengths would need to increase for the same result. This simplification is considered acceptable provided analyses using the back-analyses strengths also omit groundwater.

Strain softening parameters were chosen to reflect the expected strength reduction due to shear and tensile strain due to sliding as described in Reference 8.
Analyses were undertaken primarily using a static solution scheme whereby all element forces must come into equilibrium in order to arrive at a solution i.e. global stability. Additionally some pseudo-dynamic analyses were undertaken whereby movements are calculated from velocity and inertia effects. The pseudo-dynamic analyses allow local instability to continue without the need for global stability.

Four monitoring prisms were chosen for calibration based on their proximity to the plant site and the available survey records. Prism FT20 is considered indicative of predicted movements for the plant site while the greatest magnitude of movement was recorded at Prism 76.

With the initial material parameters given in Tables 8.1 and 8.2 the predicted movements at selected prisms are much lower than observed under a static solution scheme, Figure 20. However, under a dynamic solution scheme the predicted displacements are similar to observations. This trend is similar to the other selected prisms as shown in Appendix D. Differences between predicted and observed are likely due to:

- Variable rock mass properties across the site
- Groundwater pressures
- Mesh density.

Differences in rock mass strength and modulus are expected given that the initial parameters were largely derived from back analysis of 2D sections, which ignores the side shear resistance mobilised during sliding of the west wall.

Parametric analyses found that displacements at selected prism locations were most sensitive to rock mass modulus followed by rock mass strength and then strain softening. The model displacement response due to changes in rock mass modulus for Prism 76 is shown in Figure 20. Model displacement response for all prisms is shown in Figures D10 to D13 in Appendix D.

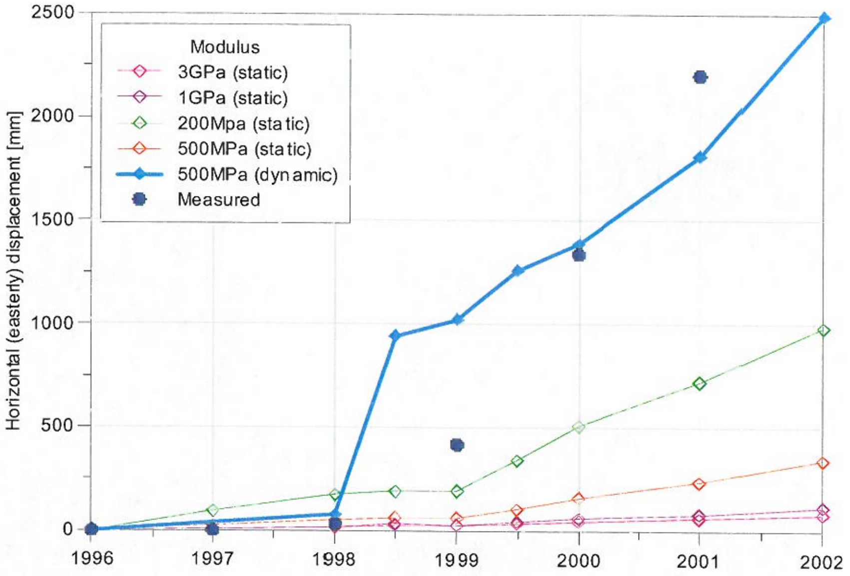


Figure 20 Calibration model and Prism 76 observed movement comparison

Parametric study of rock mass strength found that even small reductions in internal friction and cohesion resulted in numerical instability. This instability was found to occur at the full excavation depth of Round Hill Pit and coincided with excessive movement at the base of the west wall as shown in Figure 21. Once backfill had been placed, model stability with Round Hill Pit returned. However, such instabilities highlight a limitation of both 'static' and pseudo dynamic numerical analysis whereby discrete time steps of a manageable duration must be adopted, in this case years, whereas the actual process of pit development and backfill is continuous.

Increasing mesh density from 50,000 to 100,000 total elements was found not to have a significant impact on predicted displacements.

