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25 January 2007

Kalgoorlie Consolidated Gold Mines Pty Ltd
PMB 27
Kalgoorlie WA 6430

Attention: Mrs Michelle Berryman, Senior Environmental Coordinator

Dear Madam

A Review of Flyrock Potential in the Golden Pike Cutback

Background

The proposed Golden Pike cutback (the cutback) has the potential to extend the life of the Fimiston open pit in Kalgoorlie-Boulder by approximately five years to 2017. The cutback will mean that open pit activity, including blasting, will take place marginally closer to residential and industrial sites than is currently the case.

One of the potential hazards from blasting is flyrock. Consequently, the operator of the Fimiston open pit, Kalgoorlie Consolidated Gold Mines Pty Ltd (KCGM), has undertaken a series of studies to assess the risk associated with this hazard and to suggest ways to manage this risk to within acceptable levels. To facilitate the cutback operation, KCGM is seeking to reduce the current Blast Clearance Area (BCA) from 400m to 200m. KCGM has had its proposal for the cutback exposed to public scrutiny via the Western Australian State Government Public Environmental Review (PER) process.

The purpose of the this report is to comment on the validity of the outcomes and conclusions reached in the other reports provided in relation to the cutback and the level of confidence in the conclusions drawn. The review also considers the relevance of issues directly relating to flyrock raised during public comment for the PER and provides responses to such comments, where appropriate.

Principal findings of the review

Terrock's flyrock model greatly simplifies what is dynamically a very complex problem in physics. However, the algorithm is likely to yield broadly conservative outcomes and is therefore considered to be appropriate by the writer. What validates its use in this application is the fact that the model is calibrated to actual conditions and further observations are made thereafter to confirm model performance.

Terrock concludes in its November 2006 study that, provided stemming length never reduces below 5m, the factor of safety against flyrock being thrown beyond the 200m BCA is over 7, based on the mean throw distance. The writer concurs with this conclusion based on the data presented.

TNL Consultants' January 2006 study estimates the fatality risk beyond the 200m BCA in the adjacent industrial area to be about 5.3×10^{-7} (that is, about 1 in 1.8 million) per year. Based on the updated inputs obtained from Terrock's November 2006 report, the writer suggests that this risk might be conservatively estimated to be somewhat lower, but of the same order of magnitude, at 1.50×10^{-7} (that is, less than 1 in 6 million) per year. Provided stemming length (5m or more) and related blast parameters are strictly controlled, therefore, the writer concludes that the risk of death or severe injury by flyrock to be negligible beyond a 200m BCA. KCGM will need to continue to place a great deal of emphasis on blast design implementation to achieve these low risk levels.

The majority of the public comments relate to: the perceived inadequacy of a 200m BCA (indeed some support an increase in the BCA to more than 400m) based on anecdotal and first hand evidence of flyrock travelling large distances at KCGM and other mines; the perception of an increase in risk as a consequence of the smaller BCA; the simplicity of the Terrock model; the lack of risk assessment in the Terrock modelling process; and the dependence on good QA/QC and the impact of human error on flyrock outcomes. The writer has outlined responses to these key issues.

Information provided by KCGM

The following documents and files were provided to the writer by KCGM for the purposes of this review:

1. Internal KCGM document.
2. Terrock Consulting Engineers, *Kalgoorlie Consolidated Gold Mines Golden Pike cutback flyrock control and calibration of a predictive model*, 30 November 2005.
3. Internal KCGM document.
4. *KCGM Blast management plan*, July 2006.
5. Terrock Consulting Engineers, *Kalgoorlie Consolidated Gold Mines flyrock model calibration update*, 22 November 2006.
6. PER Public Submissions relating to flyrock.
7. Internal KCGM document.
8. Internal KCGM document.

Where these data sources are quoted in this report, the reference number is used in italicised square brackets (for example, *[4]* refers to KCGM Blast management plan, July 2006).

