# LIDDELL COAL OPERATIONS

APPENDIX **P**

## Addressing Flyrock Impacts for Blasting in the Vicinity of the Chain of Ponds Inn

(Enviro Strata, 2013)

**APPENDICES**

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# ADDRESSING FLYROCK IMPACTS FOR BLASTING IN THE VICINITY OF THE CHAIN OF PONDS INN

## REPORT NO LC-1303-040613

**Thomas Lewandowski**
**4th June 2013**

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## 1. INTRODUCTION

Enviro Strata Consulting was requested by Liddell Coal Operations (LCO) to assist with a flyrock impact assessment study for the proposed extension of open cut mining at Liddell Coal. The proposed mine extension is scheduled to advance in a southerly direction towards the historic structure of the Chain of Ponds Inn, see **Figures 1A-B**.

The initial part of the study identifies various flyrock sources and addresses the potential impact of close range blasting and related effects such as flyrock impacts on the adjacent Chain of Ponds buildings.

The second part of the study provides a recommended strategy for LCO when advancing towards the historic structure, i.e. the Chain of Ponds Inn. This is to minimise the possibility of flyrock and related damage.

## 2. FLYROCK OCCURENCE

Flyrock occurrence can generally arise due to three different reasons, specified as follows:

- Face burst and related flyrock ejection
- Flyrock through stemming column
- Flyrock through inappropriate practice

## 2.1 Face Burst and Related Flyrock Ejection

The flyrock in this situation usually occurs through inadequate burden distance or lack of its control. The flyrock can potentially be ejected if there is an insufficient burden distance between the face of the blasted bench and the first row of holes.

When considering flyrock due to face burst there are a number of possible reasons, which could play a role. The face burst could be caused by, for example, unusual geology such as a series of parallel joints which could cause detachment of the front part of the bench and therefore reduce the effective burden distance.

Another possibility is human error such as incorrect hole positioning, which effectively could reduce the burden distance or excessive face removal using a digger when undertaking a previous bench excavation, which again could potentially reduce the effective burden distance.

A very common problem resulting in face burst is related to face pre-conditioning from the previous shot. If pre-conditioning occurs there will be a high number of cracks generated within the blasted area. As such the lack of cohesion of the strata in the front part of the shot could potentially lead to flyrock occurrence. Note that face pre-conditioning is sometimes difficult to detect and is very much dependent upon site assessment and site conditions.

As indicated there could be a variety of reasons which could play a role in possible flyrock occurrence due to face burst. It ought to be noted that the flyrock generated from a face burst is usually emitted from the front part of the face. Therefore, the trajectory path is usually limited to the front of the face and away from it. From a practical point of view there is no possibility of the face burst flyrock being emitted towards the back of the shot and as such the most effective way to optimise control would be via blast face positioning away from the given point of concern.

## 2.2 Flyrock Through Stemming Column or Around Stemming Column

Flyrock can occur when a sub-standard stemming material and / or an insufficient stemming column is used. Occasionally, weak ground conditions (weak strata such as clay or broken strata materials) in the top part of the blast can contribute to flyrock occurrence.

A typical example of flyrock through the stemming column is when an insufficient stemming column is placed on top of the explosive column. This could occur for a number of reasons such as human error or bridging of the stemming material due to, for example, wet ground conditions.

Another possibility of flyrock through stemming material could occur when there is a sub-standard stemming material placed on top of the explosive column. This could be related to some impurities (such as clay) included in the stemming material.

Again, as in the previous case, there are a variety of possibilities, which could practically contribute to flyrock through the stemming column.

### 2.3 Flyrock Through Inappropriate Practice

Occasionally, an inappropriate drilling or loading practice could lead to flyrock occurrence.

Under the umbrella of inappropriate practice there are potentially a number of possibilities which could contribute to flyrock occurrence. It should be realised that a common practice undertaken by mine sites includes hole re-drilling. The holes are usually re-drilled if a hole is lost. This could occur due to hole slumping, ground movement or others. The subsequent hole re-drilling if incorrectly placed, i.e. close to the previous hole, could potentially allow for a high gas emission through the old hole and therefore potentially contribute to possible flyrock.

