Acid Drainage Risk Evaluation Fimiston Operations

1 August 2006

Prepared for:

Kalgoorlie Consolidated Gold Mines
PMB 27
Kalgoorlie WA 6433

Report by:

HLA-Envirosciences Pty Limited

ABN: 34 060 204 702
18 Warabrook Boulevarde Warabrook NSW 2304
PO Box 73 Hunter Region MC NSW 2310 Australia
Ph: +61 2 4968 0044
Fax: +61 2 4968 0005

HLA Ref: N60424_RPT01Final01_01Aug06

DISTRIBUTION

Acid Drainage Risk Evaluation
Fimiston Operations
1 August 2006

Copies	Recipient	Copies	Recipient
1	**Michelle Birch** **Senior Environmental Officer** Kalgoorlie Consolidated Gold Mines PMB 27 Kalgoorlie WA 6433		
1	**HLA File**		

This document was prepared for the sole use of Kalgoorlie Consolidated Gold Mines and the regulatory agencies that are directly involved in this project, the only intended beneficiaries of our work. No other party should rely on the information contained herein without the prior written consent of HLA-Envirosciences Pty Limited and Kalgoorlie Consolidated Gold Mines.

By

HLA-Envirosciences Pty Limited
ABN: 34 060 204 702
18 Warabrook Boulevarde Warabrook NSW 2304
PO Box 73 Hunter Region MC NSW 2310 Australia

Tom Farrell
Principal Scientist, Mining

Peer Review: **Date:**

1 August 2006

Peter Scott
Principal Environmental Geochemist

CONTENTS

TABLES

FIGURES

PLATES

EXECUTIVE SUMMARY

Kalgoorlie Consolidated Gold Mines (KCGM) commissioned HLA-Envirosciences Pty Limited (HLA) to undertake an independent, desktop evaluation of the potential for the occurrence of acid drainage (AD) at its Fimiston operations in Kalgoorlie, WA.

This was partly in response to KCGM's desire to implement best practice environmental management of its operations.

There is evidence of the occurrence of acid drainage at mines in the Kalgoorlie region. This is primarily associated with the presence of Black Flag Beds (or Black Flag Shales) in waste rock dumps. There is anecdotal evidence of localised acid drainage occurring from stockpiled Black Flag Beds at KCGM. Groundwater in monitoring bores and piezometers around the KCGM TSFs has a low pH, but this may be a result of rock-water interactions (ie. dry-land salinity acid sulphate from oxidising monosulphides) within the regolith profile due to mounding from the TSF rather than acid drainage from the oxidation of tailing. This assumption is untested at KCGM and needs to be assessed and verified.

The main test work currently undertaken on waste rock that can be used to assess acid drainage potential is the analysis of total sulphur. There are limited test work results for acid generating potential of waste rock previously mined at KCGM. A similar lack of information exists for the Fimiston tailing. The volume of waste rock within the remaining pit shell that can be classified as Black Flag Beds represents about 7% of the total waste rock within the 0.5g/t Au cut-off. Given that the Black Flag Beds material appears to have the greatest potential for acid generation, any impacts from acid drainage from waste rock mined for the remainder of the mine life can most likely be managed.

Given the limited acid base accounting data available, and the evidence of acid drainage present in mining waste from the Fimiston operation, a phased program of investigations into acid drainage at KCGM is recommended. The Phase I program, comprising confirmation and evaluation and which could be completed in three to four months, incorporates the following recommendations for KCGM:

- A program of geochemical characterisation should be implemented at least for all waste rock lithologies, with particular emphasis on the Black Flag Bed, and tailing from the Fimiston mill;
- Geochemical characterisation should include, as a minimum, standard Australian acid base accounting tests;
- Static acid base accounting tests should be undertaken on the Black Flag Beds material stockpiled on the Lakewood waste rock dump;
- Sufficient quantities of all samples analysed for static acid base accounting tests should be retained for possible further test work such as multi-element scans;
- Long-term field kinetic tests should be established with fresh Black Flag Beds waste rock and Black Flag Beds material stockpiled on the Lakewood waste rock dump;
- The results of the static acid base accounting should be incorporated into the KCGM geological model;
- A waste model should be developed to produce the volumes and distribution of the different waste rock lithologies, classified according to their acid drainage potential, that will enable generation of a mining waste schedule for the life of the mine;