Review of work undertaken by KCGM

Terrock *[2]* uses a flyrock distance prediction algorithm which is based partly on the fundamental laws of physics (by making use of the general trajectory calculation) coupled with an empirical formulation that relates face velocity to scaled burden (or stemming) distance (that is, burden or stemming distance divided by the square root of the charge weight per delay). Terrock then calibrates the model based on flyrock distances measured at KCGM and uses it to predict potential flyrock outcomes for various blast locations in the pit, relative to the bund wall, and so on.

Terrock's flyrock model greatly simplifies what is dynamically a very complex problem in physics. However, the algorithm is likely to yield broadly conservative outcomes and is therefore considered to be appropriate by the writer. What validates its use in this application is the fact that the model is calibrated to actual conditions and further observations are made thereafter to confirm model performance.

Terrock *[2]* examined actual flyrock data during a study in 2004 that involved routine blasting operations. In these blasts, no additional flyrock controls were in place and blast designs were suitable for use within a 400m blast clearance radius. These data show that, where flyrock was created by primary blasts, it travelled less than 50m in 72% of the blasts observed, with the maximum distance travelled being 95m. The subsequent modelling study undertaken by Terrock *[2]* suggests that control of minimum stemming length to 5m and 4.1m in the oxide and sulphide zones, respectively, would permit the BCA to be reduced to 200m with a factor of safety of 4. Terrock [2] also recommends that very carefully designed secondary blasting (or mechanised methods) be used for secondary breakage in the cutback area.

Further monitoring work was undertaken by Terrock *[5]* during 2006 for blasts in which stemming length had been increased to the values indicated above. Where blasting took place in areas where no voids are present, maximum flyrock distance observed reduced to 45m and 26.7m for 4.1m and 5m stemming heights, respectively (note that these particular data are most appropriate to the cutback scenario as the writer understands that the cutback is most unlikely to contain voids *[2 and 5]*). The mean flyrock throw distance was 14.7m and 8.7m for 4.1m and 5m stemming heights, respectively. Of the void-free blasts observed by Terrock *[5]*, about 36% appeared to have no flyrock at all (although the sample size is small).

Furthermore, KCGM has made significant changes to its drilling and blasting practices to reduce the likelihood of flyrock *[8]* and to monitor its behaviour *[7]*.

Terrock *[5]* concludes that, provided stemming length never reduces below 5m, the factor of safety against flyrock being thrown beyond the 200m BCA is greater than 7, based on the mean throw distance. Whilst this is a relatively large factor of safety in engineering terms, it does not fully quantify the risk to the individual. Consequently, KCGM also undertook a qualitative and quantitative assessment of the flyrock risk for the proposed cutback.

The qualitative risk assessment was performed by KCGM in conjunction with TNL Consultants *[1]*. This process, which the writer considers to be entirely appropriate under the circumstances and relatively comprehensive, identified the key issues (15 of them) that might lead to a flyrock hazard, rated the likelihood and consequence of each issue in terms of hazard risk, business risk and technical risk, and also rated the level of uncertainty in each issue. The risk assessment then led to the documentation of risk treatment planning and procedures, and a risk management plan. These outcomes are then embodied in the KCGM blast management plan *[4]*.

The quantitative risk analysis *[3]* assessed the risk to the most vulnerable individual. It was based on a number of assumptions. These are shown below, with the writer's comments also shown:

- Flyrock distance is assumed to follow an exponential distribution. The writer believes this to be an appropriate assumption. That is, the probability of flyrock exceeding a distance of 200m is given by $exp(-200/\mu)$, where μ is the mean flyrock distance.
- The mean flyrock distance is assumed to be 25m. This is a conservative assumption as the mean distance is likely to be closer to 15m or less in the cutback (see notes above on Terrock observations). This reduces, by a factor of about 200, the estimated probability of flyrock exceeding 200m from 3.4×10^{-4} (or about 1 in 2,900 for a mean of 25m) to 1.6×10^{-6} (or about 1 in 625,000 for a mean of 15m).
- The spatial distribution of flyrock is assumed to be uniform around the 360° surrounding each hole. This is an appropriately conservative assumption, as flyrock is more likely to occur in the direction facing the effective burden than behind the blast. That is, it is more likely to occur in the direction facing away from the cutback wall (and away from the community).
- It is assumed that one hole in 200 (0.5%) will crater. The writer cannot comment on the validity of this assumption. However, Terrock's *[5]* data shows that, of those blasts in void-free areas monitored in 2006, 29% showed the mechanism to be cratering. Whist this doesn't easily translate into the likelihood of a hole cratering and yielding flyrock, it does provide a more conservative point of reference.
- The writer concurs with the remaining assumptions made by TNL Consultants *[3]*. That is, area of zone at risk is about 47,124m^2, the area occupied by people is about 40m^2 and the vulnerability is conservatively set at 100%.