Another situation that could contribute to flyrock generation is if a hole is re-drilled almost through the same hole. This could lead to subsequent enlargement of the hole diameter. If this happens then the original stemming column designed for the original hole will be insufficient to hold the explosive reaction for the enlarged hole and consequently could result in stemming ejection.

A different example could include the use of inappropriate blasting parameters for a modified drill size (if introduced). For example, the application of a larger hole diameter (i.e. 229 mm in place of 200 mm) will require a revision of the blasting practice and blasting parameters. If not undertaken the parameters could influence blasting outcome and possibly contribute to stemming ejection and flyrock occurrence.

## 3. FLYROCK PROBABILITY AND LCO OPERATIONAL PARAMETERS

It should be pointed out, that various mines operate on different exclusion zones. LCO operates on a 300 metre exclusion zone for equipment. Therefore, by analogy it can be suggested that 300 metres should be sufficient to provide an adequate barrier between the open cut blasting area and the Chain of Ponds Inn. To investigate this point further a more detailed assessment is presented below.

Firstly, the range of flyrock should be considered. Generally, a typical range of flyrock is less than 500 metres, see **Appendix 1A**. Note that Little and Blair (2009), when modelling flyrock risks, suggested a one in a million chance that flyrock will exceed a range of 640 metres. This range applies to blasts characterised by an absence of pit walls. However, in the presence of pit walls the flyrock range is reduced to 560 metres.

Based on the author's experience however, the more likely scenario is for flyrock to occur within a 0 – 50 metre radius (i.e. the highest percentage), while for a 50 to 200 metre radius, there is a lower percentage of flyrock occurrence. In addition, small portions of flyrock will be limited to a 200 – 300 metre distance, and only occasional pieces will extend beyond a 300 metre radius. The described distribution applies to the majority of cases. Generally, the possibility of flyrock from further distances (i.e. than the discussed 300 metres) is rather unlikely.

The author's observations are in general agreement with other authors' studies (Davies 1995); (refer to **Appendix 1B)**, which summarises reported flyrock distances from the United Kingdom and Hong Kong. Please note that the data summary is based on reportable incidents only, and therefore should be treated with caution as it represents a rather skewed sample. Nevertheless, similar findings to that described above have been obtained.

Summarising, the discussed 300 metre distance coincides with the above mentioned LCO exclusion zone, which is considered a sufficient distance to accommodate flyrock.

To meet the 300 metre flyrock limit criteria the mine operates using certain blasting parameters depending upon the bench height. To provide some indication about the current blasting practice at LCO a sample of blasting parameters is presented below.

- Small benches

  Bench height - generally in the order of 5 – 7 metres

  Charge per hole 250 – 350 kg

  Stemming height – 3.5 metres

- Moderate benches

  Bench height – up to 15 metres

  Charge per hole – up to 650 kg

  Stemming height – 4 metres

- Large benches

  Bench height – more than 18 metres

  Stemming height – increased to 4.5 metres

# 4. PROPOSED STRATEGY FOR FLYROCK CONTROL

The proposed strategy of flyrock control when blasting within proximity of the Chain of Ponds Inn will include the following:

- subdivision into zones
- introduction of approved blast design system
- introduction of control system based on fine tuning
- introduction of detailed field control processes
- monitoring program

**<u>High Risk Zone</u>**

The current mining practice at Liddell Coal includes a 300 metres exclusion zone for equipment and infrastructure. Therefore, from a flyrock control point of view 300 metres is considered an adequate distance.

Regarding flyrock, there will be a certain number of blasts which will be less than 300 metres in distance from the analysed Chain of Ponds Inn, see **Figure 2**. The proposed pit edge will be located approximately 65 metres from the Chain of Ponds Inn. Within the 0 - 300 metre range this area is considered as a high risk zone. Therefore, some thought should be given to precautionary measures and/or preventive steps that could be undertaken to minimise the possibility of flyrock occurrence.

## Introduction of approved blast design

This is a particularly effective method of flyrock control however quite often overlooked by a number of operators as it is not fully appreciated. Flyrock occurrence can be relatively well controlled if appropriate blasting and control processes are in place.

There are certain blast designs which are more favourable in terms of flyrock control and flyrock minimisation. For example, the flyrock due to face burst can be successfully controlled if the face of the shot is pointing away from the infrastructure of concern.