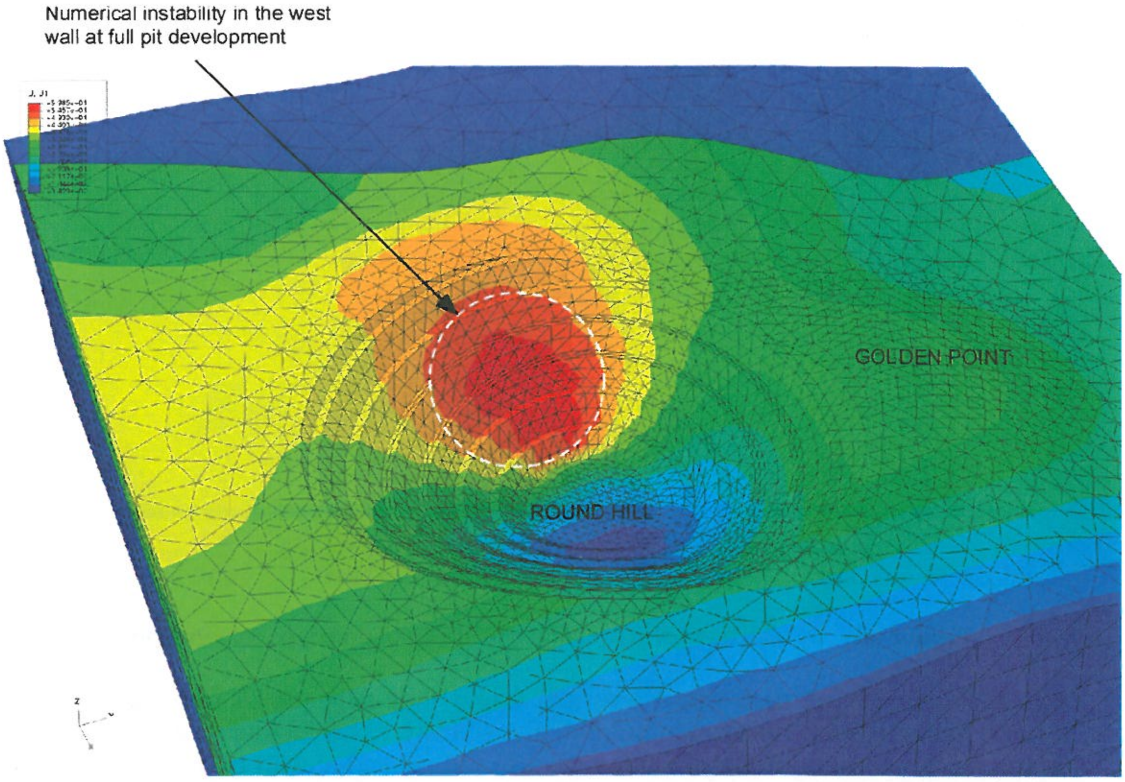

Numerical instability in the west wall at full pit development

Figure 21: Numerical instability at the base of Round Hill Pit under low strength

Close examination of analysis results showed that while the magnitude of static predictions was consistently less than observed, the location, direction and rate of movements was a good match with observations. Other similarities between predicted and observed included the extent of sliding along the FF, the significant movement predicted for the west wall and pit floor heave. Modelled horizontal displacements after Stage 9 are shown in Figure 22 and predictions for all stages are shown in Appendix D, Figures D2 to D8.

The pseudo-dynamic analysis results show a good match with observations in terms of displacements. Again the location, direction and rate of predicted movements matched observations well. The goodness of fit established during model calibration was deemed sufficient to establish a reliable forward prediction model.

It is important to note that it may be possible to arrive at a similar set of predicted displacements using an alternate set of material parameters as discussed in Section 8.2.7. It is, therefore, prudent to include a range of material parameters for predictive modelling. The most sensitive parameter identified here with respect to predicted FF sliding, is the elastic modulus.

