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Report to:-

YALLOURN MINE

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YALLOURN MINE

ASSESSMENT OF MINE BATTER STABILITY DURING PROPOSED FLOODING TO RL 38 m

Report 1155/10
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GEO-ENG PTY LTD

YALLOURN MINE
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TABLE OF CONTENTS

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TABLE OF CONTENTS (Continued....)

1 INTRODUCTION

At the request of Mr E Waghorne and Mr D Seymour of Production Technology additional work has been undertaken to assess the stability of the Yallourn Mine permanent batters following flooding of the open cut at the end of mining operations. It is proposed that flooding of the mine will be undertaken in conjunction with flattening and grassing of the upper levels of the batters as part of the overall mine rehabilitation program.

Information provided by Yallourn Mine indicates that the worked out open cut will be flooded to RL 38 metres, which is the current water level of the Morwell River along the eastern batter of the Mine.

The original rehabilitation planning proposed that the mine would be flooded to RL 33 metres, the level of the Latrobe River at the Yallourn North Open Cut bridge. All previous stability assessments were based on this flood level (refer Geo-Eng Pty Ltd report 1155/5).

2 SCOPE OF WORK

To assist in planning of flooding operations in both Yallourn and other mines it was requested that a general stability analyses be carried out on a "generic batter". It was proposed that these analyses would focus on the following batter stability issues:-

- rate of pore pressures and standing water level increase in the batter relative to the rate of filling of the mine
- effect on batter stability of relative changes in pore pressures and water levels
- the effect of horizontal drains on the build-up of pressure in the submerging batters
- effect of coal/interseam interface dip on the stability of partially and fully flooded batters
- effect of flooding on the ground movements adjacent to the open cut
- the stability of the batters above the flood water level

Additional stability analyses were carried out on the eastern and western batters (Sections 1 and 2 respectively) of Yallourn Mine and the northern and southern batters (Sections 3 and 4 respectively) of East Field (refer Figure 1). These analyses will take into account all the issues listed above and will address specific concerns regarding the following issues:-

- stability of the batters when flooded to their final levels of RL 38 metres
- stability of the batters during flooding of the mine
- acceptability of low factors of safety (ie:- 1.0 - 1.2) of batters in the long term flooded condition

3 STABILITY ANALYSIS

3.1 GENERAL

The stability of Sections 1, 3 and 4 and the "generic" section were assessed using the Geo-Eng Pty Ltd program BSLIDE. This program models the block sliding mechanism which is used to assess the stability of the coal batters in Generation Victoria's mines.

The stability conditions for Section 2, the Yallourn Western Batters, cannot be correctly assessed using the block sliding mechanism. Therefore the stability program GENSAM, which was used in the original design of the batters and in all subsequent redesigns and assessments, was used.

3.2 INTERSEAM STRENGTH PARAMETERS

The potential for block sliding of coal along both flat and dipping coal/interseam interfaces is highly dependent on the shear strength of the coal/interseam interface. As a coal batter is progressively excavated ground movements occur due to stress relief. These ground movements cause shearing strains to develop parallel to the base of the coal seam and movement to occur along the coal/interseam interface. These movements destroy cohesion and reduce the shear strength of the coal/interseam interface to its residual values (ie: $c'_r = 0$ kPa).

Previous studies of flooded batter stability (refer Geo-Eng Pty Ltd report 1155/5) used a residual friction angle of $Ø'_r = 12°$ for the eastern batter (Section 1) of Yallourn Mine. This shear strength was based on interseam strength testing carried out at East Field up to the end of 1992 and was adopted for analysis of Section 1 in this assessment.

Interseam testing on samples from the Western Batters of Yallourn Mine indicate a residual friction angle of $Ø'_r = 14°$ is appropriate for use in the stability analysis of Section 2.

Interseam testing carried out on samples of interseam obtained from East Field during the 1993/94 financial year indicated that the residual friction angle of the East Field interseam may be higher than the 12° originally assumed. Therefore the northern and southern batters of East Field have been analysed using a residual friction angle of 12° and 14° to determine the sensitivity of the batter stability to changes in $Ø'_r$.

3.3 ANALYSIS METHODOLOGY & DESIGN ASSUMPTIONS

3.3.1 Generic Section And Sections 1, 3 & 4

As mentioned in Section 3.1 of this report the stability of the batters represented in the "generic" section and Sections 1, 3 and 4 is controlled by the block sliding mechanism which is modelled by the program BSLIDE.

For a fully developed batter, resistance to block sliding derives from shearing resistance along the relatively weak coal/interseam interface at the base of the coal. Hydrostatic forces within vertical coal joints and gravity forces resulting from dipping coal/interseam interfaces produce the dominant destabilising forces responsible for large scale horizontal displacements in the block sliding mechanism (refer Figure 2). As the dip of an interseam cannot be changed, control of the unconfined water table becomes the primary method of maintaining batter stability. Flooding therefore has a substantial impact on the stability of the batter depending on how the gradual flooding effects the rise of water pressures in the batter and pore pressures along the coal/interseam interfaces.

Pore pressures in the interseams and along the coal/interseam interface are typically 80 % of the unconfined water pressure observed in the coal seam. In extreme cases the pore pressures react fully to the water pressures in the coal and approach the same levels as the unconfined coal water levels. Unless the interseam is being fed from another source (eg:- an aquifer lower in the geological strata) the pore pressures along the coal/interseam interface can not exceed the water pressures in the coal seam above. For the purposes of this analysis it has been assumed that the pore pressures on the coal/interseam interface are equal to the water pressures in the coal seam.

The rate of flooding of the Mine will effect the rate of water and pore pressure build up in the coal batters and the underlying sediments. If the rate of filling of the Mine is relatively slow the water levels in the coal will rise at a similar rate as the flood level. Water is expected to freely enter the coal via the numerous coal joints exposed in the batter and via the horizontal drain network. The horizontal drains in the batter will have little effect on the rate at which the water levels in the coal batters rise. However, should the Mine ever be emptied then the horizontal drains will provide vital pathways for the water to escape quickly from the coal preventing the build up of high hydrostatic pressures.

Due to the generally fine grained nature of the interseam materials, it is anticipated that the pore pressures in the interseams will rise at a much slower rate than the pressures in the coal and coal joints. Interface pressures are anticipated to react more quickly than the interseams but less quickly than the coal.

A factor of safety of 1.2 is typically adopted in Latrobe Valley Mines and is considered to be acceptable for the long term overall stability of the batters. The results of the analysis and factors of safety obtained in each case are discussed in detail in the following sections.

3.3.2 Section 2 - Yallourn Western Batters

The stability analyses carried out for this study used the currently accepted Western Batters strength parameters, design methodology and design criteria which have been previously documented. A more comprehensive explanation of the design and analyses procedures used for the Western Batters is contained in Mine Geoengineering Division report MGD 10 (1991) and Fuel Department report DD 209 (1986).

It has been assumed in the analysis of these batters that overall stability of the batter and Surcharge Dump will be at risk from flooding. The stability of the batter was assessed for a range of flood levels and batter water levels to a final flood level of RL 38 metres.

3.4 ANALYSIS RESULTS - GENERIC SECTION

3.4.1 General

Three "generic" sections were analysed for stability to provide general information about changes in batter stability as the mine is progressively flooded. The sections analysed have the following characteristics (refer Figure 3):-

- a flat coal/interseam interface

- a coal/interseam interface dipping at 5° into the mine
- a coal/interseam interface dipping at 5° away from the mine

The "generic" batter comprises of approximately 10 metres of overburden overlying approximately 45 metres of coal. The initial groundwater table adopted for the analyses rises at 8° - 10° from the toe of the batter, consistent with what has previously been observed at both Morwell and Yallourn Mines.

3.4.2 Effect Of Flood Depth On Batter Stability

Stability analyses were carried out on all three "generic" batters to determine the effects of increasing flood depth on the stability of the batters (refer Figures 4, 5 and 6). The analyses indicate that the stability of the batter deteriorates most in the early stages of flooding, however, once the batter is flooded to approximately 40 - 50 % of its total height the rate of batter stability deterioration is relatively small. Table 1 shows the change in the factors of safety for a progressively flooded batter with a flat coal/interseam interface. The trends indicated in this table were also observed in the data from batters with dipping interfaces.

Data contained in Table 1 and Figures 4, 5 and 6 indicates that the degree to which the batter is effected by flooding decreases with distance from the batter toe. Table 1 shows that the reduction in the stability of the batter, with rising flood levels, is generally less at the batter crest than at the batter toe, and less again at a distance of approximately 80 metres (chainage 340 metres) from the batter crest.

This data appears to indicate that should a batter failure occur, it would most likely occur in the early stages of flooding and would occur on the coal batters somewhere between the toe and the crest.

As can be seen in Table 1 significant lengths of the batter have a factor of safety less than the recommended value of 1.2 (refer shaded area), and in some cases approaching 1.0, when flooded. A factor of safety of 1.2 is considered to give an adequate safety margin in case of an increase in destabilising hydrostatic forces caused by events such as heavy rainfall or a pipe breakage. A factor of safety less than 1.2 is generally not considered to be acceptable as it does not allow for these sort of events to occur and still retain overall batter stability.

However, for the submerged section of the batter, there are considered to be no additional destabilising hydrostatic forces that can be applied to the batter as the water pressures contained in the coal are offset by the stabilising forces supplied by the flood waters outside the coal batter (ie: the destabilising force H_1 is exactly balanced by the stabilising force H_2 and U equals $W_w + W_c$ as shown in Figure 7). The submerged section of batter is therefore considered to be in equilibrium and will remain stable even with very low factors of safety.

3.4.3 The Effect Of Dipping Interseams On Flooded Batter Stability

Table 2 shows the factors of safety obtained from the three "generic" batters shown in Figure 3. In most rock and soil slopes the factor of safety of a slope decreases when an interface dips into an excavation due to an increase in destabilising gravity forces driving the slope. This is also the case in a coal batter, however, a dipping interface can also have the effect of reducing

Table 1:- Changes in Batter Stability With Depth of Flooding & Location
(Flat Coal/Interseam Interface)

Flood Water Level RL (m)	FOS at batter toe (Percent reduction)	Percent reduction in FOS at batter crest	Percent reduction in FOS at chainage 340 m
-6*	4.99	2.87	2.46
3	1.61 (68)	1.85 (36)	1.78 (28)
12	1.11 (31)	1.47 (21)	1.63 (8)
21	1.05 (5)	1.34 (9)	1.56 (4)
30	1.03 (2)	1.22 (9)	1.51 (3)
38	1.02 (1)	1.16 (5)	1.44 (5)

* Base stability condition - no flooding of the mine
Figure in brackets is percent change in factor of safety

destabilising water pressure forces acting on the slope. This has the effect of compensating for the increase in gravity forces observed when the interface dips into the excavation. The degree to which the reduction in water pressures compensates for the increase in gravity driving forces is dependent on the following factors:-

- the specific gravity of the material making up the slope
- the angle of dip of the interface
- the friction angle acting along the interface

As can be seen in Table 2, the factor of safety of a batter with a coal/interseam interface dipping towards the open cut is higher than the factor of safety for a batter with a flat interface with identical water levels (refer Figure 8). In this case the a significant reduction in the driving forces acting on the coal block has occurred compared with the increase in gravity forces. This has resulted in the batter becoming more stable.

Conversely, with a coal/interseam interface dipping into the batter it maybe observed that the factors of safety of the slope have reduced. In this case the gravity forces are acting on the batter to stabilise the slope rather than destabilise it. However, the magnitude of the water forces acting on the coal block have increased at a much higher rate than the stabilising forces and therefore factor of safety has dropped (refer Figure 8).

As noted in the previous section of this report the factor of safety of a slope reduces as the depth of the flood water increases, with the greatest reduction in the stability of the slope occurring in the initial stages of the flooding. This trend is also observed on batters with dipping coal/interseam interfaces. However, it may also be observed that the factors of safety for all three "generic" batters approach similar values as the flood level increases. At this point the driving forces supplied by the water to the batter are being balanced by the weight of the flood water pressing back against the batters and the differences between the factors of safety are provided by the differences in the gravity forces acting on each batter system.

Table 2:- Variation in Factor of Safety With Dipping Interseams
(At Batter Crest)

Flood Level RL (m)	Flat Coal/Interseam Interface	Interface Dipping Away From Open Cut at 5°	Interface Dipping Towards Open Cut at 5°
-6	2.87	2.03	9.3
3	1.85	1.56	3.29
12	1.47	1.37	1.82
21	1.44	1.35	1.69
30	1.22	1.22	1.23
38	1.16	1.16	1.15

* Base stability condition - no flooding of the mine
NOTE:- These trends are also observed at the toe of the batter.

3.4.4 Stability Of The Batters Above Water Level

Batter instability generally comes in two forms; overall batter failure and relatively small scale batter movements (ie:- over one to two coal cuts). Both types of instability occur due to build up of excess hydrostatic forces in the coal joints contained in the batter. Water levels build up until the hydrostatic force exceeds the shear strength at the base of the coal block.

Batter instability is generally prevented or minimised by drilling horizontal drains in the lower coal cuts of the batter to drain water from the coal joints and prevent it from reaching critical levels. However, once the mine is flooded the drains will be covered by water and will be unable to fulfil this function.

In an unflooded situation, a vertical coal joint extending from 1 Level to the interseam, a depth of almost 50 metres, could be filled to the top (eg: by a fire service pipe breaking on 1 Level) and exert a hydrostatic pressure on the back of the coal batter (refer Figure 9). If the bottom 25 metres of the batter was submerged an additional stabilising pressure of would be provided by the 25 metres of flood water. Therefore the potential for large scale (overall) batter instability decreases as the depth of the flood water increases.