The quantitative risk analysis *[3]* estimates the fatality risk to be about 5.3×10^{-7} (that is, about 1 in 1.8 million) per year. Based on the alternatives noted above, this risk might be conservatively estimated to be somewhat lower, but of the same order of magnitude, at about 1.5×10^{-7} (less than 1 in 6 million) per year. The Western Australian EPA considers a risk of 1 in 1 million per year or less to be appropriate for residential development *[3].* This benchmark indicates just how low a risk 1 in 6 million actually is (that is, six times lower than the EPA guideline for residential development). However, it is of course dependent on good quality control on blasting parameters, particularly stemming length and burden distance, and KCGM will need to place a great deal of emphasis on blast design implementation. The writer's understanding is that KCGM has indeed made a number of changes to drilling and blasting *[9]* that will assist in this regard, namely:

- Appropriate operator training;
- reduction in charge weight in face holes;

- dipping of holes after charging and, where overloading is observed to be in excess of 0.3m, desensitisation of the upper part of the charge with water;
- reporting of holes that have been overcharged so that they can be tracked and monitored; and
- more rigorous stemming quality control procedures.

Review of public comments and suggested responses

This section attempts to summarise the core comments or issues raised in relation to flyrock from the cutback, and provides a response to each key issue in the first person, as if the writer was responding personally to the issue raised.

<u>Comment</u>: The 400m BCA has worked in the past and reducing it to 200m will only increase risk.
<u>Response</u>: The 400m BCA was appropriate for past blasting practices at KCGM and has worked well. However, as a consequence of continuous improvement within KCGM, my view is that the systems, procedures and blast designs are now such that the flyrock risks associated with reducing the BCA to 200m are very small indeed. For example, a person outside the 200m BCA is several hundred times more likely to die in a traffic accident than from flyrock from a Golden Pike cutback blast. In fact, the Western Australian EPA guidelines for residential development accept risks that are up to six times greater than those estimated for flyrock.

<u>Comment</u>: The 400m BCA should be increased, not decreased.
<u>Response</u>: The work undertaken by KCGM, and my own independent assessment of it, has shown that, with the proposed blasting practices in place, a person outside the 200m BCA is several hundred times more likely to die in a traffic accident than from flyrock from a Golden Pike cutback blast. In fact, the Western Australian EPA guidelines for residential development accept risks that are up to six times greater than those estimated for flyrock. I believe, therefore, that the flyrock risk is very low indeed, so an increase in the size of the BCA is simply not justifiable.

<u>Comment</u>: Flyrock control is dependent on good QA/QC. This can't be guaranteed because it involves human error.
<u>Response</u>: I agree completely that good QA/QC will be essential to minimise the likelihood of human error. However, it's clear to me that KCGM's blast implementation procedures have been evolving over several years with ongoing improvements and validation of flyrock models, thereby improving the quality control aspects of blasting. The company's Blast Management Plan outlines the preparation (including training of personnel) that is being put in place to ensure a quality outcome for Golden Pike blasts. The Blast Management Plan also outlines the operational practises that will be used to assure quality. For example, the charge in the front row of blast holes is reduced to further minimise bursting from the face. The depth to the top of the explosive charge column is measured in each hole after charging and, where overloading is observed to be in excess of 0.3m, desensitisation of the upper part of the charge is effected. Where overcharging (and associated desensitisation) is noted, KCGM reports these holes so that they can be tracked and monitored for performance to ensure that the desensitisation process is working. More rigorous stemming quality control procedures are also in place. All of these controls give me a strong sense of confidence that KCGM is fully aware and in control of the QA/QA issues.