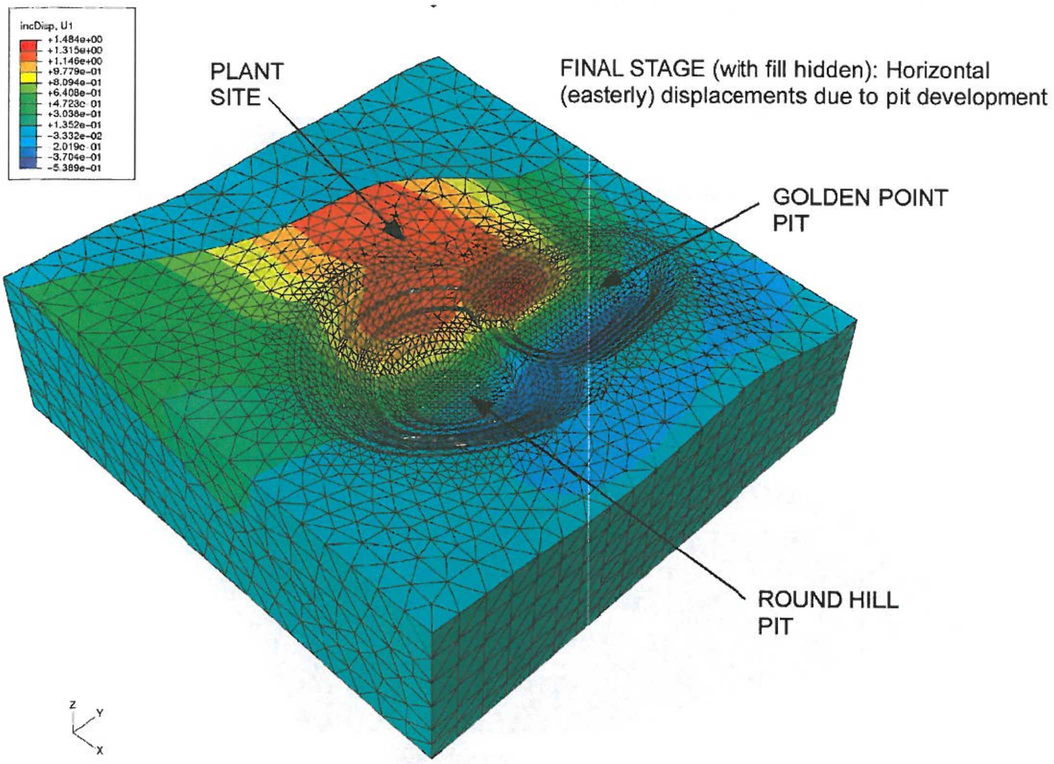


Figure 22: Calibration horizontal (easterly) displacements at the final stage (Stage 9)

9.3. Predictive

9.4. Solid

The modelling process for forward prediction is again divided into two separate phases; solid model development and numerical analysis.

The solid model development involved simplifying the survey data and design pit geometries to facilitate efficient incorporation into *Abaqus*. The solid model incorporated the following surfaces supplied by OceanaGold.

- Original surface topography before mining
- Previous extent of mining and filling
- Proposed pit stages 2010, 2012, 2013, 2014, 2015, 2016, 2017 and 2018
- Proposed drystacking on the existing tailings dam to 2020.

The surfaces were combined to create a staged excavation sequence for use in *Abaqus*. During this process simplifications were made to reduce complexity without compromising the geometric features relevant to the aim of the analysis, this being to assess potential sliding on the FF. In addition stages were combined where mined volumes were low and/or largely comprised the removal of existing fill. A comparison of OceanaGold's surfaces and the final solid model are shown in Figure 23.