Overburden batter instability may potentially occur in the mine where the flood water level is above the top of coal. These areas include the entire East Field mine area and most of the eastern and southern batters of the current Yallourn Mine. It is anticipated that the instability may occur due to undercutting of the overburden batter by wave action. Efforts should be made to either protect the overburden batters in theses areas (eg: with rip rap etc) or by laying back the overburden batters to form beaches.

3.4.5 The Effect Of Flooding On Ground Movements Adjacent To The Mine

In addition to the possible batter movements described above, smaller more gradual movement of the batters takes place due to stress relief due to excavation of the coal. Survey monitoring of batters at Yallourn has shown that batter movements due to stress relief decrease with increasing distance from the crest of the batter and increase with the depth of the Mine.

In general, little stress relief related movement is observed until the excavation of No 2 Cut. The rate of batter movements reach a maximum with the excavation of No's 3 and 4 Cut and then slowly reduces as No 4 Cut moves away. Based on these observations it is anticipated that by the time the mine is flooded almost all the batters will have completed the cycle of stress relief movements generally observed. It is therefore considered unlikely that any further stress relief related ground movement is will occur at any distance from the batter crest. Conversely it is considered unlikely that flooding will cause the batters to move back into position due to the incompressible nature of the water within the joints in the batter.

3.5 ANALYSIS RESULTS - YALLOURN SOUTH EASTERN BATTERS

3.5.1 General

The south eastern batters of Yallourn Mine, adjacent to the Fire Service and Flocculation Ponds are the highest unsupported batters in the main body of the mine. In addition, the crest of this batter ranges from 150 - 500 metres from the Morwell River which is prone to flooding in the winter months.

The batter comprises approximately 10 metres of overburden overlying approximately 45 - 50 metres of coal. The coal/interseam interface is relatively flat . The presence of the Morwell River and the saturated overburden surrounding it have been taken into account when determine the initial water tables for the stability analysis of the section. The geology of this batter is represented by Section 1 and shown in Figure 10.

3.5.2 Stability Analysis Results

The stability analyses results are shown in Figure 10. The plot of factor of safety versus chainage along the batter indicates a minimum factor of safety of 1.1 at the batter crest. The factors of safety increases with increasing distance from the batter crest, indicating the batter becomes more stable.

Factors of safety below flood level vary between 1.0 and 1.1, with the lowest factors of safety occurring at the toe of the batter. As previously explained in this report once the batter is submerged the destabilising forces provided by the water in the batter are balanced by the stabilising forces provided by the flood waters. Therefore, on a flat interseam batter such as this one, there are no further destabilising forces which may act on the sections of batter with low factors of safety. It is therefore considered to be extremely unlikely that the submerged section of the batter will fail once it is flooded.

3.6 STABILITY ANALYSIS - YALLOURN WESTERN BATTERS

3.6.1 General

Section 2 was analysed to determine the overall stability of the Yallourn Western Batters under flooded conditions. Section 2 is equivalent to Section 6 as defined in report MGD 10 (1991) and Geo-Eng Pty Ltd report 1256/4. Figure 11 shows the batter and water level geometry.

As can be seen in Figure 11 the analysis has assumed that all overburden scheduled for excavation has been removed and that the Surcharge Dump has been placed to the level indicated in Geo-Eng Pty Ltd report 1256/4 (ie:- reduced from RL 33.5 to RL 26 metres). In addition, the analysis assumes that the internal overburden dump has been placed against the toe of the Western Batters as indicated in current development plans.

3.6.2 Stability Analysis Results

Analysis of the stability of the Western Batters were carried out for four water level scenarios shown on the section in Figure 11 using the methods outlined in Report MGD 10. The analyses show that the batter achieves factor of safety of 1.25, which exceeds the minimum recommended factor of safety, when flooded to the final level of RL 38 metres.

Analysis of the permanent batter indicates that the overall stability is extremely dependent on the presence of the internal overburden dump. To ensure the stability of the Western Batters it is **essential** that the internal overburden dump is placed to a minimum of RL 10 along the toe of the permanent Western Batters.

Stability analyses were also carried out to determine the stability of the Surcharge Dump if the mine is flooded. These analyses show the Surcharge Dump has an acceptable long term factor of safety, in excess of 1.2, at all stages of flooding.

3.7 STABILITY ANALYSIS - NORTHERN BATTERS, YEF

3.7.1 General

Section 3 was used to analyse the stability of the northern permanent batter of Yallourn East Field. The batter comprises of approximately 10 metres of overburden overlying 50 metres of coal with a flat coal/interseam interface (refer Figures 12 and 13). The section takes into account the presence of an existing external overburden dump which extends along much of the northern batter and its effect on the overburden and coal water levels.

Two water level profiles were analysed for the batter. These were:-

- a relatively high water table which assumes a high rate of seepage from the overburden dump which is only partially controlled by horizontal drains
- a lower water table which assumes a lower rate of seepage from the dump which is easily controlled using horizontal drains

As noted in Section 3.2 of this report recent testing of interseam samples has indicated that the current value of the residual friction angle adopted for analyses (Ø'r = 12°) may be conservative. For this reason the stability of the northern batter has been assessed using the residual friction angles ($Ø'_r$) of 12° and 14°.

3.7.2 Stability Analysis Results - High Water Table

Plots of factor of safety versus chainage (refer Figure 12), indicate that the factor of safety at the batter crest reduces from its original, unflooded, value of 1.53 to a minimum value of 1.05 when the batter is submerged to approximately 50 % of its height (RL 12 metres). The factor of safety at the batter crest then gradually increases to 1.13 once the mine is fully flooded to RL 38 metres.

A factor of safety of 1.05 for a partially submerged batter is not considered to be acceptable as considerable potential still exists, at this point, for relatively large destabilising forces to build up in coal joints above the flood level.

The northern batter was then analysed with identical flood water levels and a friction angle of 14°. This analysis showed that the factor of safety dropped from its original value of 1.78 at the batter crest to 1.11 when flooded to 50 % of its overall height. The factor of safety then increased to 1.16 when the mine was fully flooded. These factors of safety are considered to be more acceptable than those obtained from the analysis carried out for a friction angle of $Ø'_r$ = 12°.

Submerged sections of the batter, particularly at the toe, have low factors of safety, in the range of 1.0 - 1.3. As explained more fully in Section 3.4.2 of this report, the submerged sections of the batter will remain stable despite the low factors of safety as no further driving forces are able to act on the batter once it is submerged.

3.7.3 Stability Analysis Results - Low Water Table

Plots of factor of safety versus chainage along the batter are shown in Figure 13. When analysed with a friction angle of 12° the factor of safety at the batter crest was found to drop from its original level of 8.04 to a minimum of 1.13 when the batter is fully flooded. When analysed with a friction angle of 14° the factors of safety range from 9.4 to 1.28 when flooded to RL 38 metres.

The factors of safety obtained from the analysis for both friction angles (12° and 14°) are considered acceptable once the mine is flooded to the final level of RL 38 metres.

Once again the toe of the batter showed low factors of safety once flooded with values approaching 1.0 . However, it is considered that little or no additional driving forces can act on the batter to destabilise it and it is therefore considered that the overall factor of safety against failure is satisfactory.

Further discussion of the results of the stability analysis will be made in Section 3.9 of this report.

3.8 STABILITY ANALYSIS RESULTS - SOUTHERN BATTERS YEF

3.8.1 General

Section 4 was used to analyse the stability of the southern permanent batter of Yallourn East Field (refer Figure 14 and 15). The batter comprises of approximately 9 metres of overburden overlying 70 metres of coal with a relatively flat coal/interseam interface. The section takes into account the presence of the Morwell River Diversion Channel which extends along the entire length of the southern batter and its effect on the overburden and coal water levels.

The stability of the section was analysed using the water levels shown in Figure 14 and 15. High and low water table options were analysed for stability. Figure 14 shows the higher water table which assumes relatively high rates of seepage under the River Diversion Cut-off and Figure 15 shows the lower water table which assumes a lower, more readily controllable rate of seepage.

As noted in Section 3.2 of this report recent testing of interseam samples has indicated that the value of the residual friction angle adopted for analyses carried out to date may be conservative. Therefore the stability of the southern batter was also assessed using the residual friction angles ($Ø'_r$) of 12° and 14°.

3.8.2 Stability Analysis Results - High Water Table

Plots in Figure 14, showing the factor of safety versus chainage, indicate that the factor of safety at the batter crest drops from its original value of 2.14 to a minimum of 1.09 when the batter is flooded to RL 38 metres and analysed with a friction angle of 12°.

The southern batter was then re-analysed with identical flood water levels and a friction angle of 14°. This analysis showed that the factor of safety dropped from its original value of 2.52 at the batter crest to 1.1 when fully flooded.

The factors of safety obtained for analyses at both friction angles (12° and 14°) are lower than is generally acceptable for the long term stability of the batter. However, because the southern batters are almost fully submerged, it is considered that no additional driving forces are likely to act on the batter to destabilise it. Therefore the long term stability of the batter is considered to be satisfactory.

Submerged sections of the batter, particularly around the toe, have very low factors of safety which approach 1.0. As explained in Section 3.4.2, the submerged sections of the batter should remain stable despite the low factors of safety as no further driving forces are able to act on the batter once it is submerged.

3.8.3 Stability Analysis Results - Low Water Table

As can be seen in Figure 15 the factor of safety, assuming a friction angle of 12°, at the batter crest drops from its original level of 4.81 to a minimum of 1.09 once the batter is fully flooded. When analysed with a friction angle of 14° the factors of safety range from 5.64 to 1.1 when flooded to RL 38 metres.

These factors of safety for both friction angles are considered satisfactory once the mine is flooded to the final level of RL 38 metres. It is considered that little or no additional driving forces could be applied to the batter and it is therefore considered that the overall factor of safety against failure is unlikely to drop further.

Once again the toe of the batter showed low factors of safety once flooded with values approaching 1.0, however as previously explained this factor of safety is not considered to be critical.

Further discussion of the results of the stability analysis will be made in Section 3.9 of this report.

4 DISCUSSION OF YEF ANALYSIS RESULTS

The stability of a submerged batter is dependent on the water levels in the batter prior to the initiation of the flooding program. As the East Field batters have yet to be excavated the final, pre-flooding, water level profile can only be predicted by using experienced gained from monitoring of existing, geologically similar, batters at other Latrobe Valley mines.

Monitoring data indicates the water level profile in a typical Latrobe Valley coal batter generally rises at an angle of 7° - 9° from the toe of the batter. However, the overburden on these batters has generally been clayey and unsaturated and therefore contributes little to the recharge of groundwater levels in the batter.

The overburden at East Field, in contrast, is sandy and saturated. At this time it is unclear how much of an effect the recharge from the saturated overburden and from sources such as the overburden dump on the northern batters and the River Diversion on the southern batters will have on the water and pore pressure profiles in the East Field batters. However, it is felt that drilling of horizontal drains into the permanent batters will result in a water and pore pressure profile approaching that in Figures 13 and 15 (ie:- the lower water tables).

An ongoing program to determine the interseam shear strength parameters is currently under way at Yallourn East Field. Interseam strength data obtained since the last review indicate that the preliminary design parameters (ie: c' = 0 kPa and Ø' = 12°) for the Yallourn East Field permanent batters may be conservative. Further interseam testing should be carried out over the next 5 years and it is anticipated that the interseam strength parameters will prove to be higher than the 12° originally assumed for the analyses.

Work carried out to date indicates that the northern and southern batters at Yallourn East Field will be stable during and following flooding to RL 38 metres. However, this conclusion is dependent on the following:-

- further interseam testing confirming the residual friction angle is greater than the 12° currently assumed in the original analyses.
- the water and pore pressure levels in the batters being lowered to levels approaching those shown in Figures 13 and 15.

5 CONCLUSIONS

The following conclusions have been drawn from the batter stability assessment of the "generic" and permanent batters carried out as part of this review into flooding of the Yallourn Mine:-

- All permanent batters within the Yallourn and Yallourn East Field Mines are expected to be stable under both partial and fully flooded conditions.

- The rate of flooding of the Mine will effect the rate of water and pore pressure build up in the coal batters and the underlying interseams. If the rate of filling of the Mine is relatively slow the water levels in the coal should rise at a similar rate to the flood level. However pore pressures in the clayey interseam materials are anticipated to rise at a much slower rate than the pressures in the coal.

- The analysis of the "generic" batter indicates that the stability of a flooded batter deteriorates most in the early stages of flooding, however once the batter is flooded to approximately 40 - 50 % of its total height the rate of deterioration in batter stability becomes relatively small and once flooded satisfactory conditions should occur.

- Analyses of the "generic" batters show that the dip of the interseam below a submerged batter effects the stability of the batter by increasing or decreasing the hydrostatic and gravity forces acting on the batters. Flooding the batter reduces the influence of hydrostatic forces on the stability of the batter.

- Flooding of the Mine is not expected to cause major ground movements to adjacent or at a distance from the Mine.

- The potential for both large and small scale batter instability above flood water level decreases with increasing levels of flooding.

- Stability analyses carried out for the south eastern batters (Section 1) indicate the batter will have an adequate level of stability when partially and fully flooded. Factors of safety in the submerged sections of the batter were below recommended levels, however, the batter is not expected to become unstable.

- Stability analyses carried out on the Western Batters (Section 2) show the batter will be stable when flooded provided the internal overburden dump is placed to at least RL 10 metres along the toe of the entire permanent batter.