- Hydrogeological and geochemical investigations should be undertaken to assess the cause of low pH values recorded in boreholes and piezometers around the Fimiston TSFs;
- Develop and implement as soon as possible a Standard Operating Procedure that sets out specific controls on the placement of Black Flag Beds rock in the Fimiston waste rock dump;
- Identify clear internal responsibility for acid drainage investigations;
- Ensure that all relevant internal and consultant reports are incorporated into the Environment Department database (SECRIS) to ensure free exchange of all available information;
- Undertake a thorough assessment of monitoring data in the environmental database to determine any spatial or temporal patterns in the pH of water being monitored;
- Expand the environmental monitoring program to ensure that rainfall runoff and seepage from the Fimiston waste rock dump is sampled and analysed (for a range of appropriate indicators that includes at least pH, EC, acidity, alkalinity and sulphate) during and following rainfall events; and
- Undertake a regular review of the environmental monitoring data to detect any changes in analytical parameters.

The Phase II program would be dependent on the results of Phase I and could include the following steps:

- Kinetic test work on waste rock and tailing by establishing columns of these materials under controlled laboratory conditions;
- Further refinement of the waste rock scheduling for management of potentially acid generating waste rock;
- Design and construction of a waste rock dump for the encapsulation of potentially acid generating rock;
- Investigations into appropriate decommissioning and rehabilitation techniques for waste rock dumps containing potentially acid generating material;
- Assessment of the potential for acid drainage to occur from exposed Black Flag Beds in the Fimiston open pit and its long-term implications;
- Review of tailing deposition and management of TSFs to account for potential acid formation in the repositories; and
- Further refinement of environmental monitoring programs to enable better investigation of the potential for or occurrence of acid drainage at KCGM.

If not done so in Phase I, establishment of an “acid drainage taskforce” to oversee and manage the work would be an appropriate step at the commencement of Phase II.

In 2005, field kinetic tests were established using weathered Black Flag Beds from the Lakewood waste rock dump and fresh material obtained from the Fimiston pit. These materials were placed in IBC containers and left exposed to natural climatic conditions. In the almost two years since these were established no drainage has appeared from the base of the rock beds. This is most likely a result of the continuing low rainfall regime at Kalgoorlie.

Based on the information reviewed for this report, HLA considers that the volume of potentially acid generating waste rock at KCGM is minor, when compared to non-acid generating waste rock. This suggests that potential environmental impacts from the occurrence of sulphide oxidation in the Fimiston waste rock dumps, open pit and tailing storage facilities can be managed.

1 BACKGROUND

HLA Envirosciences Pty Limited (HLA), specifically Mr. Tom Farrell Principal Scientist, Mining, was commissioned by Kalgoorlie Consolidated Gold Mines Pty Limited (KCGM) to undertake an independent, desktop evaluation of the potential for the occurrence of acid drainage (AD) at its Fimiston operations in Kalgoorlie, WA. This report provides an update on previous findings of this study.

Best practice environmental management requires the evaluation of environmental risks and, if these are considered to be substantial, the development of appropriate mitigation strategies. KCGM is committed to the implementation of best practice in all of its operations.

KCGM operates one of Australia's largest gold mines adjacent to the town of Kalgoorlie, approximately 600 km north-east of Perth. Although ore is extracted using both open pit and underground methods, the most visible evidence of mining is the Fimiston Pit, commonly known as the Super Pit. Approximately 12 million tonnes of ore and 85 million tonnes of waste rock are extracted each year by the mining operations. The ore is processed through two treatment plants – the Fimiston Mill and Gidji Roaster – depending on its mineralogy. The Fimiston Plant treats mainly oxide ore while sulphidic concentrate is transported to the Gidji Roaster, approximately 20 km to the north, for roasting prior to leaching and gold extraction.