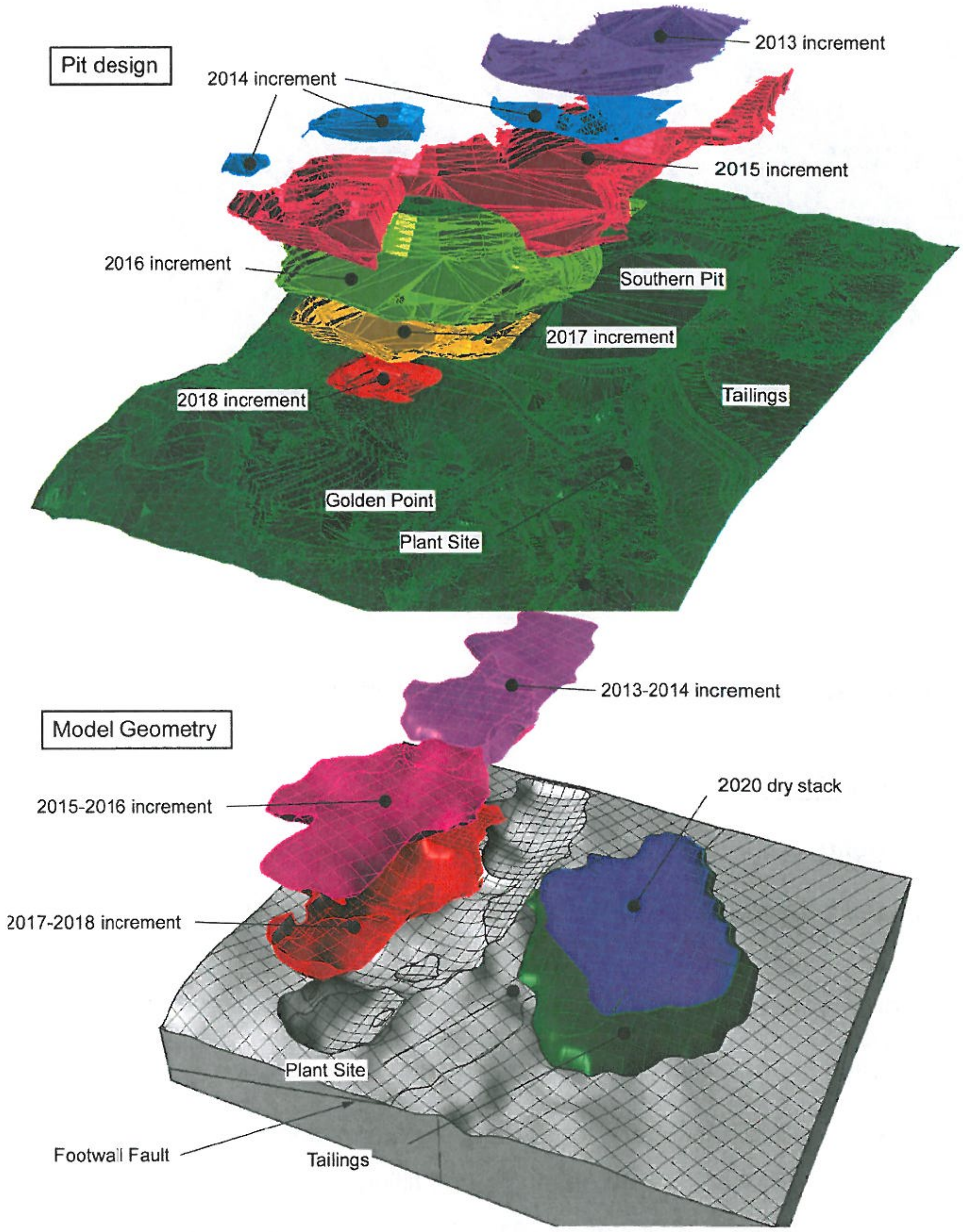


Figure 23: Supplied geometry and adopted solid model

9.5. Material Properties

The material properties derived from the retrospective analysis and used in the prediction analysis are provided in Tables 8.3 and 8.4.

TABLE 8.3
MATERIAL PROPERTIES

MATERIAL TYPES	DENSITY (kg/m^3)	COHESION (kPa)	FRICTION (°)	DILATION (°)	YOUNGS MODULUS (GPa)	POISSON'S RATIO	TENSILE (kPa)
Backfill	2200	0	30	0	0.04	0.35	0
Rock above FF	2600	180	45	0.5	0.2 to 3	0.3	90
Rock below FF (modelled elastically)	2600	-	-	-	10	0.3	-

A range of elastic moduli were assessed based on the findings of the retrospective model. The base case modulus is taken as 0.5GPa.

TABLE 8.4
MAJOR FAULT PROPERTIES

FAULT	COHESION (kPa)	FRICTION (°)	TENSILE (kPa)
FF	0	9	0

9.6. Stages

Six stages were modelled including stress initialisation (Stage 0) and five development stages (Stages 1 to 5):

1. All excavation prior to 2010
2. Fill prior to 2010 (including dry stack)
3. Proposed excavation to 2014
4. Proposed excavation to 2016
5. Proposed excavation to 2018.

The proposed 2020 dry stack was conservatively added to the model at Step 3 (with the removal of existing fill) to reduce computation requirements.

Incremental volumes for each stage are shown in Table 8.5.

TABLE 8.5
VOLUMES OF MATERIAL ADDED (+) OR REMOVED (-)

STAGE	INCREMENTAL VOLUME (Mm^3)	DESCRIPTION
1	-68	All excavation prior to 2010
2	+124	All fill prior to 2010 (includes Stage 1 volume)
3	-10	Excavation from 2010 to 2014
4	-61	Excavation from 2014 to 2016
5	-32	Excavation from 2016 to 2018

9.7. Parameter Sensitivity

Continuing the methodology described in Section 8.2.6, the following parameters were varied to assess their effect on the model results.

- Lowering of material stiffness and strength
- A coarse mesh of about 125,000 elements and a finer mesh of about 500,000 elements.
- Static and pseudo dynamic analysis.

9.8. Results

The predicted total and horizontal displacements at the final stage are shown in Figure 24.

Interrogation points at the same approximate location as survey prisms 69, 76, 79, FT19 and FT20 have been used to track movements in the vicinity of the plant site. The predicted movements at these locations during mining are shown in Figure 23.

Sensitivity analyses indicate that the maximum horizontal displacements predicted by the 3D model are in the order of 1 to 1.5 m at the plant site and approximately 4 m at the tailings dam embankment.