An appropriate initiation sequence and encouraged face movement (controlled by appropriate face relief) will also minimise the possibility of flyrock occurrence, i.e. the energy is controlled and directed appropriately.

The other obvious control of flyrock can be achieved when a free face for the shot is available. Note that confined shots are designed in such a way as the only relief of the energy is through the stemming area and therefore very limited. The free face shot on the other hand could potentially produce an extra face relief which can allow for better energy relief and therefore minimise the possibility of flyrock.

Therefore, to minimise the possibility of flyrock on the Chain of Ponds Inn the following recommendations in regards to the approved blast design have been made:

- Undertake blasts with the free face pointing away from the Chain of Ponds Inn. This is for all the blasts within a 300 metre radius of the structure.
- Undertake blasts with appropriate initiation timing where most of the energy is relieved through the face. The timing should take into consideration the face relief and face movement.
- Confined shots not to be fired within a 300 metre radius of the Chain of Ponds Inn whenever practical.

## Introduction of control system based on fine tuning

It is acknowledged that the current system at Liddell Coal is effective and operates well within specified operational parameters. Note that the mine operates successfully utilising the 300 metre exclusion zone radius for equipment and infrastructure. As such it is stressed that the system is effective for control of flyrock to within a 300 metre radius. However, to progress to the next stage, i.e. that no flyrock occurs past 65 metres from the blast (towards the Chain of Ponds), some fine tuning of the blasting parameters will be required.

The proposed fine tuning can commence following a series of field trials using various stemming column heights and detailed site assessments. The final outcome of the fine tuning process could include findings similar to those presented in **Table 1**. Note that the Table should be treated as an example only as site assessment is required to verify the optimum blasting parameters for the given site conditions.

This in turn will provide a firm basis for recommended stemming column height. Note that the identification of the optimum stemming height is a crucial step from a flyrock control perspective. Therefore, this proposed fine tuning is considered an essential part of the proposed strategy.

**Table 1: Summary of Fine Tuning Study – an Indicative Example only**

| Stemming Height (m) | Ejection Distance*(m) | Surface Fragmentation |
|---|---|---|
| 3.0 | 156 | Blown out around holes to acceptable |
| 3.2 | 106 | Acceptable / Good to satisfactory |
| ***3.4*** | ***80*** | ***Satisfactory*** |
| ***3.6*** | ***46*** | ***Satisfactory to slabby*** |
| 3.8 | 32 | Slabby to tight |
| 4.0 | 29 | Tight to blocky |
| 4.2 | 27 | Blocky to cracked but reduced movement |

***-distance based on field measurements for x hole diameter***

## Introduction of detailed field control processes

The introduction of detailed field control loading processes is a necessary part of the proposed strategy when blasting within 300 metres of the Chain of Ponds Inn. It should be stressed that appropriate log paperwork be introduced and followed. LCO has recently procured Datavis DBS to improve drill and blast design, efficiency and review.

The logging process is to commence during the drilling cycle where drillers will provide various additional information besides hole depth.

The design of each blast should then be adjusted accordingly.

Following this stage the field control process advances to the loading cycle, which is most important as it can directly affect the potential occurrence of flyrock. During the loading stage an extensive process of logging relevant details will be introduced. Blast patterns will be analysed during each stage of the drill and blast process to verify conformance with the design. The field results are to be compared with the actual design. Any discrepancies from the proposed design to the field measurements are to be rectified (if identified).

Note that the system eliminates any potential errors which can arise from incorrect loading practice or field errors. Also, the implemented paperwork will allow for the appropriate supervision and accountability of all involved parties.

The postulated system, if implemented correctly, will identify potential issues prior to the blast execution stage and therefore will provide a valid tool in the identification of possible flyrock issues.

**Monitoring program**

The above listed strategy should also be supplemented by a monitoring program. This applies to blasts fired within the high risk zone, that is within 300 metres of the Chain of Ponds Inn and could consist of the following:

- Video monitoring of each blast and appropriate assessment for flyrock occurrence.
- Site inspection to follow such blasts to assess for flyrock location and appropriate reporting.