Waste rock from the Fimiston Pit is placed on engineered dumps to the south and east of the mine, extending further east towards the Fimiston II tailing storage facility that takes tailing from the Fimiston Plant.

A feature of the milling and processing operations at Kalgoorlie is the extensive use of hypersaline water, with up to seven times the salinity of seawater. The use of this water, extracted from palaeochannels that occur in the region, leads to high salinities in the tailing and in decant water.

2 SCOPE OF WORK

The scope of work for this project was established as:

- Evaluate current knowledge at KCGM concerning acid drainage potential of various materials;
- Understand previous concerns about acid drainage and its by-products at Kalgoorlie;
- Review geological controls and understanding of various lithologies that may result in acid drainage at the Fimiston operations;
- Undertake a desktop appraisal of inherent risk of acid drainage from waste rock dumps and tailing storages based on existing knowledge at KCGM and industry experience;
- Develop, in conjunction with the Environment and Mining Departments, a strategy to understand the potential for acid drainage and its management at KCGM; and
- Assess projected residual risk if KCGM undertakes the recommended work to understand better acid drainage potential.

3 ACID DRAINAGE OCCURRENCE AT KALGOORLIE

3.1 Background

Acid drainage occurs at mining operations when sulphide minerals, principally pyrite, present in the ore and host rocks oxidise, resulting in generation of acid that is mobilised by water. In the absence of water and oxygen, acid drainage generation is limited. Most terrains containing sulphide-bearing mineral deposits generate acid salts as part of the natural oxidation or weathering process. The mobilisation of these acid salts by water, such as runoff water from pit faces, groundwater, or stormwater etc, results in acid drainage. The mobilised acidity or acid drainage can also lead to leaching and mobilising of metallic ions contained in the ore and wall rocks associated with the ore deposit. The acid drainage and mobilised metals can result in environmental impacts and harm to receiving environments, including biological environments and man-made structures.

There is a perception that acid drainage generation does not occur in arid climates such as at Kalgoorlie. However the climate of the Eastern Goldfields, as well as some of the other semi-arid to arid regions of Western Australia, can be ideal for promoting oxidation of exposed sulphidic mine waste such as waste rock and tailing. This area receives sufficient rainfall to mobilise any oxidation products generated during the long dry periods of the year.

Acid drainage can be moderated or buffered by the presence of natural acid neutralising minerals in the mine waste. Carbonate alteration minerals such as ferroan dolomite and calcite are common in the Kalgoorlie District gold deposits. The calcium and magnesium based carbonate minerals, when available and present in sufficient concentration, can reduce or minimise acid generation. They do not reduce oxidation but they can neutralise any acid that may be generated when sulphide minerals are exposed to atmospheric oxygen and precipitation. Iron carbonates normally have a weak to non-existent acid neutralising capacity.

Acid generation will occur as soon as sulphide minerals are exposed to atmospheric oxygen. The impacts may not be immediately apparent, may be minimal for a long period of time or even non-existent, depending on the presence and reactivity of acid neutralising minerals. The presence of acid generation can be detected early in the oxidation cycle an increase in calcium and magnesium as well as sulphate and near neutral pH with low acidities. As oxidation proceeds and neutralising minerals are consumed, magnesium and sulphate continue to be released. This is accompanied by a decrease in pH. With continuing oxidation and increase in acidity, metals such as iron are released, with a corresponding increase in sulphate concentration. Other metals present in the exposed mine waste and ore may also be mobilised under a wide range of pH and Eh conditions. The oxidation process leading to acid drainage generation can be detected long before low pH water and high metal concentrations manifest themselves. Increasing concentrations of sulphate, calcium and magnesium in drainage is a good indicator that oxidation is occurring.