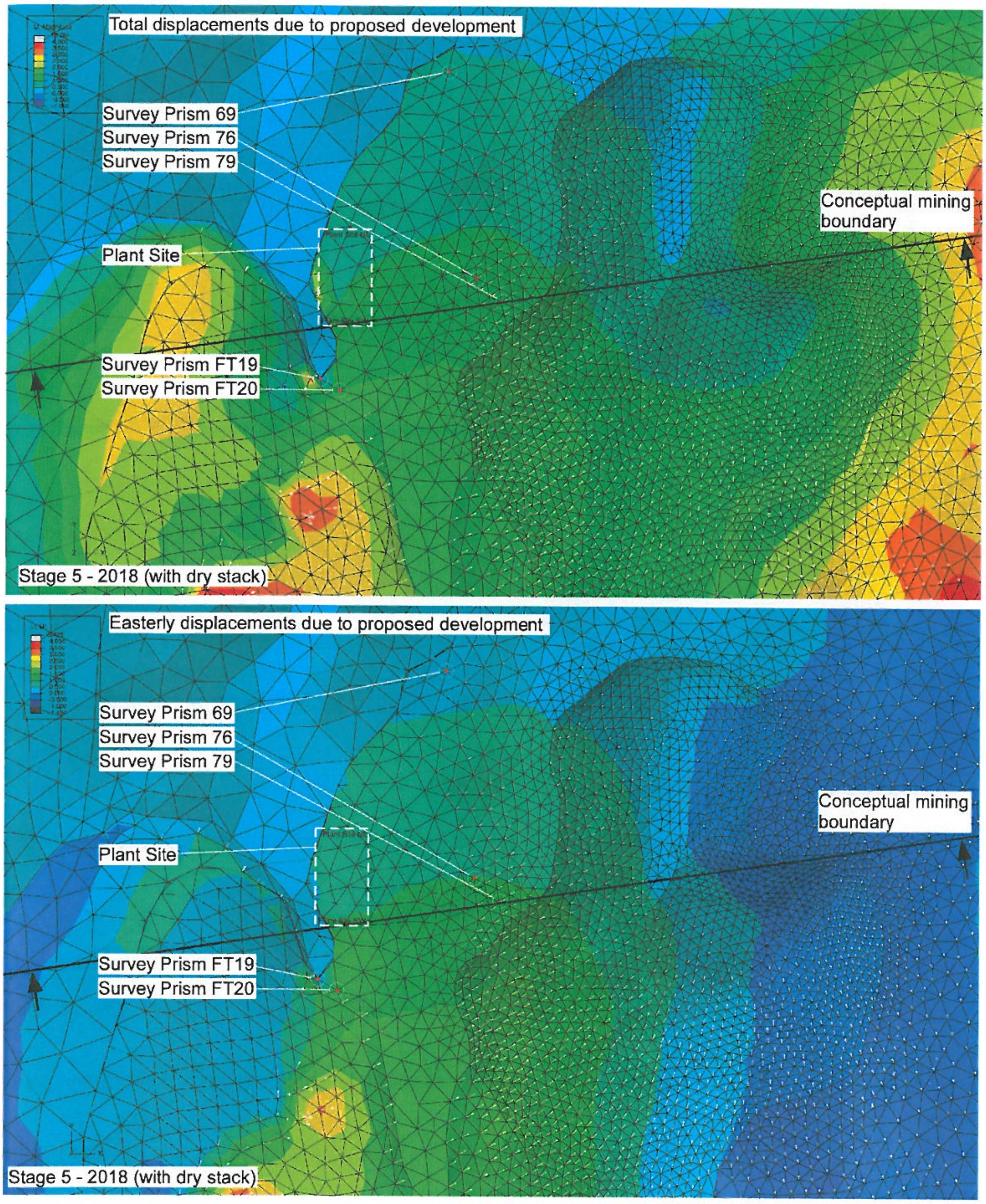


Figure 24: The model predicted total and easterly displacements at the final stage