## 5. CONCLUSIONS AND RECOMMENDATIONS

At the request of LCO an assessment of the impact of blasting from the proposed South Pit extension on the immediately adjacent Chain of Ponds Inn was undertaken. The assessment was requested as part of the Environmental Impact Statement, which incorporates blasting impacts on the Historical Structures. The study presents an evaluation of the impact of flyrock on the Chain of Ponds Inn. The assessment includes a recommended strategy in regards to mitigation measures for flyrock control as well as monitoring recommendations.

There were three causes identified behind flyrock occurrence:

- Flyrock due to face burst;
- Flyrock through stemming column
- Flyrock through inappropriate practice

The operational parameters used by LCO have been discussed in section 3 together with flyrock probability.

***Strategy outline***

To minimise the possibility of flyrock the following strategy has been recommended. The strategy will consist of the following six modules:

- High risk zone;

  The area within a radius of 300 metres (which constitutes an equipment exclusion zone for LCO) of the Chain of Ponds Inn is considered as a high risk zone.
- Introduction of approved blast design system;

  This is a very effective method of flyrock control, it utilises blast designs which are favourable in terms of flyrock control and flyrock minimisation. The following recommendations have been made:

  - Undertake blasts with the free face pointing away from the Chain of Ponds for all blasts within a 300 metre radius.
  - Undertake blasts with appropriate initiation timing where most of the energy is relieved through the face. The timing should take into consideration the face relief and face movement. This applies to all blasts within a 300 metres radius of the Inn.

- Introduction of control system based on fine tuning for blasts within 300 metres;

  The fine tuning can be established following a series of field trials using various stemming column heights and detailed site assessments.

- Introduction of detailed field control processes for blasts within 300 metres;

  The field control processes documenting field activities help to identify and eliminate potential errors which can arise from incorrect loading practice or field errors. The design of each blast should be adjusted according to the information collected.

- Monitoring program;

  To assess flyrock occurrence and location video monitoring and site inspections are recommended for each blast in a high risk zone (i.e. less than 300 metres from the Chain of Ponds Inn).

**Thomas Lewandowski**
**4th June 2013**

## REFERENCES

Davies, P, 1995. Risk–based approach to setting of flyrock "danger zones" for blast sites, Transactions of the Institutions of Mining and Metallurgy, Mining Technology, 104:A96-A100

Little, T N, Blair, D P, 2009. Mechanistic Monte Carlo models for analysis of flyrock risk in proceeding Fragblast 9. Rock Fragmentation by Blasting - Granada 2009, CRC Press, p. 641-647