Mining operations in arid areas of Australia have typically assumed that the risk of onset of acid drainage is minimal because of the low or intermittent rainfall that occurs in these areas and the ephemeral nature of rivers and streams. However, recent experience at the Mount Whaleback iron ore mine in the Pilbara of Western Australia has shown that this assumption is not always valid. Although there has been a history of spontaneous combustion and heating in waste rock dumps at the mine, the association of this with acid drainage was not recognised until the 1990s. Waste dumping practices were changed in 1995 to segregate and encapsulate acid generating material but, as there was no segregation prior to that time, most overburden storage areas at the mine have the capacity to generate acid drainage.

3.2 Presence of Sulphides in Waste Rock at KCGM

The KCGM Mining Department undertakes total sulphur analysis on all material to be mined, whether ore or waste. These data are entered into the geological model and can be readily accessed. By far the majority of waste rock from the Fimiston open pit, in the order of 95%, will consist of Golden Mile Dolerite. In 2004, KCGM geologists calculated the following quantities of waste rock remaining in the current final pit design at different gold cut-offs.

Table 1: Total Sulphur Distribution in Waste Rock Remaining in Fimiston Pit

Sulphur (%)		Tonnage at			
From	**To**	**<0.5 g/t Au**	**%**	**<0.9 g/t Au**	**%**
0	0.5	522,145,585	92.12	535,805,850	85.04
0.5	1	31,265,781	5.52	54,655,521	8.67
1	2	11,660,680	2.06	33,041,586	5.24
2	3	1,659,595	0.29	5,695,996	0.90
3	4	59,460	0.01	720,396	0.11
4	5	11,144	0.00	76,435	0.01
>5		1,955	0.00	69,435	0.01
Total		566,804,200	100	630,065,219	100

Under a worst-case scenario that all sulphur is present as sulphides and using a simple rule of thumb that unmanageable acid drainage is unlikely to occur unless the sulphur concentration exceeds 0.5%, between 7% and 15% of the waste rock to be generated in the future, depending on gold cut-off, has potential to form acid drainage.

KCGM geologists have also identified a black shale formation known as the Black Flag Beds as the lithological unit at KCGM most likely to oxidise and potentially generate acid. This is partly because of known elevated concentrations of sulphides in the material, visual identification of pyrite nodules, visual evidence of oxidation by-products in stockpiles (such as sulphate efflorescence) and characteristic iron staining in drainage lines from these stockpiles. The Black Flag Beds formation is a narrow vertical band of rock up to 100 m wide that is easily seen in the western wall of the Fimiston Pit (Plate 1).

Plate 1: Black Flag Beds Exposed in Fimiston Pit

Approximately 30 Mt of Black Flag Beds, at an average total sulphur grade of 0.3%, has been placed in the KCGM waste rock dumps. Although there has been no segregation or special handling of this material, the Mining Department aims to avoid placing Black Flag Beds within 50 m of the face of a waste rock dump. However, this requirement is not yet formalised in a Standard Operating Procedure and the effectiveness of the existing approach in preventing exposure of Black Flag Beds in the waste rock dump is uncertain.

A better estimate of the quantity of waste rock with the potential to form acid drainage can be obtained from a review of the volumes and sulphidic distribution of Black Flag Beds waste rock. KCGM geologists estimated in 2004 that approximately 40 Mt of Black Flag Beds, at an average sulphur grade of 0.32%, remained inside the final pit boundary. As the sulphur distribution in this rock is not related to gold distribution, the distribution of it as ore and waste cannot be calculated. Table 2 shows the quantities of this material according to sulphur distribution.

Table 2: Distribution of Black Flag Beds in Fimiston Pit by Total Sulphur

Total Sulphur (%)		Tonnage	%
From	To		
0	0.5	36,201,837	90.15
0.5	1	1,715,516	4.27
1	2	1,594,982	3.97
2	3	472,464	1.18
3	4	128,483	0.32
4	5	18,135	0.05
>5		25,110	0.06
Total		40,156,527	100

The Black Flag Beds material is the main potentially acid generating waste rock present in the current and final pit shells and the remaining volume of Black Flag Beds waste rock to be mined from 2004 was 40,156,527 t, which is approximately 7% of the total waste to be mined at the 0.5 g/t Au cut-off.