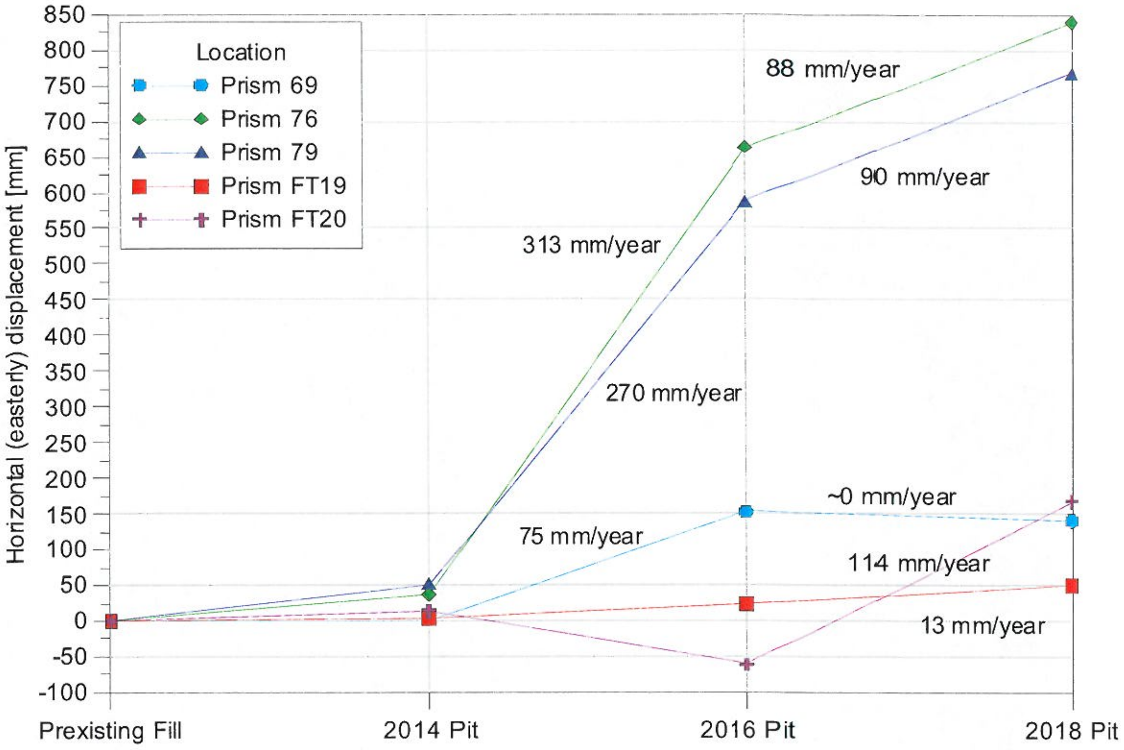


Figure 25: The model predicted horizontal displacements at key locations

The 3D numerical analyses indicate that:

- The movement rates are relatively constant in three separate periods.
  - up to 2014
  - Between 2014 and 2016/2017
  - Post 2016/2017
- The distribution of movement in and around the plant site is relatively uniform,
- The predicted movement is significantly lower than previously predicted as a result of:
  - Smaller mining footprint; mining occurs south of approximately 15250mN;
  - The west wall of the pit is effectively kept 25m from the FF;
  - This modelling has better captured the full extent of previous mining and associated ground relaxation.

As assessed for the 2D analyses the absolute values are not as important as the differences between model stages and sensitivity analyses. Excluding the effects of groundwater, these analyses indicate than increased movements are likely to be small and are consistent with a smaller final pit being located further away from the west wall compared to previous designs.

10. DISCUSSION

10.1. Analyses

As stated in Section 4, no single method provides "the answer". Instead it is the collective results of the methods that instruct the expected behaviour of the west wall. The conclusions reached by the various methods are summarised below.

The empirical method (Section 5) indicated that mining down to approximately 350 mRL and mining south of approximately 15250 mN (the line shown in Figure 12) is not expected to cause movement of the west wall that will adversely impact the plant site. For comparison, the overall movement recorded during the mining of Golden Point was approximately 5m.

The observations of the Frasers pit, suggests that the magnitude of displacements quickly diminishes with distance north (or south) from the actively mined area. In other words, the bulk of the movement occurs immediately adjacent to the active pit. The analogy with the proposed Southern and Round Hill pits, is that displacements at the plant site could be as low as 10% of those at the soon-to-be disused tailings dam.

Treating the problem as a retaining wall (Section 6) suggested that the balance between the forces driving the west wall and those resisting, tips in favour of driving the west wall movement once the perpendicular offset from the FF is less than approximately 25 to 50m. The recent performance at Frasers indicating that a 25mm offset is appropriate.

The results of the 2D finite element analyses (Section 8) suggest that mining the proposed Southern and Round Hill East pits down to 350 mRL will not adversely affect the plant site. However, mining below 350mRL is expected to re-initiate movement beneath the plant site and at levels greater than that observed in the past. Predicted displacements are between 2.5 m and more than 10 m at the tailings dam, and up to 2.5 m at the plant site.

The 3D analyses (Section 9) predict displacements in the order of a few hundred millimetres as a result of mining up to the end of 2014. From 2015, the expected response is one of increasing movement although the west wall is predicted to remain relatively "stable", ie not fail. The bulk of the movement is predicted to occur over a two year period up to 2017.

Horizontal displacements at the plant site in the order of a 1.5 m at rates of up to 10 mm/week as a result of the proposed mining are predicted by the model. The maximum displacements at the tailings dam embankment are predicted to be approximately 4 m.

10.2. Synthesis

The various analyses predict that movement of the west wall at the Macraes plant site will be reactivated with the mining of the Southern and Round Hill East pits.

The proposed mining plans incorporate strategies based on these analyses to limit the impact on the west wall such as mining south of approximately 15250 mN and maintaining a minimum 25m offset between the FF and the pits.

The behaviour of the west wall when the Round Hill and Golden Point pits were mined suggests movement could be approximately 5 m. Comparison with the Frasers pit suggests displacement at the plant site could be 10% of the movement at the tailings dam.

The 2D finite element analyses predict a range of displacements at the plant site up to approximately 2.5 m.

The 3D analyses suggest displacements in the order of 1.5 m at the plant site and up to approximately 4 m at the tailings dam with the bulk occurring between the years 2015 and 2017.

If the restriction to mine south of the line at approximately 15250 mN was lifted, it is expected the plant site would see movement of similar magnitude to that at the tailings dam embankment.