# FIGURES

**Figure 1A – Liddell Coal – Proposed Mining Boundary and the Chain of Ponds Inn**

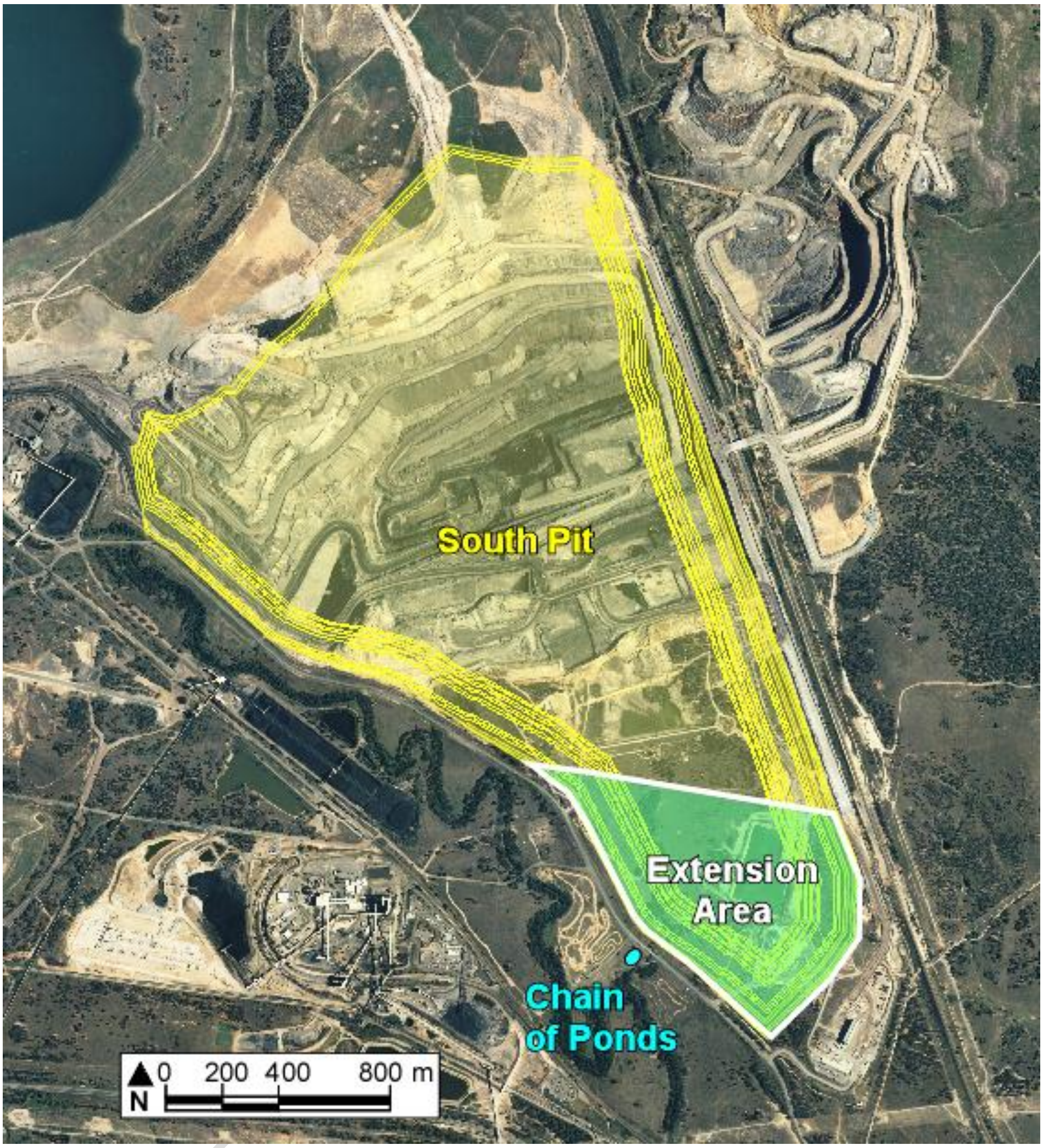


**Figure 1B – Close up of Proposed Mining Boundary and the Chain of