<u>Comment</u>: Terrock's modelling doesn't quantify the risk of flyrock outside the BCA.
<u>Response</u>: The Terrock model is not a quantitative risk assessment tool. It is an empirical engineering design tool. I'll explain what I mean as follows: The purpose of the Terrock flyrock model is to assist KCGM to determine what stemming length is required to reduce flyrock. The selected stemming length is then applied and the change in flyrock behaviour monitored. The model is then updated with the new information. Terrock's analysis has provided what is called a "factor of safety" against flyrock. Whilst the factor of safety obtained is relatively large (over 7) and, to an informed observer, indicates a very low risk indeed, it does not fully quantify the risk to an individual. Consequently, formal risk assessment has been conducted outside and in addition to the Terrock modelling process. My own estimation is that the risk of death by flyrock outside the 200m zone is less than 1 in 6 million. This means that a person outside the 200m BCA is several hundred times more likely to die in a traffic accident than from flyrock from a

Golden Pike cutback blast. By way of another comparison, the Western Australian EPA guidelines for residential development accept risks that are up to six times greater than my estimate.

<u>Comment</u>: Terrock modelling doesn't take into account geology, other blasting parameters (e.g. blast hole diameter) and human error.
<u>Response</u>: The purpose of the Terrock flyrock model is to assist KCGM to determine what stemming length is required to reduce flyrock (since cratering due to insufficient stemming length is the key cause of flyrock behind a blast). The model was calibrated using actual KCGM blast data, thereby taking KCGM's geological conditions into account. Changes recommended by the model were then implemented and monitored. This monitoring process is on going. Whilst the model itself doesn't take into account the uncertainty of human behaviour, other QA/QC procedures relating to charge length, stemming length and stemming quality are all designed to minimise these.

<u>Comment</u>: Terrock's monitoring is based on a small sample of blasts.
<u>Response</u>: My understanding is that KCGM currently monitors all of its blasts for flyrock. Therefore, whilst the initial samples may appear to have been relatively small, the on going work is based on a much larger sample.

<u>Comment</u>: There is both anecdotal and first hand evidence of flyrock at KCGM travelling over 200m and even over 400m.
<u>Response</u>: My assessment is that KCGM's blast implementation procedures have changed significantly in recent months, reducing the likelihood of flyrock. For example, the charge in the front row of blast holes is reduced to further minimise bursting from the face. The depth to the top of the explosive charge column is measured in each hole after charging and, where overloading is observed to be in excess of 0.3m, desensitisation of the upper part of the charge is effected. Where overcharging (and associated desensitisation) is noted, KCGM reports these holes so that they can be tracked and monitored for performance to ensure that the desensitisation process is working. More rigorous stemming quality control procedures are also in place. All of these controls give me a sense of confidence that KCGM is fully aware of and in control of the issues leading to flyrock, and that the chance of flyrock carrying beyond 200m is very small indeed.

<u>Comment</u>: There is evidence from other mine sites of flyrock travelling long distances.
<u>Response</u>: Some other large open pit mines use very large blast holes (up to 2.5 times the diameter and six times the charge weight of the KCGM blast holes). Some also operate in very remote environments where flyrock hazards are not a matter for public concern (for example, in the Pilbara where mines are located several kilometres, sometimes tens of kilometres, from their town sites). It therefore doesn't surprise me that flyrock in such mines travels a longer distance. However, as large open pit mining businesses go, KCGM operates with relatively small diameter blast holes close to a city. Practices are necessarily different and, in my view, appropriate.

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Thank you for the opportunity to assist Kalgoorlie Consolidated Gold Mines Pty Ltd with this review. Please do not hesitate to contact the undersigned on 08 6436 8613, on 0408 924 912 or at Peter.Lilly@csiro.au should you require any further information.

Yours faithfully

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