- Stability analyses indicate that the northern and southern batters at Yallourn East Field should be stable when flooded to RL 38 metres provided further interseam testing confirms the residual friction angle is greater (ie:- around 14°) than the current design value (12°) and the water and pore pressure levels in the batter are able to be reduced to the levels shown Figures 12 and 14.

6 RECOMMENDATIONS

Based on the conclusions listed above the following recommendations are made:-

- The internal overburden dump should be placed to at least RL 10 metres along the entire length of the permanent Western Batters.

- Installation of horizontal bores along the northern and southern batters of Yallourn East Field be undertaken to reduce the groundwater levels and achieve satisfactory stability conditions.

- A further review of the stability of the submerged batters at East Field should be undertaken when sufficient additional interseam testing is carried out and a section of coal batter is fully developed to confirm the adopted shear strength and groundwater conditions.

- The current interseam sampling and testing program should continue until a sufficient number of direct shear tests are available to reliably define the design parameters.

7 REFERENCES

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Geo-Eng Pty Ltd (1993):- Yallourn Open Cut, Mine Rehabilitation, Assessment of Open Cut Stability, Proposed Flooding Option. Geo-Eng Pty Ltd Report 1155/5.

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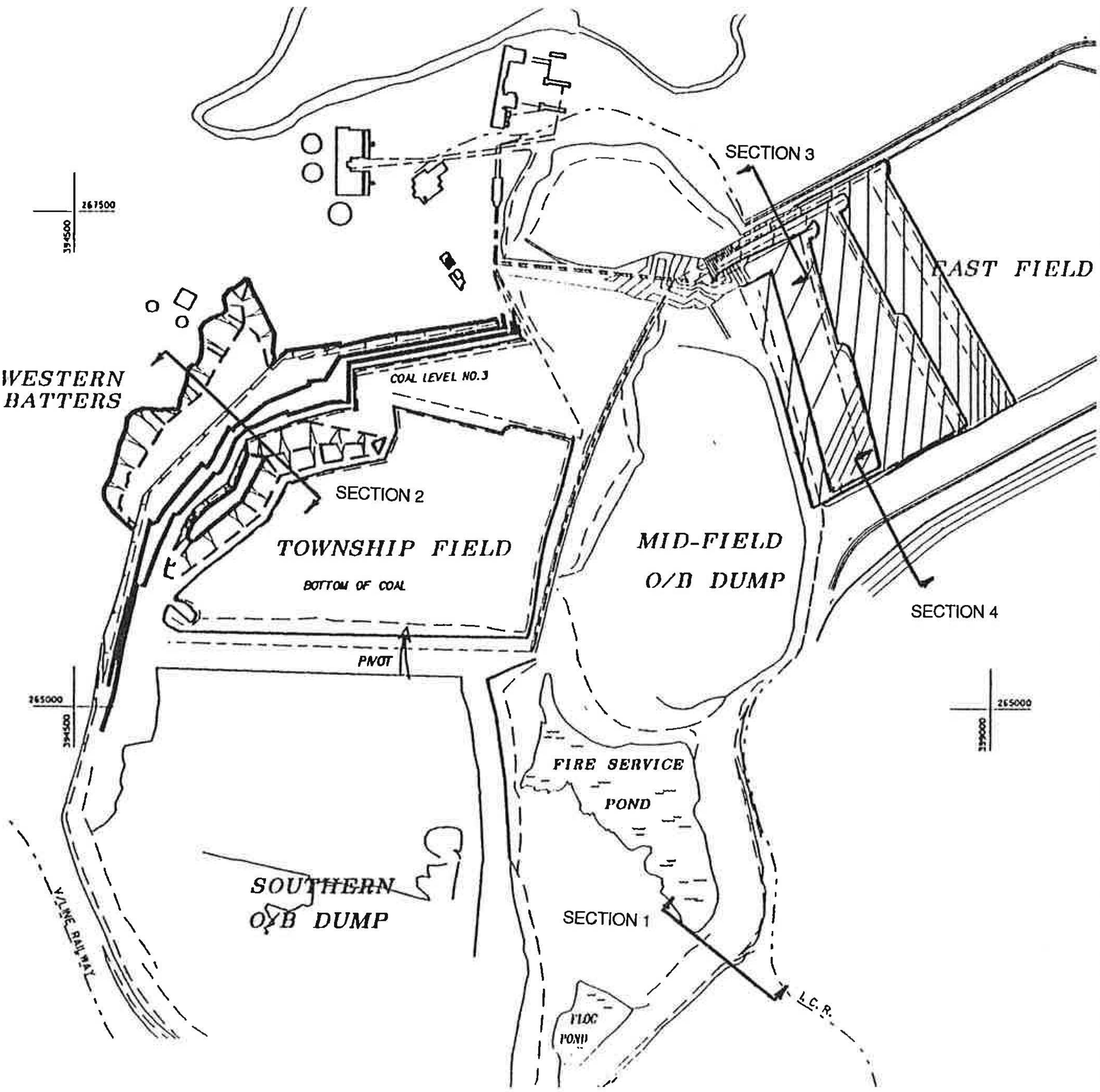
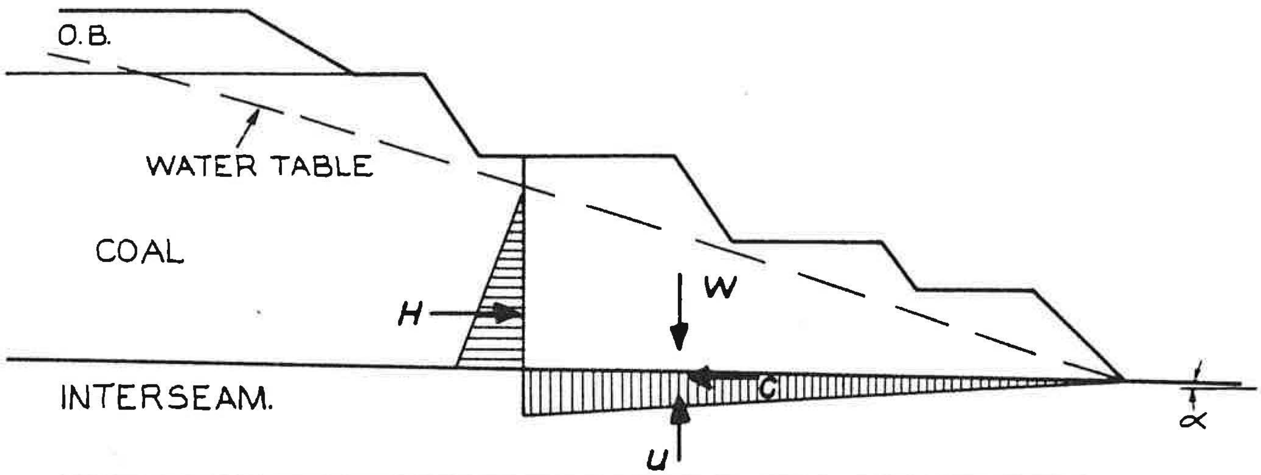
LIST OF FIGURES

FIGURES



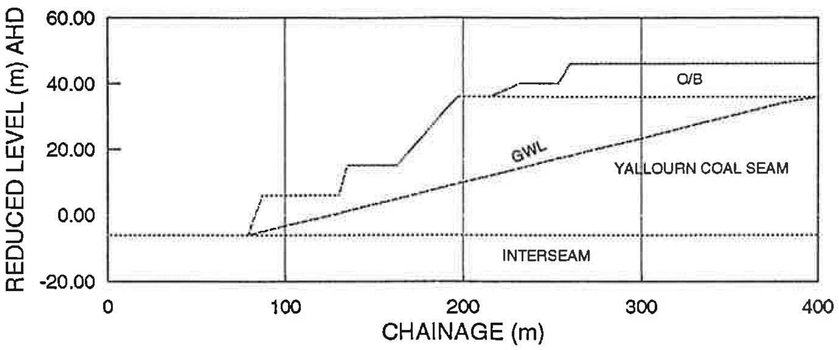
SCALE	N.T.S	GEO-ENG PTY LTD	FIGURE 1
DATE	21/12/94	YALLOURN MINE FLOOD STUDY	
DRAWN	JAS	LOCATION OF SECTIONS	
APPROVED	AGJ	ANALYSED FOR STABILITY	

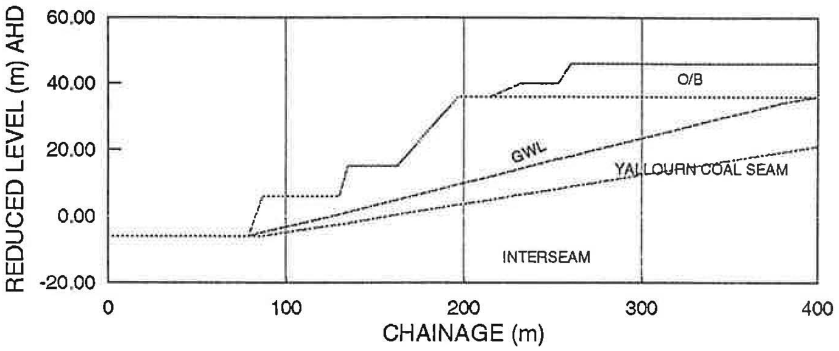


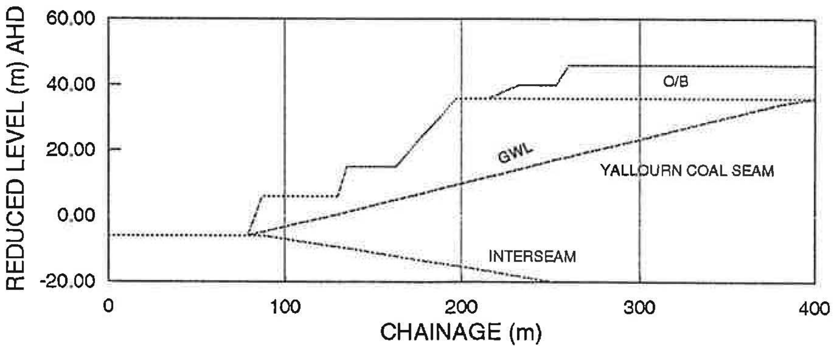
FACTOR OF SAFTEY = $\dfrac{C + (W-U)\tan(\phi-\alpha) - U\sin\alpha}{H}$

H = WATER FORCE
W = WEIGHT OF BLOCK
U = UPLIFT DUE TO PIEZOMETRIC PRESSURE.
C = COHESIVE FORCE
α = SLOPE OF BASE
Ø' = SHEAR FRICTON ANGLE

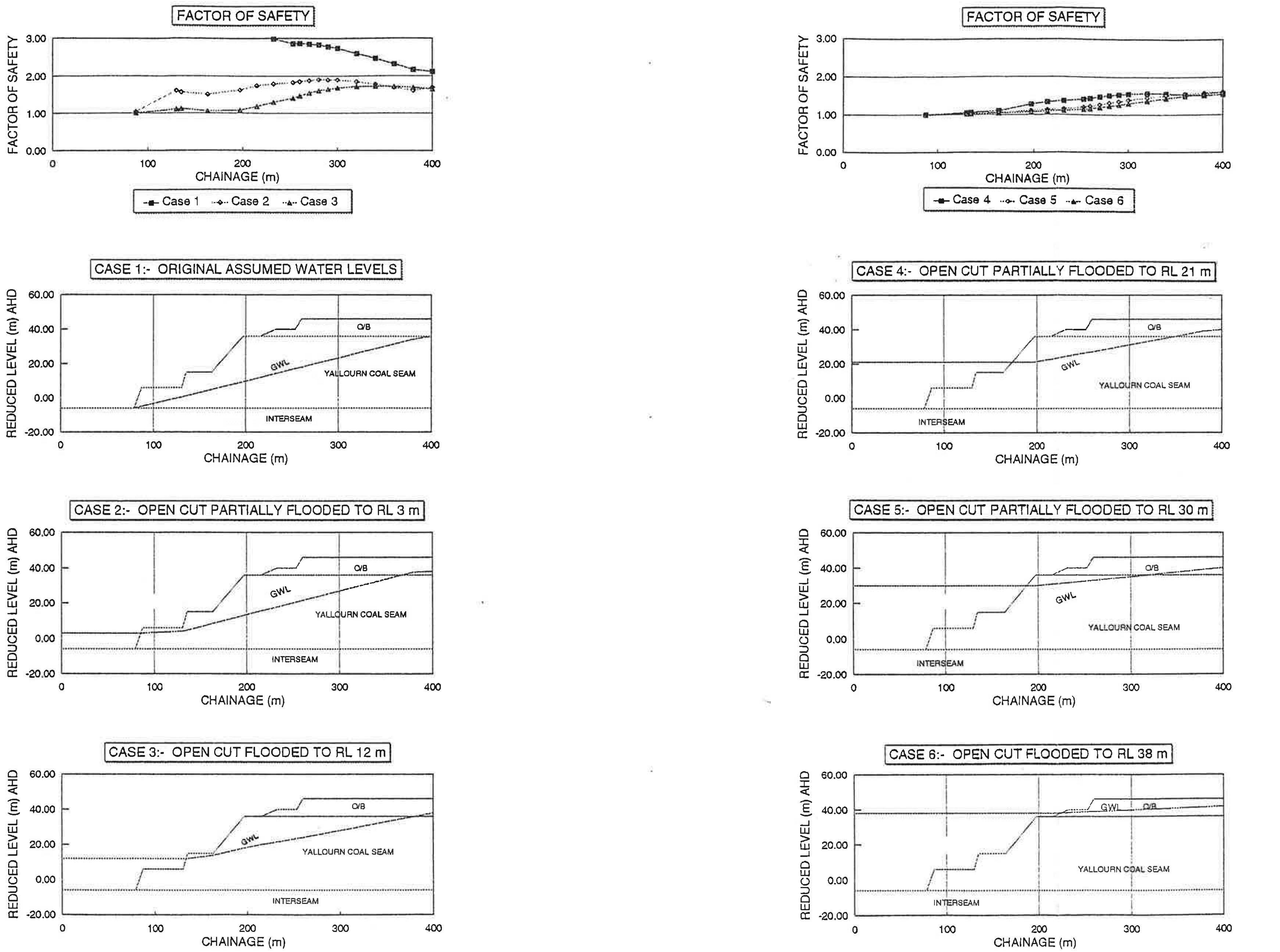
SCALE N.T.S	GEO-ENG PTY LTD	FIGURE	2
DATE 21/12/94	YALLOURN MINE FLOOD STUDY		
DRAWN JAS	BLOCK SLIDING MECHANISM		
APPROVED AGJ			