Ponds Buildings**

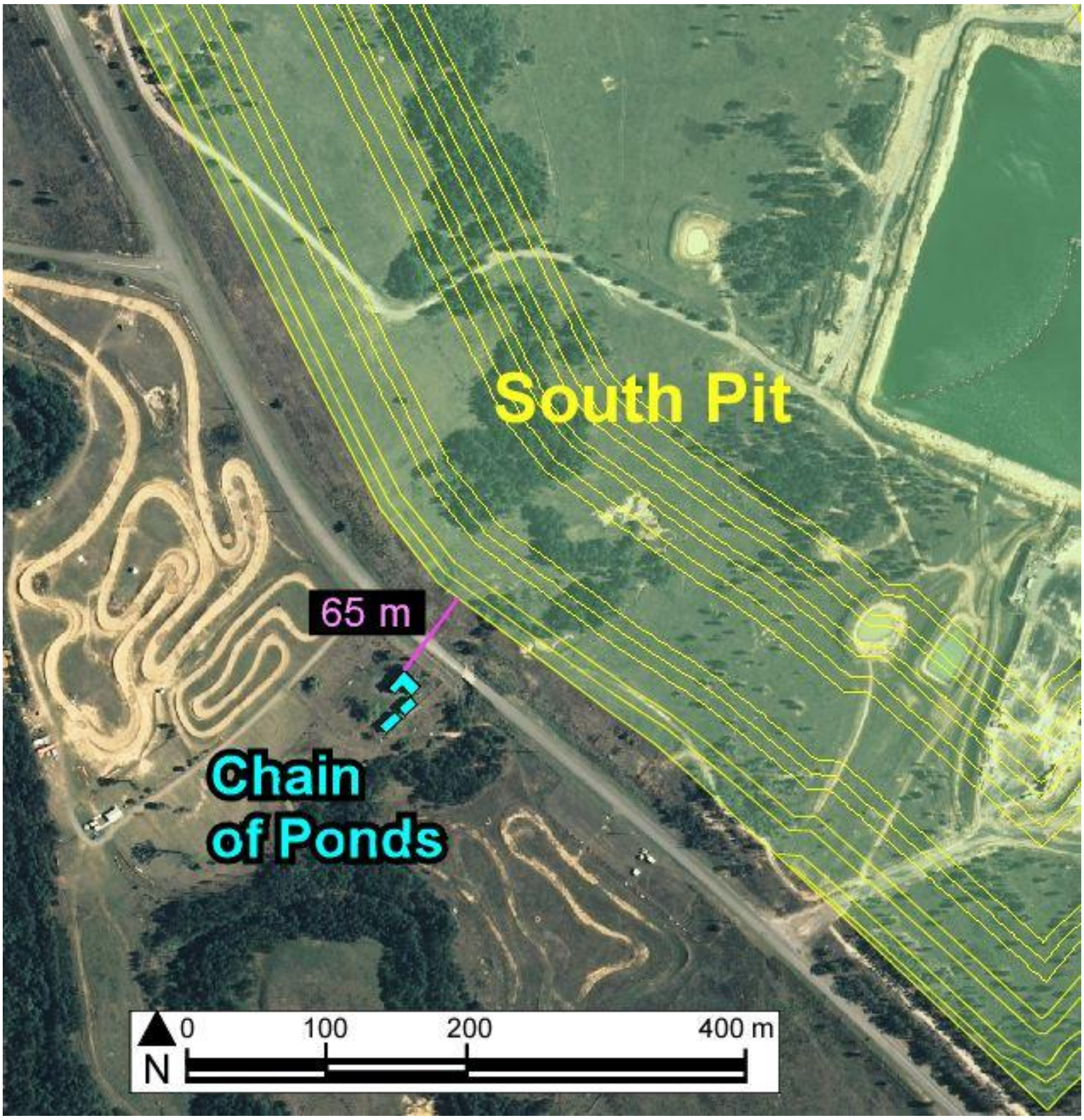
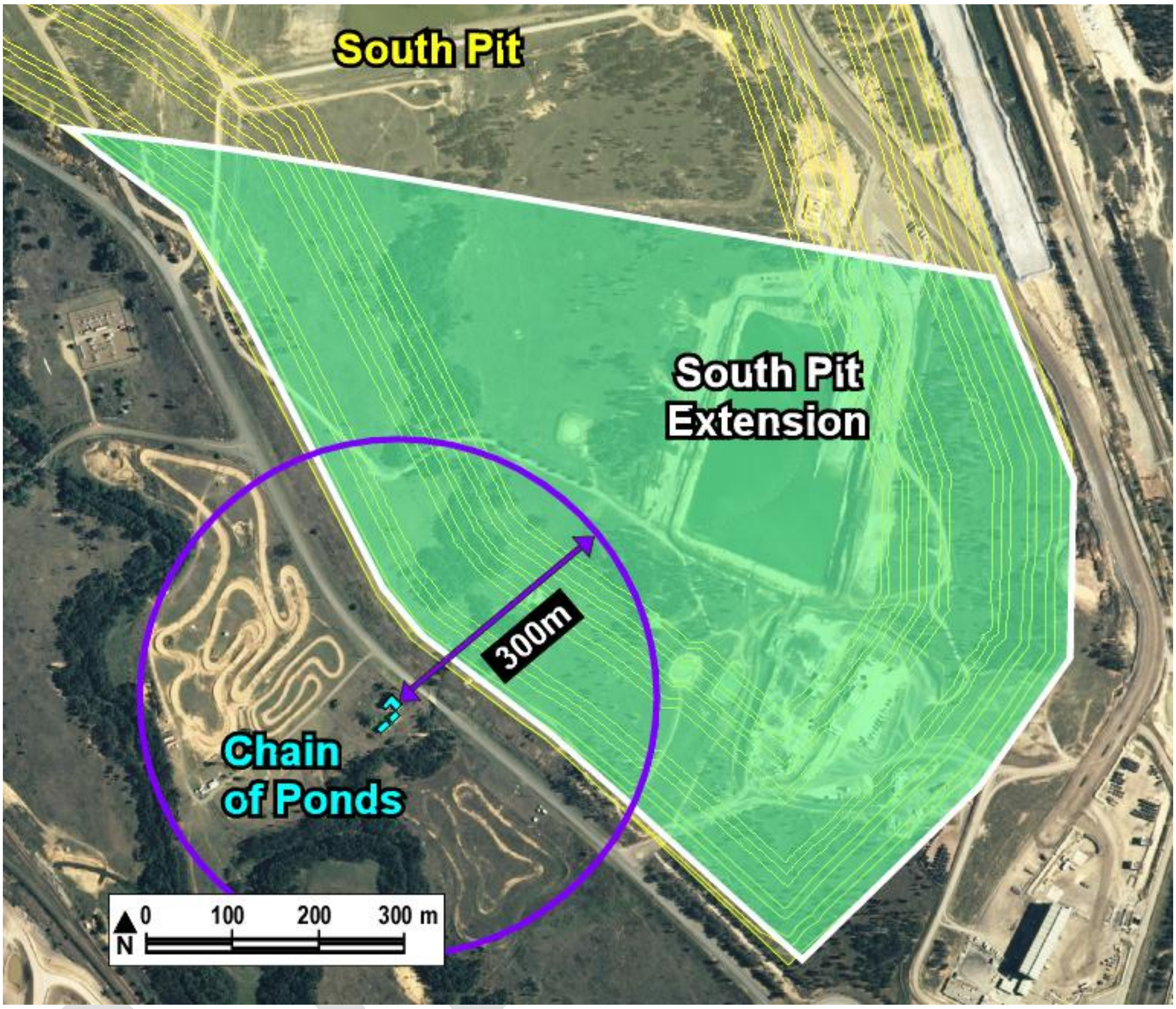
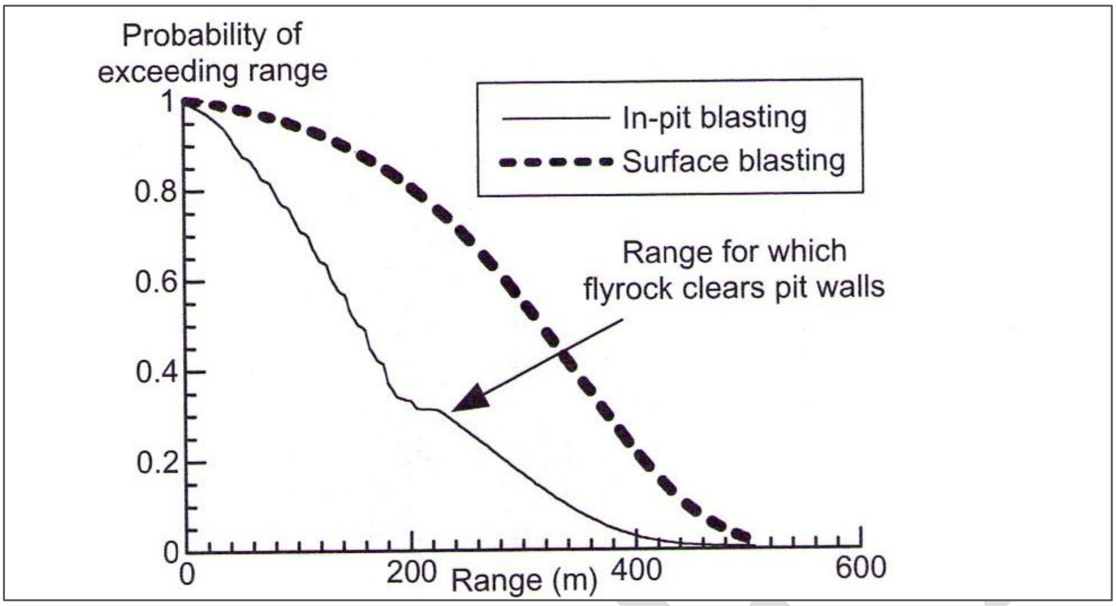


**Figure 2 –Chain of Ponds Inn and High Risk Zone (300 metre radius)**



# APPENDICES

## Appendix 1A – The probability of flyrock range exceeding a prescribed value (after Little and Blair 2009)




## Appendix 1B – Reported Flyrock Distances (after Davies 1995)