4 REVIEW OF AVAILABLE DATA AT KCGM

There have been no formal investigations into the potential for acid drainage at KCGM. There is some anecdotal evidence that localised acid drainage has occurred in stockpiles and on waste rock dumps but these occurrences have not been systematically investigated. Further details are provided in this section.

4.1 Black Flag Beds Stockpiles

A quantity of Black Flag Beds waste rock, mostly shale, was stockpiled on the top of a waste rock dump at Mount Percy in the late 1990s (Plate 2). The author inspected this material in 1999 and yellow and red staining of the ground surface in localised drainage lines, indicative of sulphur and iron oxidation products, was clearly visible (Plate 3). In addition, a distinct oxidising sulphur odour and the presence of visible sulphide oxidation products was noted (Plate 3 and Plate 4). No samples of this material were collected for chemical analysis or static acid-base accounting. It was said that this material had been stockpiled on the surface for only about six weeks. It this was the case, then oxidation had taken place very rapidly, indicating this material was very reactive and required careful management to avoid potential impacts to the receiving environment[1].

Plate 2: Black Flag Beds on Waste Rock Dump at Mount Percy

Plate 3: Black Flag Beds Stockpile at Mount Percy

Plate 4: Visible Oxidation Products at Mount Percy

Plate 5: Oxidation Products in Black Flag Beds Profile, Mount Percy

Following an observation made on a colour aerial photograph of KCGM operations in 1999, a further stockpile of paddock-dumped mineralised Black Flag Beds was located on the top of the Lakewood waste rock dump at the southern end of the operations (Plate 6). In contrast to the

[1] Shortly after, this material was apparently moved and buried under tailing in the former Sir John open pit.

material observed at Mount Percy, this Black Flag Beds rock had no sulphurous odour of sulphide oxidation and no obvious deposits of oxidation products (e.g. sulphate salts) were located. There was some general yellow discolouration of the surface (Plate 7) but this could not be definitively identified as oxidation products. No samples of this material were taken for analysis or static acid-base accounting.

Plate 6: Black Flag Beds Stockpile on Lakewood WRD

Plate 7: Possible Oxidation Products in Black Flag Beds, Lakewood WRD

The Lakewood waste rock dump was revisited in May 2004 to assess briefly whether any changes had occurred to the Black Flag Beds. There appeared to have been little change except for surface weathering of the material. Some large boulders of Black Flag Beds (Plate 8) were inspected but there were only occasional slight sulphide odours and no visible deposits of oxidation products. Some rocks had a green discolouration (Plate 9) that could be due to copper or iron oxidation products.

Plate 8: Black Flag Beds Boulder on Lakewood WRD

Plate 9: Possible Iron or Copper Oxidation Product, Lakewood WRD

It would appear that this Black Flag Beds material had been exposed to the atmosphere for almost five years and, although oxidation and acid generation have certainly occurred, there was no visual evidence of acid drainage.

In 2005 this material was removed and encapsulated in the Fimiston waste rock dump.

4.2 Open Pit and Waste Rock Dumps

There is some poorly documented evidence suggesting that localised acid drainage from the Fimiston waste rock dumps could have occurred in the past. This is based on recollections of Brett Bussell, formerly employed in the KCGM Environment Department.

During rehabilitation of the Mount Percy waste rock dumps, some Black Flag Beds rock was used to construct a runoff drop structure down the dump (Plate 10). This rock apparently oxidised and vegetation along the drain died off. Some oxidation products were visible at the base of the drain (Plate 11). While the rock was apparently removed from the drain, no further investigations were undertaken into the acid drainage characteristics of the rock or quality of runoff water.

Plate 10: Black Flag Beds in Dump Drainage Structure, Mount Percy

Plate 11: Oxidation Products in Drainage Structure, Mount Percy

Following a period of heavy rainfall in the late 1990s, discoloured water, possibly containing elevated concentrations of iron (Plate 12), was observed coming from the southeast corner of the Fimiston waste rock dump (see Plate 13 for approximate location). However, no results of chemical analysis of this water can be located at KCGM. KCGM staff reported that no similar discharge has been seen from the Fimiston waste rock dump since this occurrence.