SCALE N.T.S	**GEO-ENG PTY LTD**	**FIGURE**	**3**
DATE 21/12/94	**YALLOURN MINE FLOOD STUDY**		
DRAWN JAS	**GENERIC CROSS - SECTIONS**		
APPROVED AGJ	**ORIGINAL WATER LEVELS**		



SCALE	N.T.S	GEO-ENG PTY LTD	FIGURE 4
DATE	21/12/94	YALLOURN MINE FLOOD STUDY	
DRAWN	JAS	GENERIC ANALYSIS	
APPROVED	AGJ	HORIZONTAL COAL / INTERSEAM INTERFACE	

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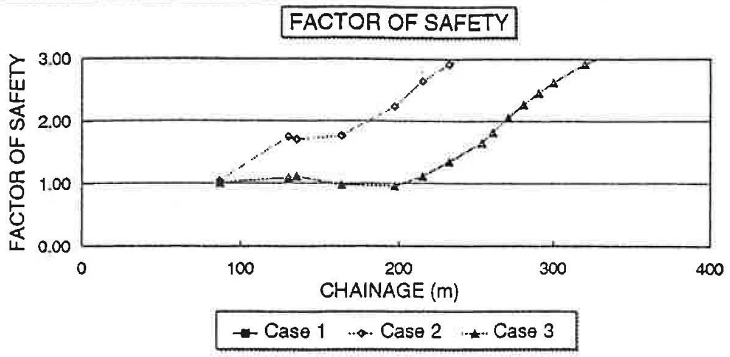
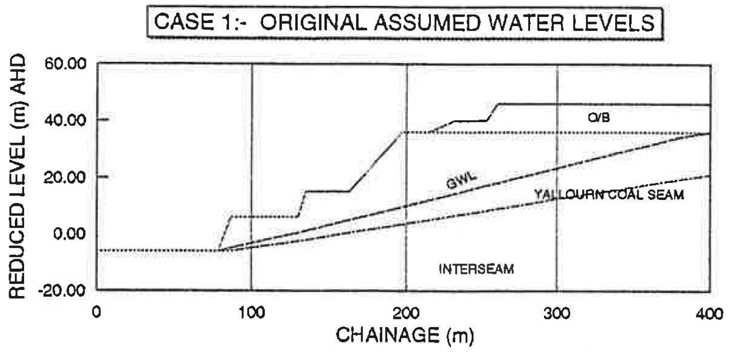
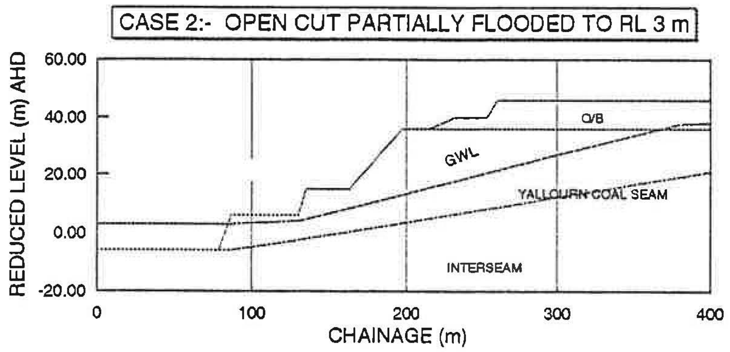
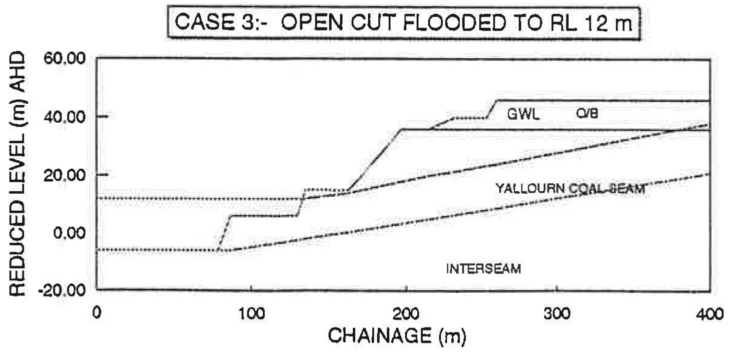
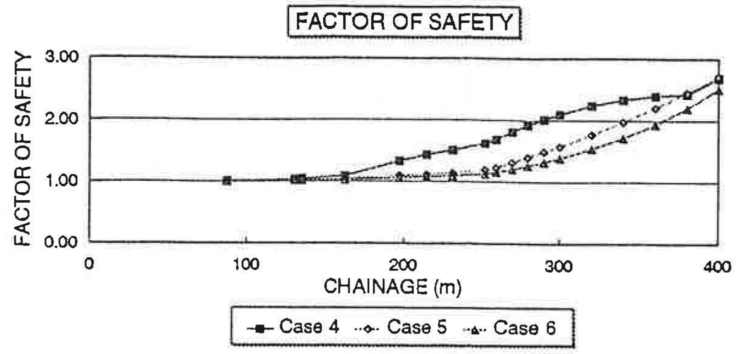
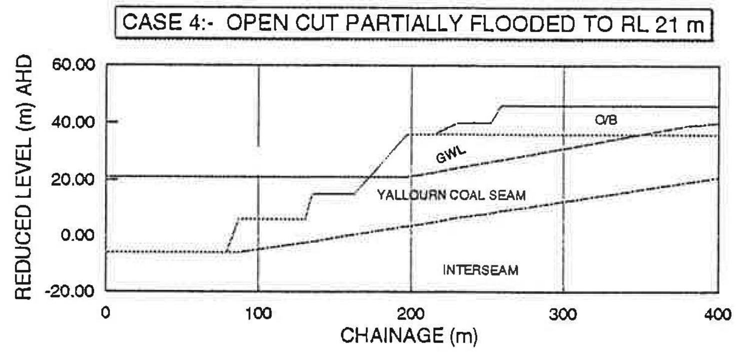


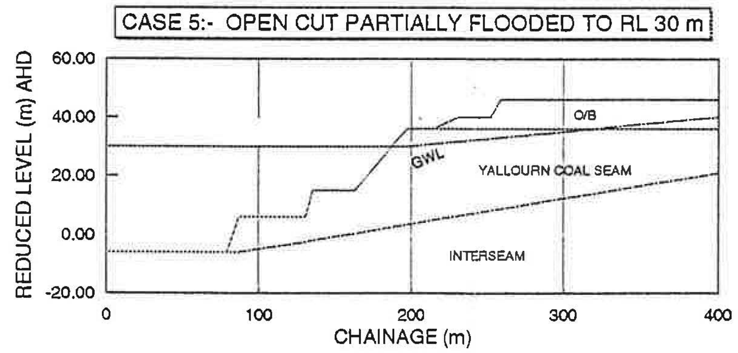


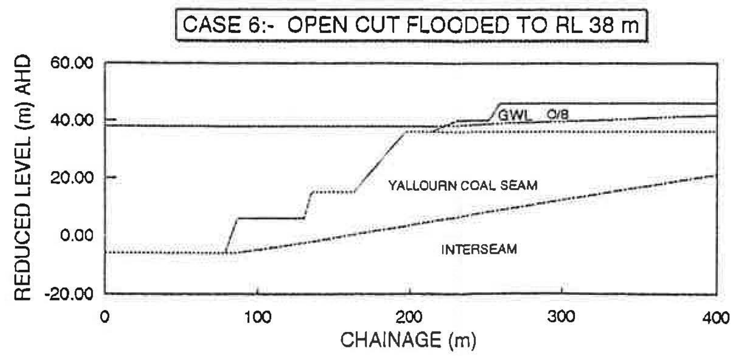




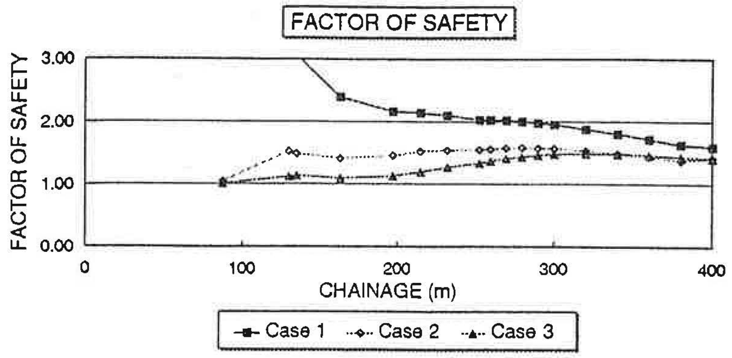


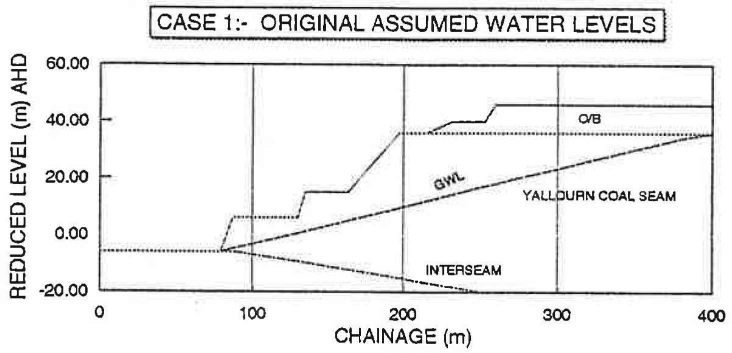


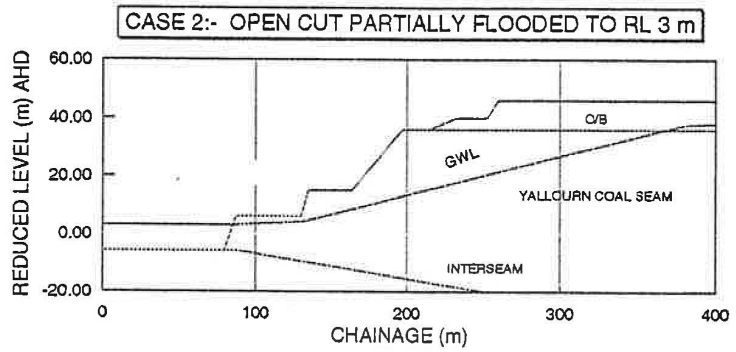


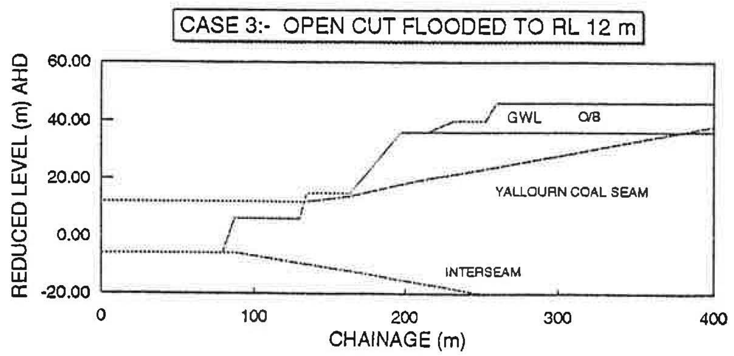


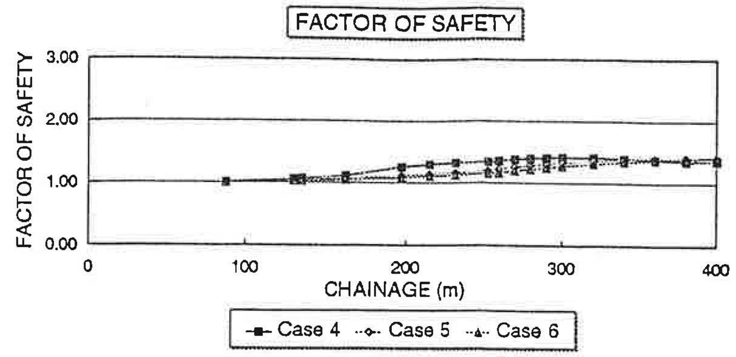
SCALE	N.T.S	GEO-ENG PTY LTD	FIGURE 5
DATE	21/12/94	YALLOURN MINE FLOOD STUDY	
DRAWN	JAS	GENERIC ANALYSIS	
APPROVED	AGJ	INTERFACE DIPPING OUT OF BATTER	