The conclusion is that proposed Southern and Round Hill East pits have been appropriately planned and scheduled to limit the impact of reactivating the west wall movement. Large displacements are still predicted to occur as a result of mining. These will have to be managed to limit the effect on the plant site. Suggested measures are discussed in the next section.

11. MEASURES TO BE ADOPTED WHILE MINING

11.1. Triggers

The preceding sections present analyses that predict movement of the west wall as a result of mining the proposed Southern and Round Hill pits. Hence it is wise to plan for the possibility that the actual movements are greater than those predicted.

The main risk is that the west wall movement goes from slow, predictable, regressive style where it 'responds' to mining to a progressive style where it is 'failing'. The change will be subtle as the key symptoms have already occurred, such as observed movement, batter failures and floor heave. However, it will be the speed or frequency of these symptoms which will indicate the change from regressive to progressive failure.

Stop-start mining was introduced at Round Hill when movement rates were 2 mm/day as a measure to protect the tailings dam embankment. The rate was raised to 10 mm/day during mining of Golden Point largely to protect the processing plant. At Fraser's pit, which does not have the impost of infrastructure, mining has continued with rates at up to approximately 50 mm/day.

The triggers recommended to be adopted during mining the Southern and Round Hill East pits are as follows.

- A general rate of 50 mm/day or more
- A rate of 10 mm/day at the plant site
- An acceleration of movement equivalent to a doubling of the daily rate
- Batter failures along the western wall
- Floor heave noticeable during a mining shift
- Distress of key components in the plant site
- Change in direction of displacement vectors of 20° or more.

Monitoring and management of data is key. The data needs to be plotted and reviewed daily.

- Daily recording of crack pins. A rod extensometer set to alarm when the daily trigger rate is reached needs to be installed across the FF scarp.
- Routine prism surveys using a robotic survey station.
- Supervisors need to inspect the pit floor and western wall for signs of floor heave and batter failures. Weekly photographs of the west wall can help capture changes in batters.

OceanaGold has experience with monitoring and managing this data having done so for the past decade, most recently at the Frasers pit.

11.2. Remedial Measures

It is worthwhile documenting at this stage that should the behaviour of the west wall change such that its failure is predicted it will be necessary to modify the pit plan. The specific remedial measure(s) adopted will depend on the situation at the time. This is likely to entail dividing the pit into either north-south and/or east-west sections; and/or increasing the offset so that the toe of the west wall is further from the FF.

12. PIT SLOPE ANGLES

No geotechnical data specific to the location of the proposed Southern and Round Hill East pits is available, nor is it likely to become available prior to mining. However, based on OceanaGold's interpreted geological model of the area, it is reasonable to expect that geotechnical conditions within the proposed Southern and Round Hill East pit will be similar to those encountered throughout the Macraes mining areas. The pit slope designs recommended herein are therefore based on PSM's 19 years' experience with open pit mining at Macraes.

Large faults and associated groundwater govern stability at bench and overall scale. Historically the eastern walls have been the worst performing slopes with north-south trending faults, such as the Northern Gully Fault (NGF), controlling stability. The exceptions are pit walls excavated within the psammite-rich rock mass which occurs well above the HWS, such as at Golden Bar and the upper sections of the Frasers.

The northern and southern walls are generally the best performing walls throughout Macraes, unless these walls are locally affected by the large east-west trending faults, i.e. Macraes and Murphy's Gully. The main stability issue for northern and southern walls is individual batter control. While part of the problem is the blocky nature of the rock mass and part is operational. Steep batters can be achieved on these walls provided they are pre-split.

High groundwater pressures impact slope stability of the eastern and western walls. Horizontal drains can reduce the groundwater pressure if they target known structures.

The recommended slope designs for the proposed Southern and Round Hill East pit are as follows.

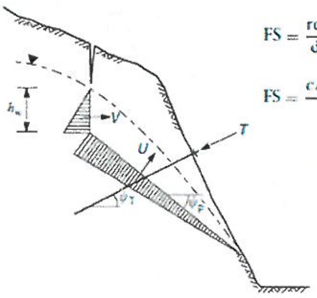
- The top two 15 m high benches are expected to be in weathered rock mass and are recommended to be battered at 50°.
- The backfill is largely loosely dumped waste material. The slope design will therefore comprise an angle of rill, 37°.
- Southern and northern walls
    - 15 m high, 85° pre-split batters and 5 m wide berms in the psammite-rich rock mass which overlies the HWS.
    - In the more pelitic rock mass which occurs closer to the HWS, say within 75 m perpendicular offset to the HWS, adopt 75° batters.

- Eastern and western walls
  - 15 m high, 60° batters and 7.5 m wide berms producing a 60m high 43° (toe to toe) interramp slope.