Plate 12: Iron Stained Drainage from Fimiston Waste Rock Dump

Plate 13: Location of Iron Stained Drainage at Fimiston Waste Rock Dump

As part of a study into the geochemistry of process tailing, limited test work was undertaken on five rock samples from the Mount Percy open pit. However, these samples were not tested *per se* for acid drainage characteristics. Rather, they were considered to be representative of bedrock materials located 'along-flowpath' from a sub-aqueous tailing bed being considered for the Mount Percy pit. Therefore, they were tested only for their potential to neutralise any acid formed by sulphide oxidation in the tailing. The results of this test work are shown in Table 3.

Table 3: Acid Neutralisation Capacity of Mount Percy Waste Rock Samples

Sample No.	Lithology	ANC (kg H_2SO_4/t)
Samples of Major Lithologies in Wall-Waste-Zone		
3545	Hannan-Lake-Serpentenite	170*
3546	Devn-Consoles-Basalt	6.5
3547	Lower-Williamstown-Dolerite	13
Samples of Minor Lithologies in Wall-Waste-Zone		
3548	Porphyry	210*
3549	Kalai-Slate	2.7 (2.3)

All results expressed on a dry-weight basis

Values in parentheses represent duplicates

ANC values labelled with an asterisk indicate that the pH of the test-mixture slurries dropped to near 3 upon the addition of H_2O_2 as the pH=7 end-point was approached when back titrating with NaOH

The following conclusion was reached from this work:

> *The testwork results indicate that the Devon-Consoles-Basalt and Lower-Williamstown-Dolerite samples had a low-to-moderate capacity to consume acid. Although the Hannans-lake-Serpentinite sample had a high capacity to consume acid under strongly-acid (viz. pH <3) conditions, this lithotype likely has a limited capacity for buffering near pH 7.*
>
> *The Porphyry sample had a high capacity to consume acid, due to reactive carbonates (eg. calcite). However, within the Wall-Waste-Zone of the Mt. Percy Pit, the Porphyry occurs only as a minor lithotype.*

From the information provided, it is not possible to determine whether the material tested contained acid generating sulphides that, upon oxidation, would reduce the acid neutralising capacity of the materials tested.

Except for the information provided above, there has apparently been no systematic or opportunistic investigation of acid drainage potential in either the Fimiston open pit or the waste rock dump.

The Black Flag Beds formation is exposed in the Fimiston open pit and is likely to remain so following cessation of mining unless the pit fills with water. In a worst case scenario, exposure of sulphide-containing rock could lead to localised acid generation that would be mobilised by runoff and result in possible contamination of any water that ponds in the pit.

4.3 Tailing

There is a generally held belief at KCGM that the Fimiston Tailing Storage Facilities (TSF) have very low potential for acid drainage to occur because the majority of the floated sulphide concentrate is trucked to the Gidji Roaster for processing. Therefore the tailing is believed to have extremely low concentrations of sulphide.

No acid drainage potential test work has apparently been undertaken on the material stored in the Fimiston facility.

4.4 Environmental Monitoring Data

KCGM operates an extensive groundwater monitoring program around the Fimiston waste rock dump and TSF. The standard suite of analyses for monitoring bores is pH, Electrical Conductivity, Total Dissolved Solids and Cyanide species – Total, Free and WAD. Infrequent Sulphate analyses are also undertaken on the samples. While a comprehensive review of KCGM's monitoring results is beyond the scope of this report, some typical data are reported here to illustrate potential issues related to acid formation and transport that may exist.

A number of the monitoring bores at Fimiston show consistently acid pH values, with pH frequently around 4 or less. Variation in pH over time in a randomly selected monitoring bore at Fimiston is shown in Figure 1.