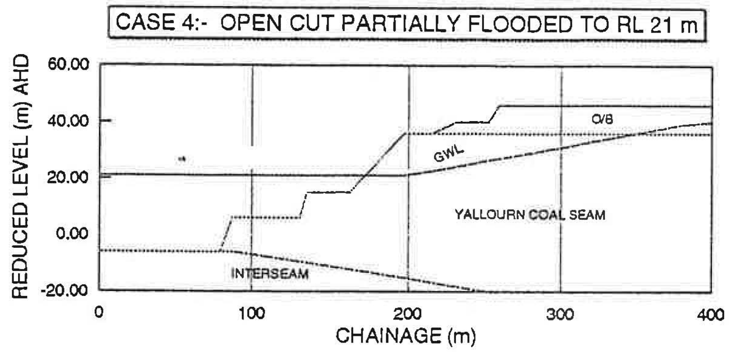


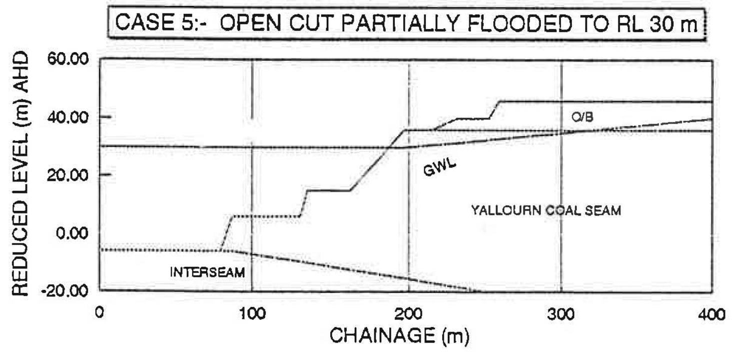


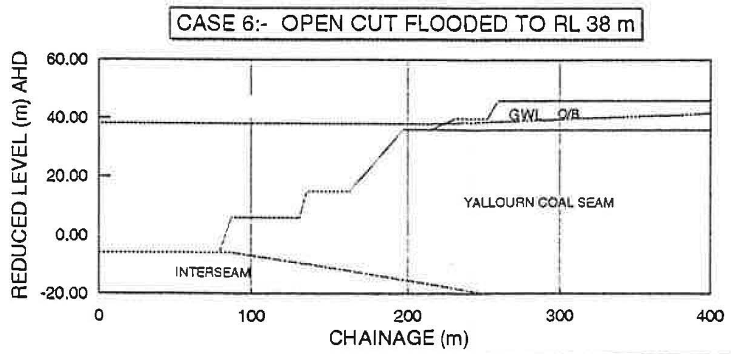




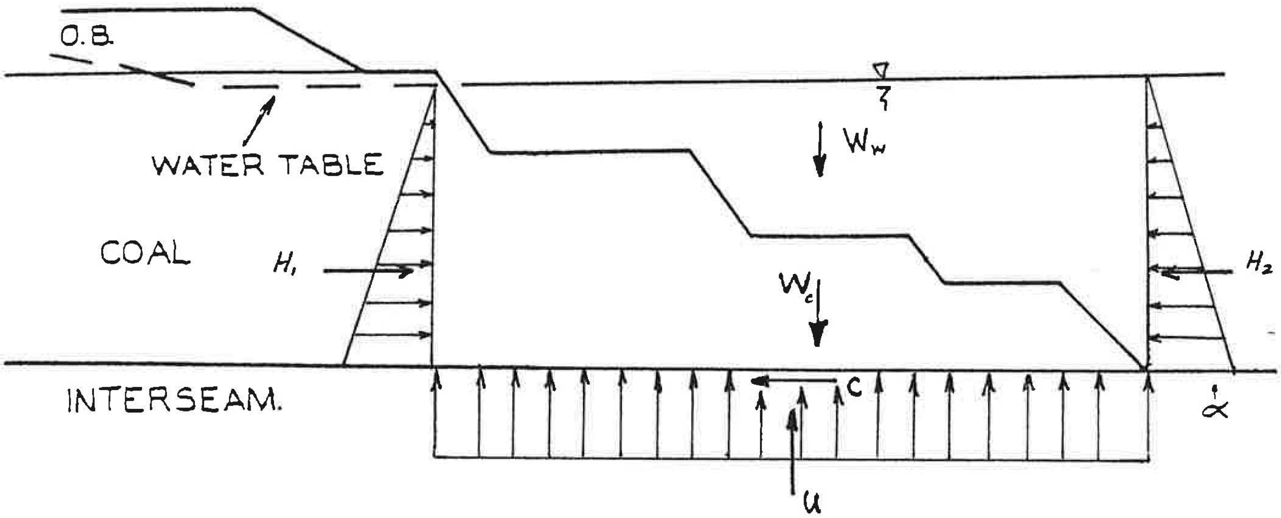








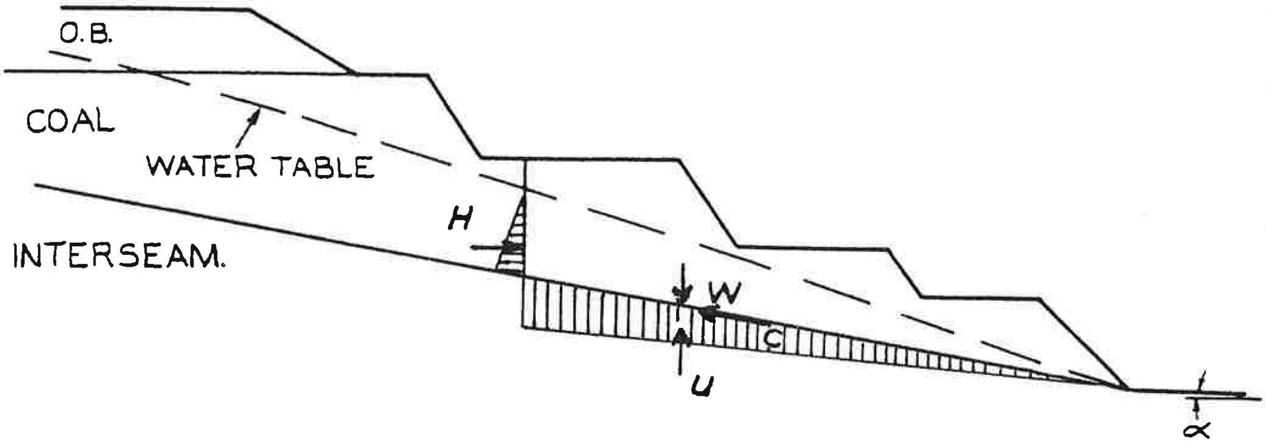
SCALE	N.T.S	GEO-ENG PTY LTD	FIGURE 6
DATE	21/12/94	YALLOURN MINE FLOOD STUDY	
DRAWN	JAS	GENERIC ANALYSIS	
APPROVED	AGJ	INTERFACE DIPPING INTO BATTER	

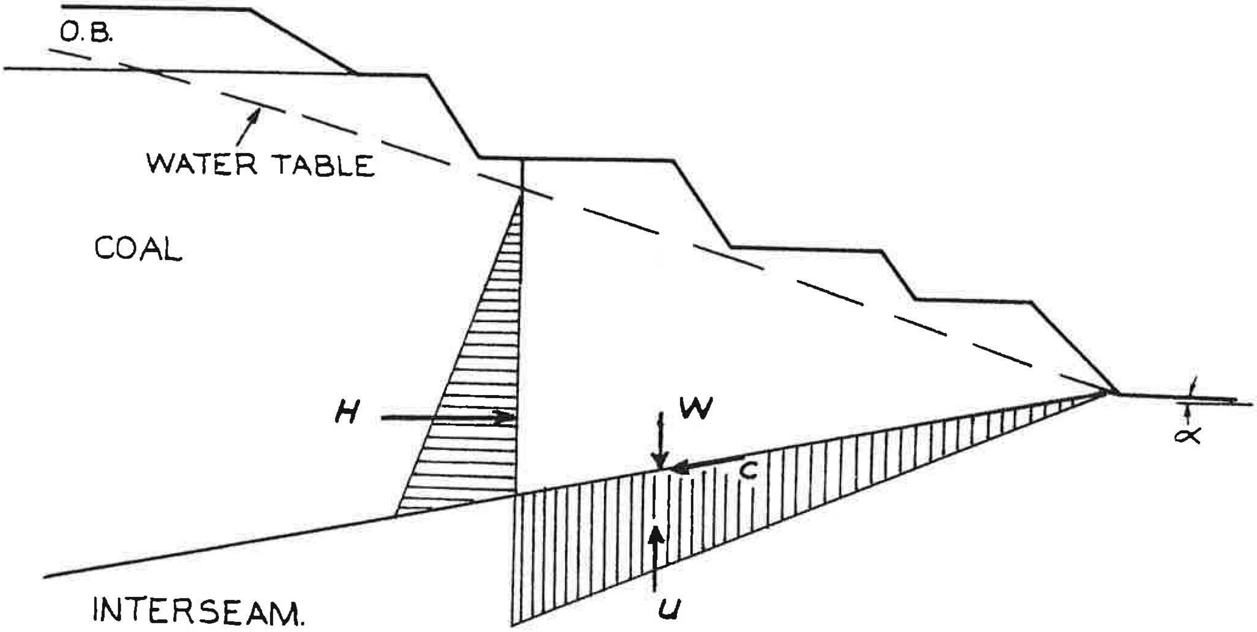


$H_{1,2}$ = WATER FORCES
W = WEIGHT OF BLOCK & WATER ABOVE BLOCK
U = UPLIFT DUE TO PIEZOMETRIC PRESSURE.
C = COHESIVE FORCE
α = SLOPE OF BASE

NOTE: $H_1 = H_2$

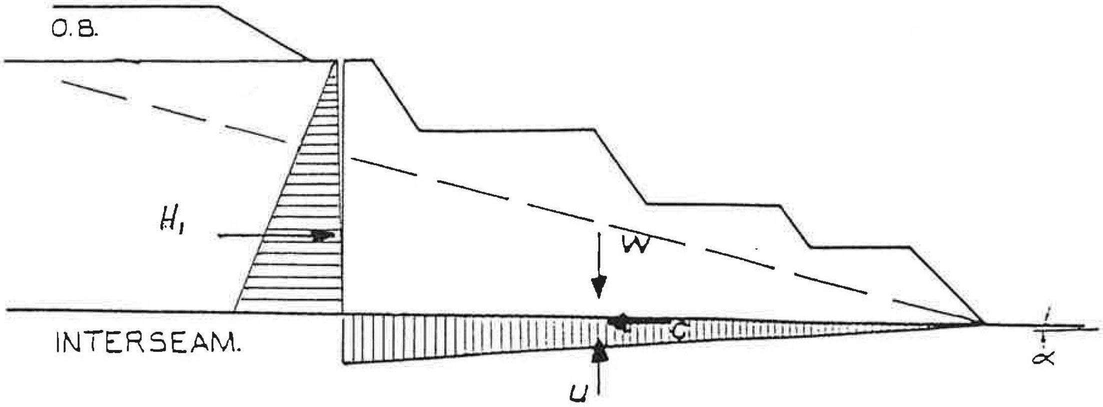
SCALE	N.T.S	GEO-ENG PTY LTD	FIGURE 7
DATE	21/12/94	YALLOURN MINE FLOOD STUDY	
DRAWN	JAS	DRIVING FORCES ACTING	
APPROVED	AGJ	ON A FLOODED BATTER	



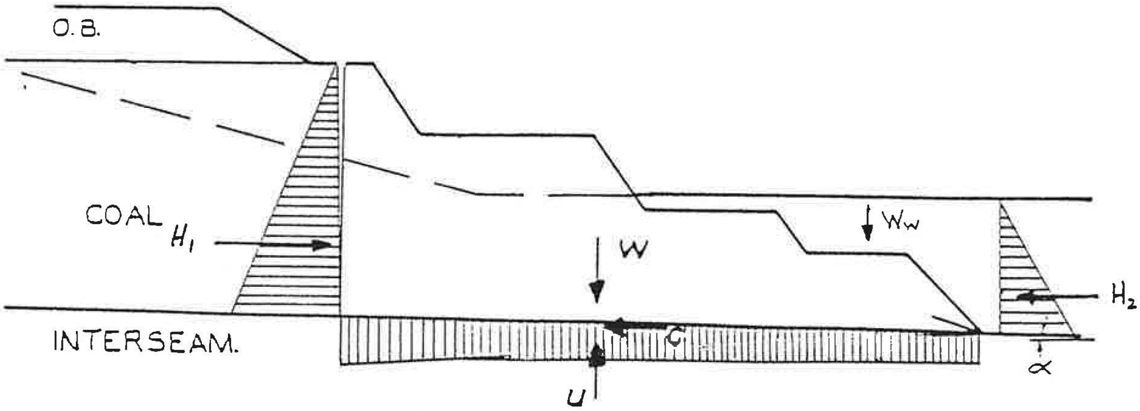


H = WATER FORCE
W = WEIGHT OF BLOCK
U = UPLIFT DUE TO PIEZOMETRIC PRESSURE.
C = COHESIVE FORCE
α = SLOPE OF BASE

SCALE	N.T.S	GEO-ENG PTY LTD	FIGURE 8
DATE	21/12/94	YALLOURN MINE FLOOD STUDY	
DRAWN	JAS	EFFECT OF DIPPING INTERSEAMS ON	
APPROVED	AGJ	DRIVING FORCES	

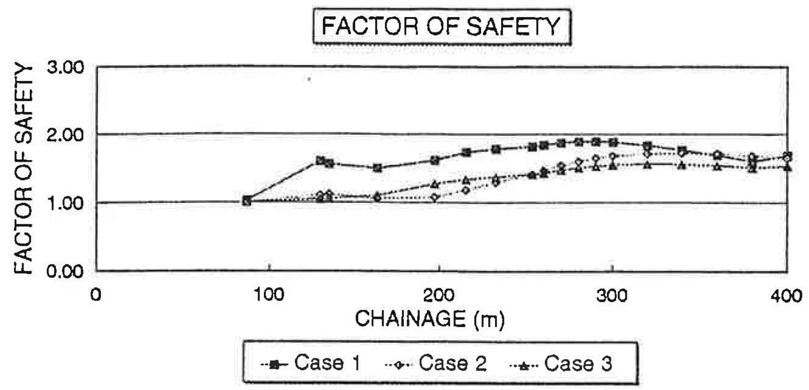


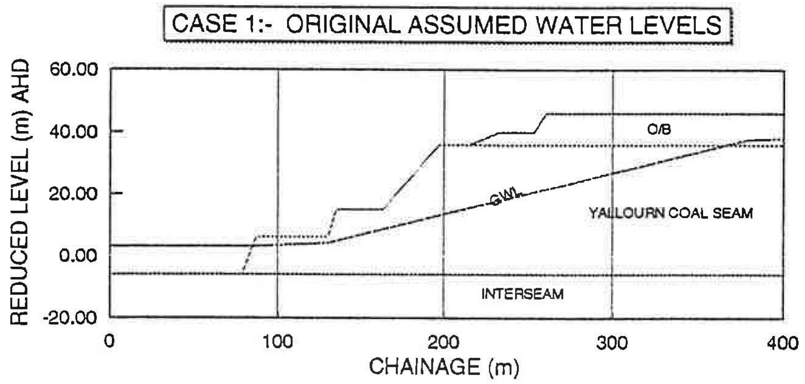
Unflooded batter, water builds up quickly in crack following heavy rain. Pore pressures at base of the coal do not react. Hydrostatic pressure in crack adds a large driving force (H_1) to the batter.