13. FINAL VOID

Groundwater and surface run-off water will enter the void created by mining the Southern and Round Hill pits. Over time the water collecting in the void will form a lake. The impact of that lake on the stability of the west wall is assessed in this section.

The rise in the level of the lake increases the pore water pressures within the rock mass near the base of the void's walls. This increase in pore water pressures effectively reduces the strength of the rock mass and also adds to the force which drives movement of the slopes, as illustrated in the equations below [4].



$$FS = \frac{\text{resisting forces}}{\text{driving forces}}$$

$$FS = \frac{cA + (W\cos\psi_p - U - V\sin\psi_p + T\sin(\psi_T + \psi_p))\tan\phi}{W\sin\psi_p + V\cos\psi_p - T\cos(\psi_T + \psi_p)}$$

where pore water pressure, U and V, are

$$V = \frac{1}{2}\gamma_w h_w^2 \quad \text{and} \quad U = \frac{1}{2}\gamma_w h_w A$$

Hence the initial water level rise decreases the stability of the void's walls. Analyses carried out for similar conditions in Fraser's final void suggest a lake level 10 m above the base of the void decreases wall stability by approximately 5% [5]. Additional movement of the west wall is expected to be in the order of centimetres while the lake reaches this level.

Rises in the lake level, while increasing the pore water pressures acting in the rock mass, also add weight to the base of the void and to the toe of the void's walls. This additional weight increases the resisting force, by effectively increasing the term $W\cos\varphi_p\tan\phi$ in the above equations. The analyses of the Fraser's final void suggest the balance is in favour of increasing stability with lake level rises higher than 10 m above the base of the void. The overall increase in wall stability is approximately 10%.

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[4] Modified from Wyllie & Mah *Rock slope engineering*, 4th edition Spon Press

[5] Frasers west waste stack, PSM71.L68, 22 December 2003

14. OTHER

The option of increasing bench heights was proposed in previous reports (References 6 and 7). It may be worthwhile repeating the suggestion in light of the Southern and Round Hill East design studies.

Bench heights are a function of ore grade control, which is carried out on 7.5 m intervals. Hence, the use of 15 m high batters allows grade control benches to blend into the waste benches. Increasing the height from 15 m to 22.5 m and increasing the berm width from 7 to 11 m may provide Oceana Gold an opportunity to save on waste removal without increasing the inter-ramp slope angle (see Figure 26).

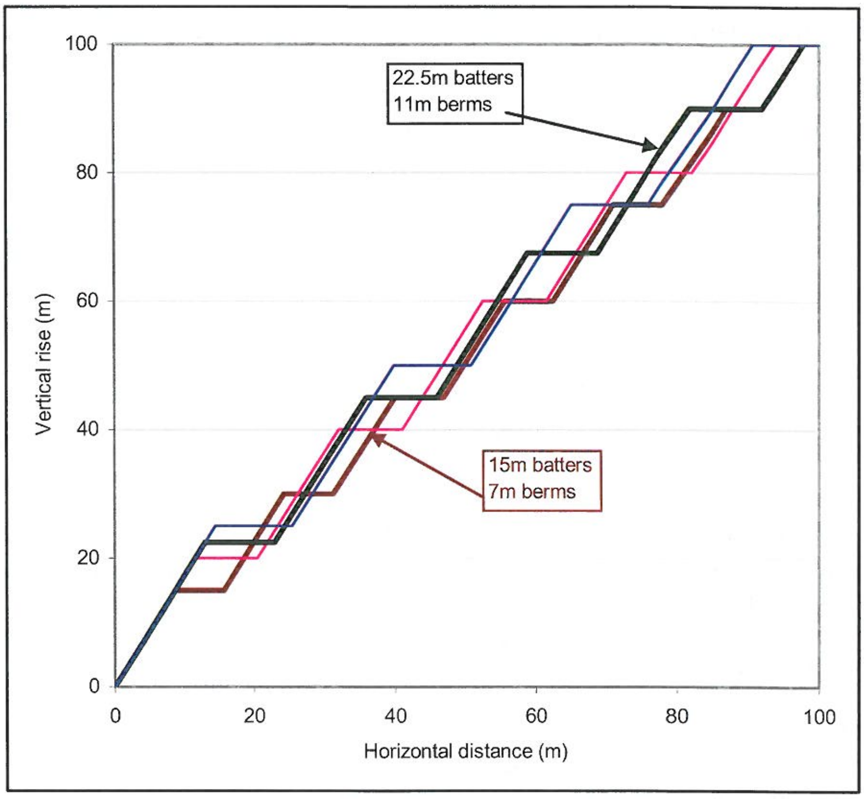

Figure 26: Profile of bench geometry options. Increasing bench height to 22.5 m reduces waste volume, without significantly increasing the inter-ramp slope angle

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APPENDIX A

CROSS SECTIONS