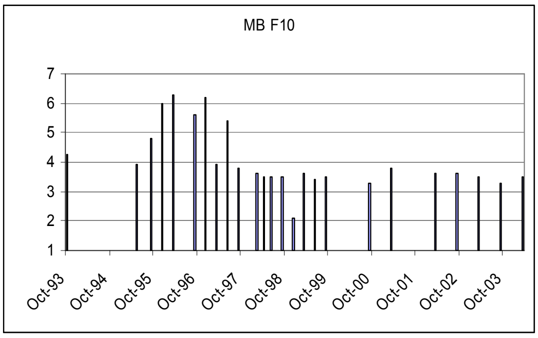

Figure 1: pH over Time, Monitoring Bore F10, Fimiston

KCGM staff noted that similar low pH groundwater has been recorded at the Cosmic Boy nickel sulphide mine near Hyden, approximately 300 km SW of Kalgoorlie, and that this was believed to a natural occurrence unrelated to acid drainage.

A possible explanation for this acidic groundwater is the occurrence of acid sulphates, associated with high groundwater salinity, in semi-arid areas. Sulphate-reducing bacteria reduce the high sulphate in near-surface groundwater to monosulphides that oxidise periodically due to groundwater mobilisation as a result of mining or flooding.

5 CONCLUSIONS AND RISK EVALUATION

There are limited quantitative data available about the potential for acid drainage production at KCGM. Most of the information available is anecdotal and not supported by sampling and geochemical analysis. However, based on the information provided in the previous sections, the risk of acid drainage occurring at KCGM's Fimiston operations can be evaluated in a qualitative manner.

There is some evidence to suggest that the Black Flag Beds lithology encountered at mines in the Kalgoorlie region is the waste rock type most likely to be potentially acid generating. Some stockpiled Black Flag Beds rock at KCGM has been observed to form sulphide oxidation products in a relatively short time. However, similar material stockpiled elsewhere appears to show little evidence of oxidation and formation of acid drainage. Again, there is some limited but qualitative evidence to suggest that acid drainage has occurred and is occurring in localised areas of the Fimiston and Mount Percy waste rock dumps. As a result, the KCGM Mining Department has implemented an informal policy of not dumping Black Flag Beds waste rock within 50 m of the final face of a dump. However, there is no other special handling or placement of this material as it is produced from the mine.

It is possible that only an estimated 4 Mt of potentially acid generating Black Flag Beds waste rock will be produced from the mine under the current (2004) life of mine plan. Although still a large quantity, this is less than 0.5% of the waste rock likely to be produced in the remaining life of the mine.

Under the current process flowchart, high sulphide concentrate is trucked to the Gidji Roaster for processing. This means that the sulphide concentration, and the corresponding acid generating capacity, in the Fimiston tailing are low. However, there has been no evaluation of this tailing for either sulphide concentration or acid-base accounting.

KCGM monitoring of groundwater at Fimiston shows that the groundwater in many bores is consistently acid, with pH values less than 4 being common. However, there is some suggestion that this low pH is a result of rock-water interactions within the regolith profile due to mounding under TSFs rather than acid drainage from the oxidation of tailing. This hypothesis has not been specifically tested or validated at KCGM.

Based on these conclusions, HLA considers that the risk of acid drainage formation in the Fimiston waste rock dumps is moderate to low and any acid drainage that occurs is most likely manageable. There is a slightly higher risk of localised acid drainage, or at least elevated sulphate concentrations in neutral seepage, resulting from past incorrect management of, in particular, Black Flag Beds waste rock. The anticipated quantities of Black Flag Beds waste rock in the remaining life of the mine are relatively small compared to the total volume of waste rock to be mined but, as a precautionary measure, these should be managed as if they are acid generating.

Unless there is a change to the process flowsheet that results in higher sulphide tailing reporting to the Fimiston TSFs, the risk of acid drainage occurring in these facilities is also moderate to low. However there needs to be an assessment of this tailing to justify this assumption.