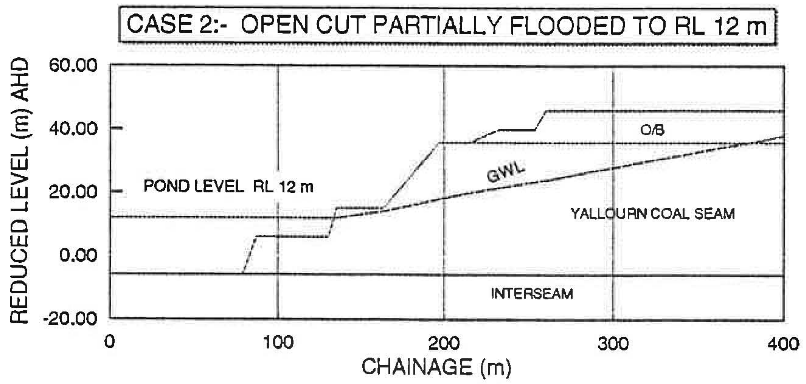


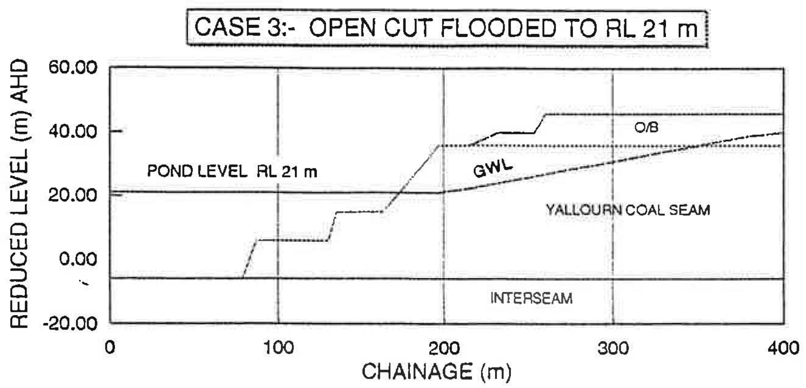
Partially flooded batter. Water builds up quickly in crack following heavy rain. Pore pressures at base of the coal are already slightly elevated due to the flood water but do not react to the joint water. Hydrostatic pressure in the crack adds a large driving force (H_1) to the batter, however this force is partially balanced by force H2 provided by the flood water.

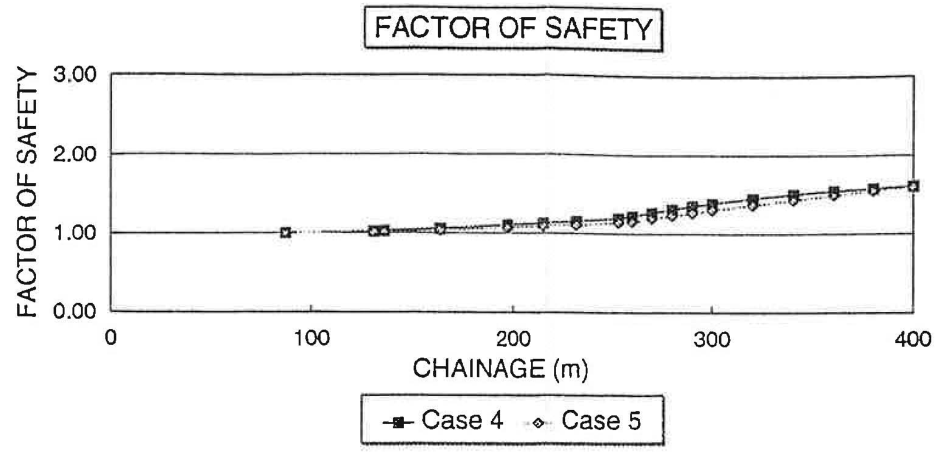
SCALE	NTS	GEO - ENG PTY LTD	FIGURE 9
DATE	09/06/95	YALLOURN MINE FLOOD STUDY	
DRAWN	AGJ	WATER PRESSURES ACTING ON A	
APPROVED	EW	PARTIALLY FLOODED BATTER	

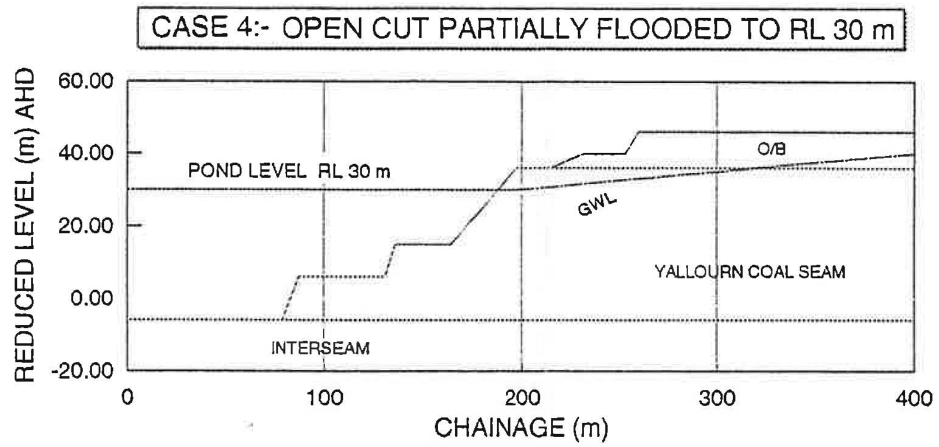


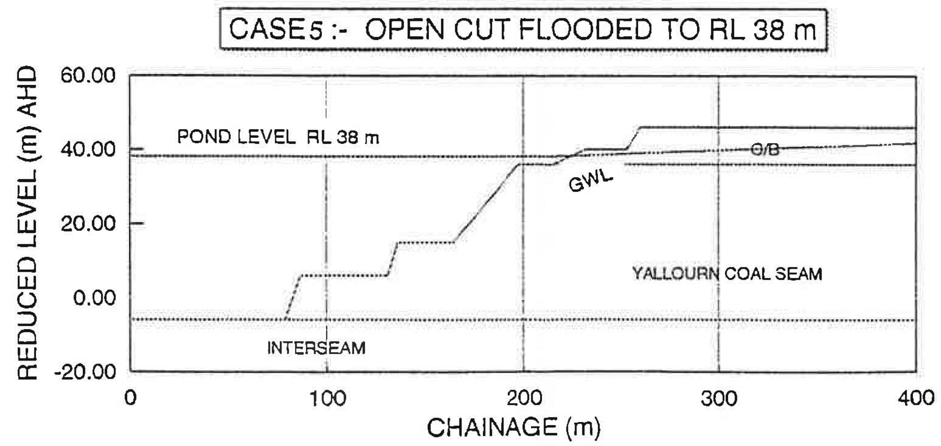




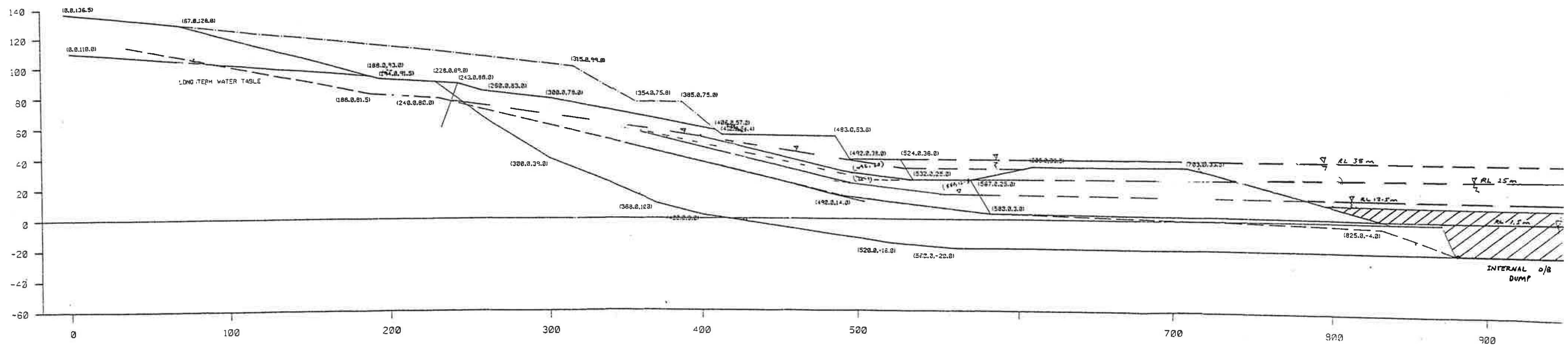








SCALE	N.T.S	GEO-ENG PTY LTD	FIGURE 10
DATE	21/12/94	YALLOURN MINE FLOOD STUDY	
DRAWN	JAS	SECTION 1	
APPROVED	AGJ	SOUTH EASTERN BATTERS	



SCALE	N.T.S	GEO-ENG PTY LTD	FIGURE	11
DATE	21/12/94	YALLOURN MINE FLOOD STUDY		
DRAWN	JAS	SECTION 2		
APPROVED	AGJ	WESTERN BATTERS		

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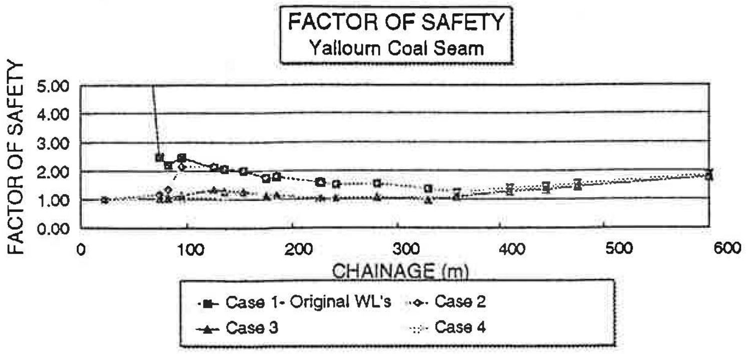
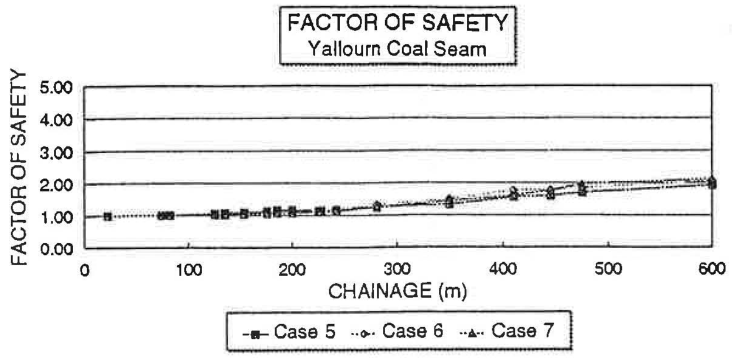
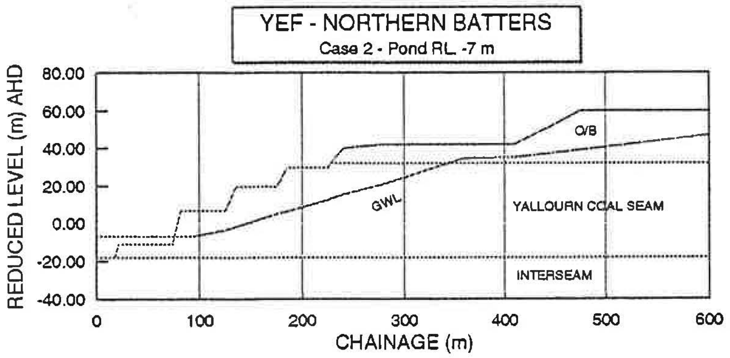
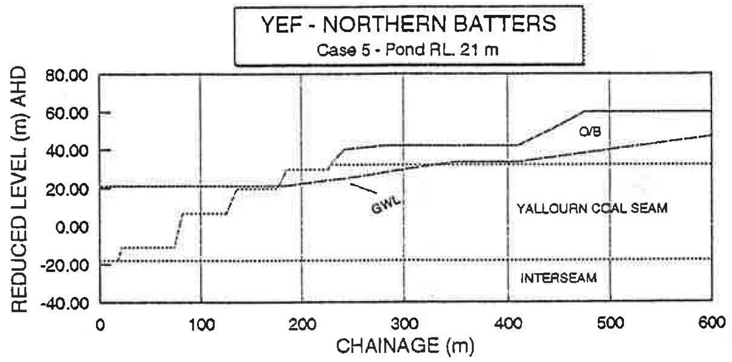
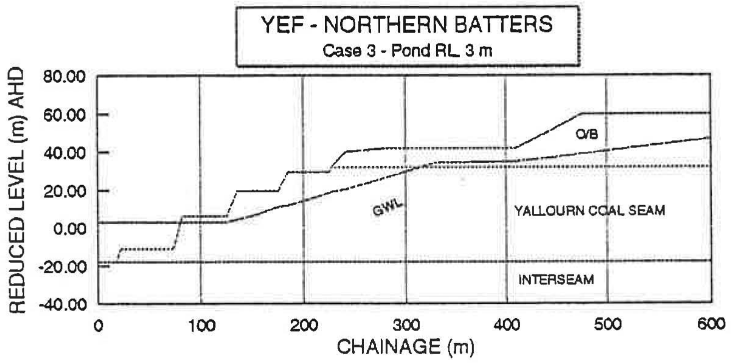
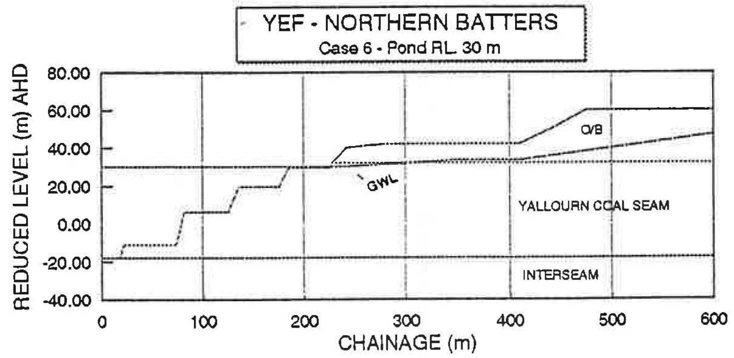


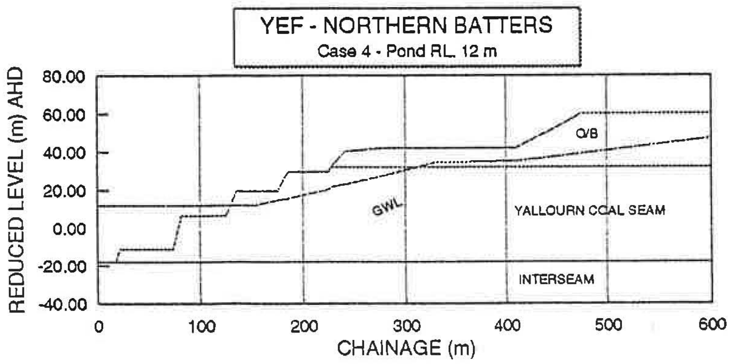


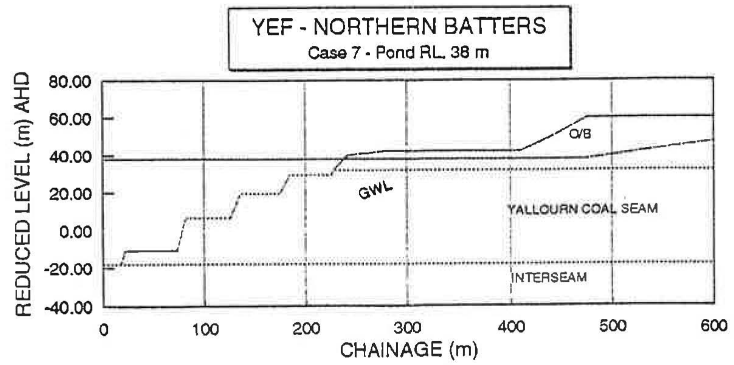




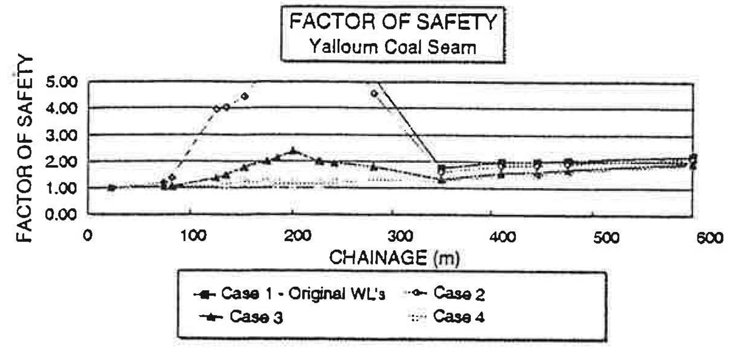


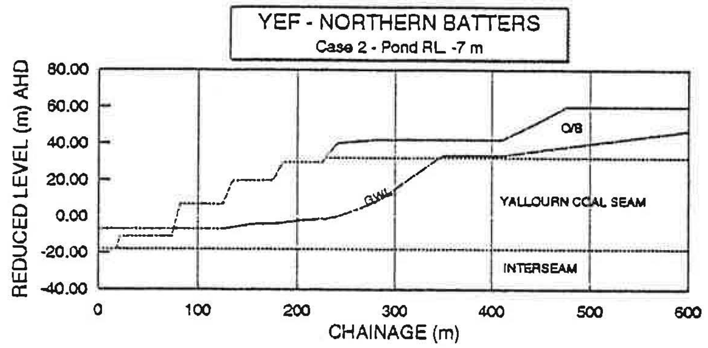


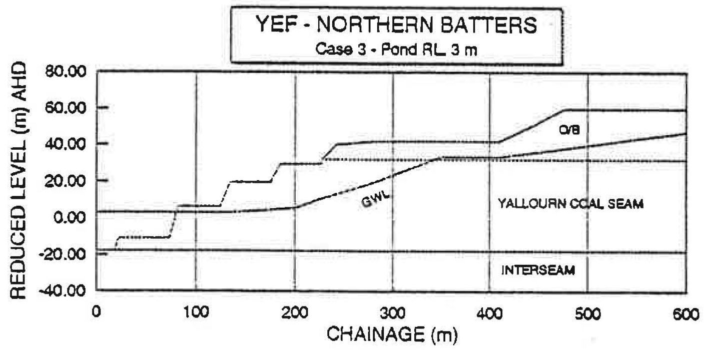


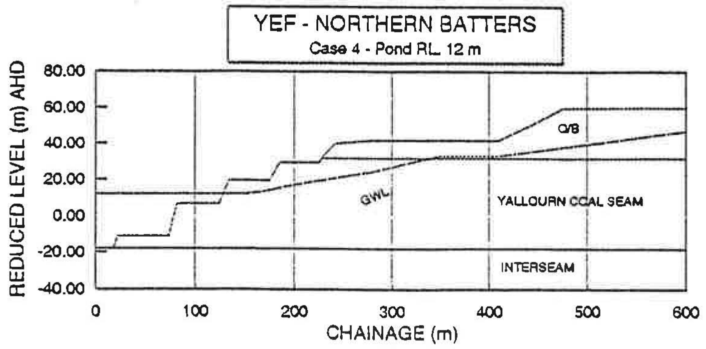


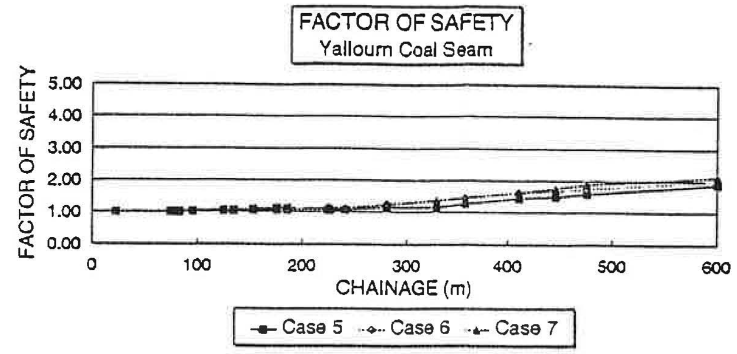
SCALE	N.T.S	GEO-ENG PTY LTD	FIGURE 12
DATE	21/12/94	YALLOURN MINE FLOOD STUDY	
DRAWN	JAS	SECTION 3 - YEF NORTHERN BATTERS	
APPROVED	AGJ	HIGH WATER TABLE	

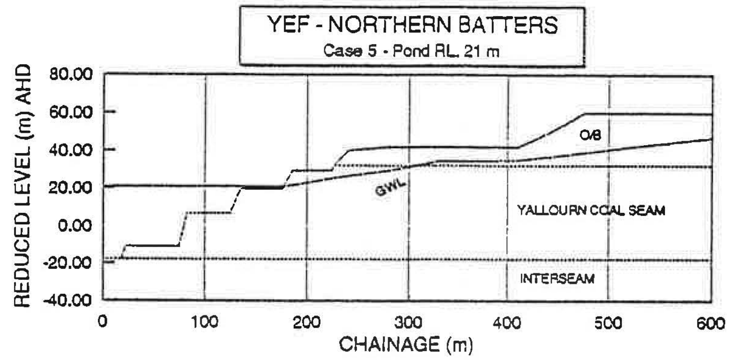


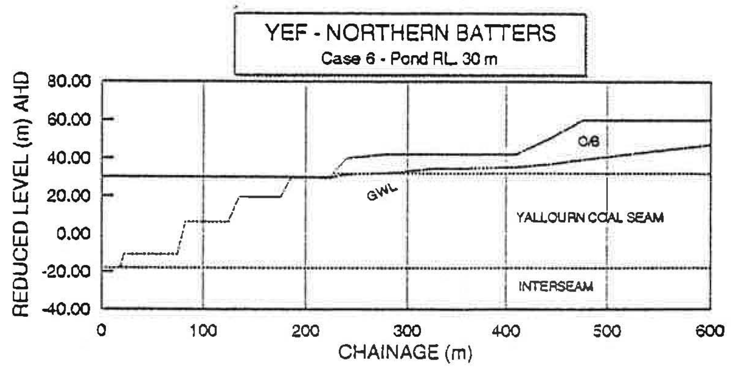


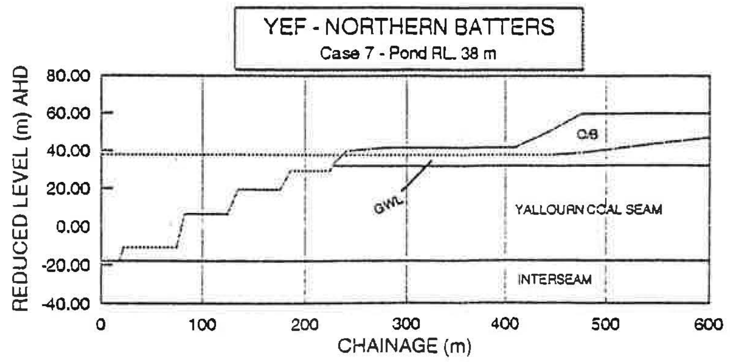




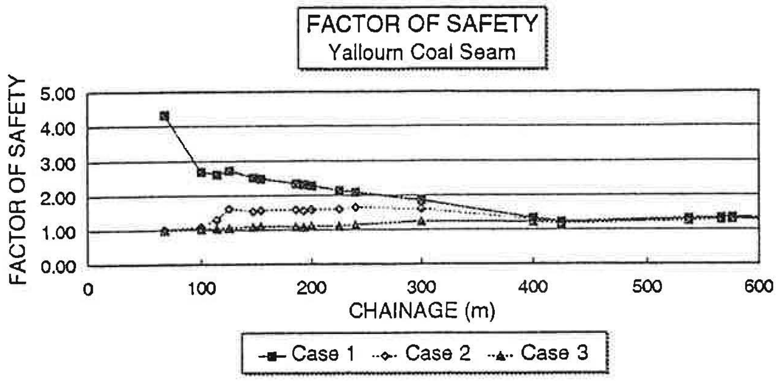


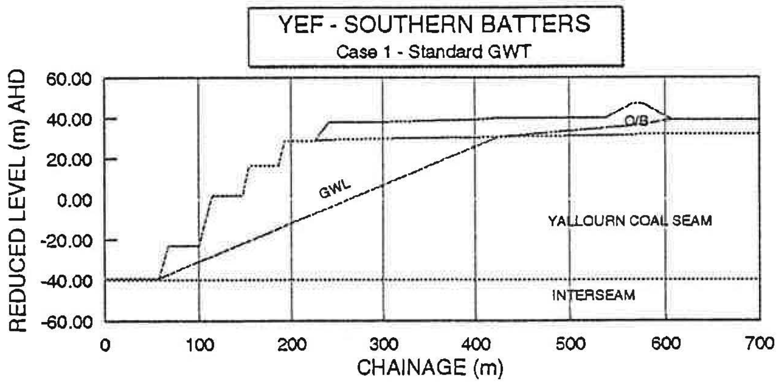


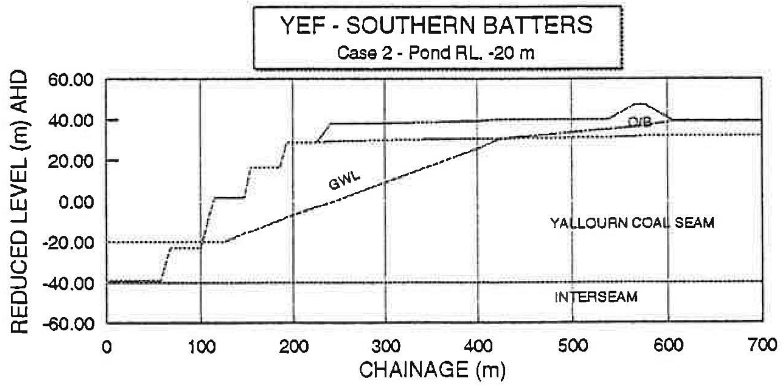


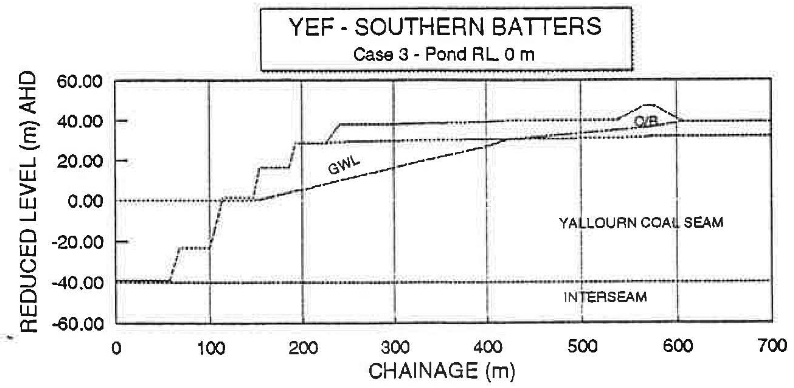


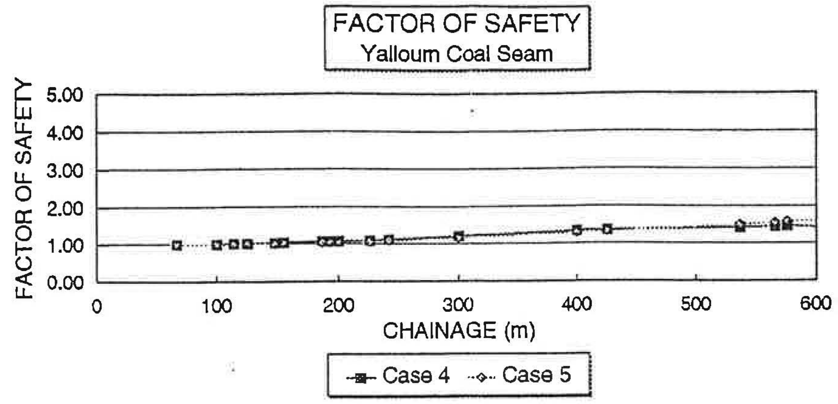
SCALE	N.T.S	GEO-ENG PTY LTD	FIGURE 13
DATE	21/12/94	YALLOURN MINE FLOOD STUDY	
DRAWN	JAS	SECTION 3 - YEF NORTHERN BATTERS	
APPROVED	AGJ	LOW WATER TABLE	

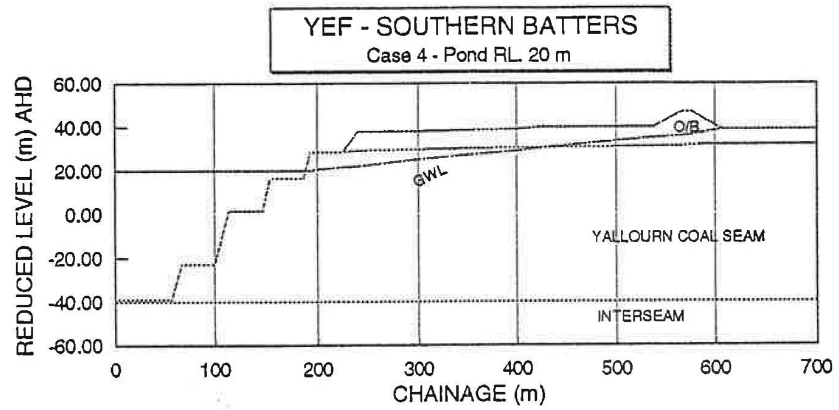


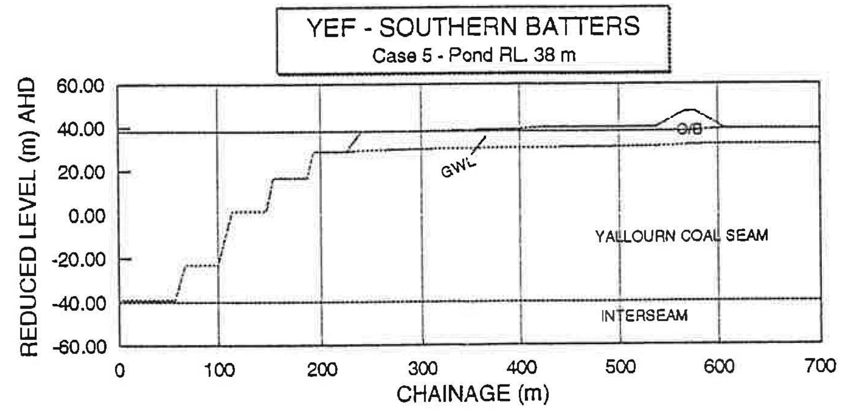




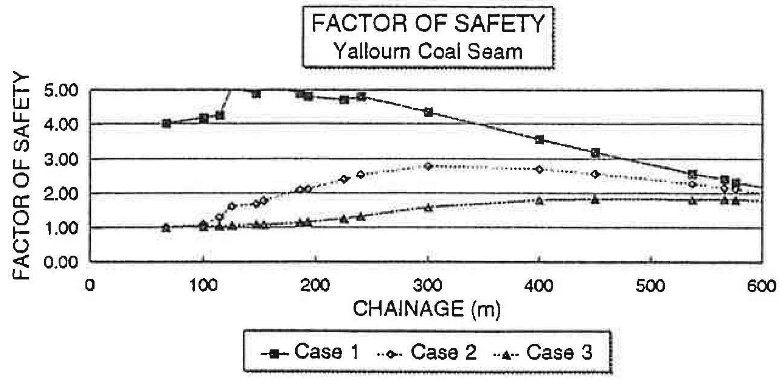


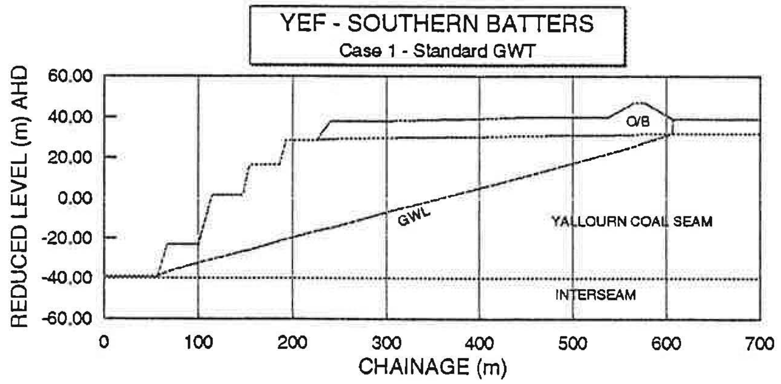


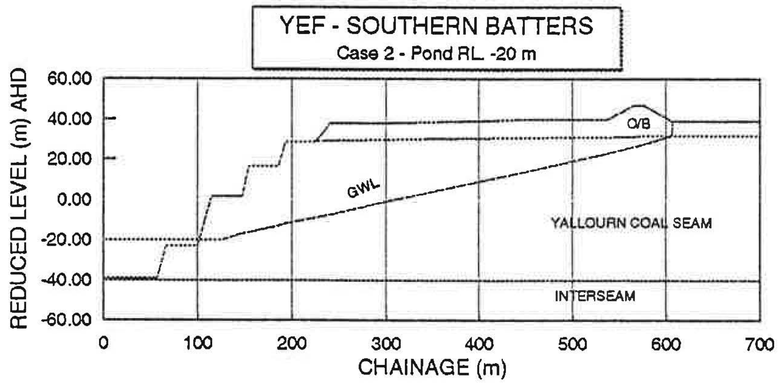


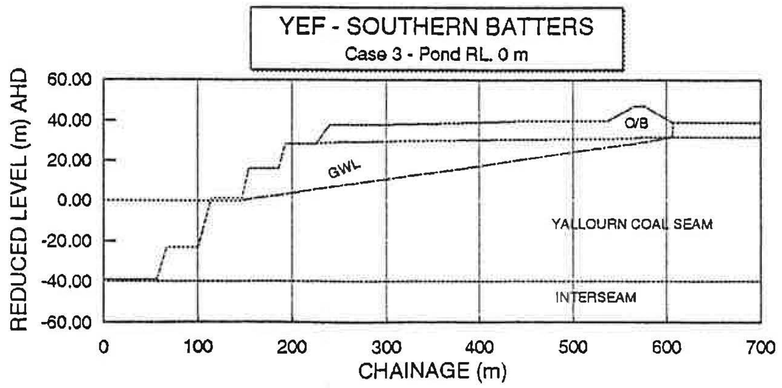


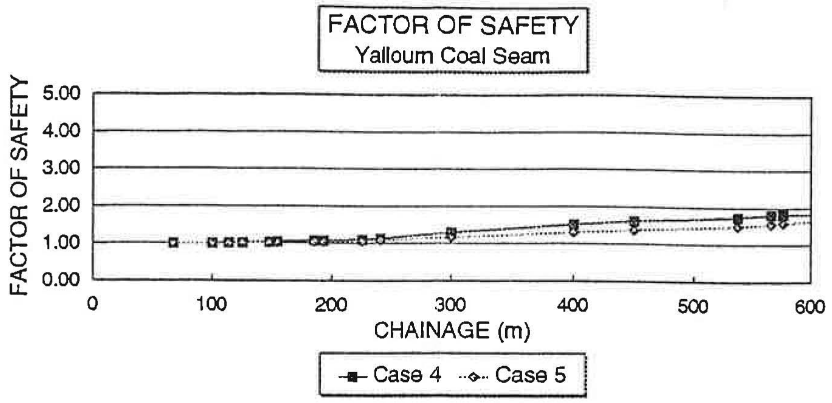
SCALE	N.T.S	**GEO-ENG PTY LTD**	**FIGURE 14**
DATE	21/12/94	**YALLOURN MINE FLOOD STUDY**	
DRAWN	JAS	**SECTION 4 - YEF SOUTHERN BATTERS**	
APPROVED	AGJ	**HIGH WATER TABLE**	

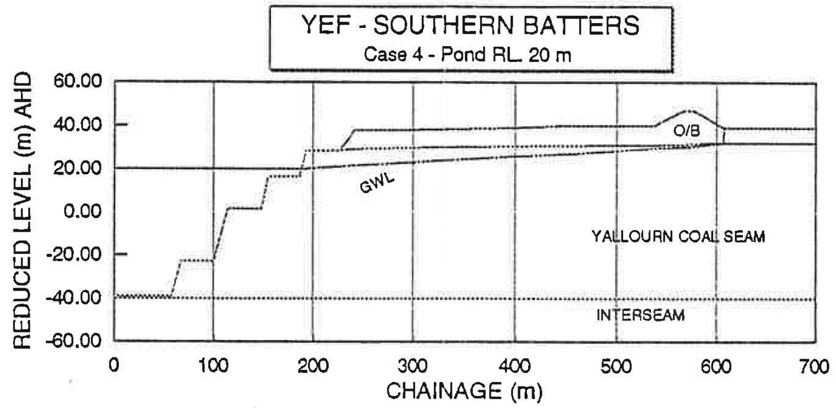


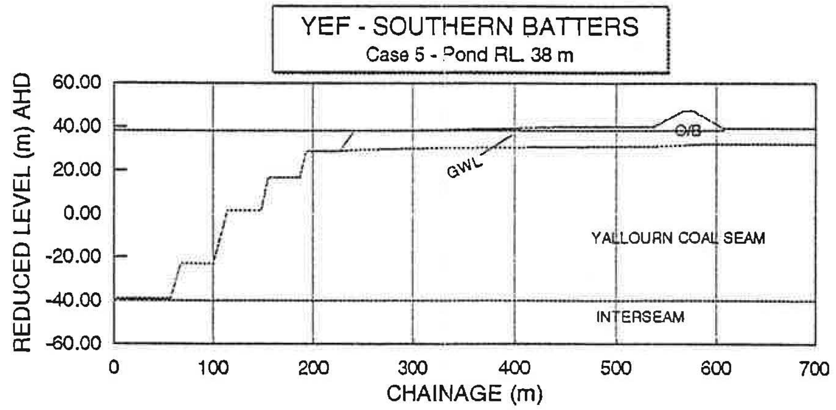












SCALE	N.T.S	GEO-ENG PTY LTD	FIGURE 15
DATE	21/12/94	YALLOURN MINE FLOOD STUDY	
DRAWN	JAS	SECTION 4 - YEF SOUTHERN BATTERS	
APPROVED	AGJ	LOW WATER TABLE	