6 RECOMMENDED ACID DRAINAGE STRATEGY

As outlined in the previous sections, there is a moderate to low risk of acid drainage occurring at KCGM's Fimiston operations as a result of its mining activities. Because this risk has not been clearly identified in the past, there are no controls in place to assess the likely extent or environmental impact of acid drainage.

Best practice environmental management requires that such risks be quantified where possible and appropriate controls established to prevent any such impact.

Given that the principal Potentially Acid Generating waste rock unit is known, its volume and distribution can be modelled and a mining waste schedule generated for the life of the mine. This will enable selective mining and placement of this waste in a suitably engineered emplacement to minimise impacts of acid drainage and to facilitate management if adverse drainage occurs.

In order to fill the data gaps in the mine waste acid generation capacity, HLA recommends a phased approach to development of an acid drainage management strategy at the Fimiston operations. The results of the first Phase, which could be completed in three to four months, can then be assessed to determine whether the subsequent Phase is required.

Details of the proposed strategy are outlined below. Recommended actions are identified in italics and further explanation (if required) is provided below each recommendation.

6.1 Phase I – Confirmation and Evaluation

Phase I is designed to gather more definitive evidence of the potential for acid drainage to occur at Fimiston and to put in place procedures to respond to potential issues before they occur.

6.1.1 Static Acid Base Accounting Test Work

KCGM should implement a program of geochemical characterisation of all lithologies, with particular emphasis on the Black Flag Beds and tailing produced from the Fimiston Mill.

> While the Black Flag Beds waste rock is the most likely lithology to produce acid drainage, all lithologies (including ore) should be characterised initially to conform to the precautionary principle, best practice and industry standards. The tailing from the Fimiston mill has not been tested for acid drainage characteristics.

Geochemical characterisation should include, as a minimum, standard Australian acid base accounting tests.

> Static tests determine both the total acid generating and total acid consuming potential of a sample and are used to predict the potential of the rock to produce acid. Acid-base accounting (ABA) methodology has been modified in recent years by using definitive testing for sulphide sulphur using Chromium Reducible Sulphur analysis coupled with standard ANC testing to generate a Net Acid Producing Potential account. HLA supports this modified ABA approach as a reliable ABA methodology.
>
> The tests recommended for the waste rock lithologies are:
>
> - Paste or slurry pH tests to measure the surface acidity of rocks;
> - Total sulphur and chromium reducible sulphur (ie. sulphide-S);

- Determination of Maximum Potential Acidity (MPA) and Acid Neutralising Capacity (ANC);
- Net Acid Producing Potential (NAPP) which is the theoretical balance between a sample's capacity to generate acid and its capacity to neutralise the acid that is generated (NAPP = MPA – ANC); and
- Net Acid Generation (NAG) test, which uses hydrogen peroxide to stimulate oxidation to assess how much acid production may occur.

Static acid base accounting tests should also be undertaken on the Black Flag Beds rock stockpiled on the Lakewood waste rock dump.

The availability of this material provides an opportunity to test mineralised Black Flag Beds rock that has been exposed to the atmosphere for some years to gain an indication of its residual acid drainage potential. Although this material has now been buried in the Fimiston waste rock dump, sufficient quantities remain in the field kinetic trial to enable these tests to be completed.

Sufficient quantities of all samples analysed for static acid base accounting tests should be retained for possible further test work such as multi-element scans.

Multi-element scans are commonly used to indicate potential environmental issues that may arise from mobilisation of metals from rock and tailing as a result of acid drainage. As Kalgoorlie is a mineralised area, metal concentrations in waste rock and tailing are expected to be naturally elevated. As a cost-effective measure, multi-element scans can only be undertaken on lithologies and samples that show the potential to be acid generating. However, all materials should be sampled for future reference. The elements of most interest are those that have elevated concentrations at KCGM, namely Ag, As, Bi, Cd, Co, Cu, Hg, Mo, S, Sb, Se and Zn.

6.1.2 Kinetic Acid Drainage Test Work

Establish long-term field kinetic tests using fresh Black Flag Beds waste rock and also rock stockpiled on the Lakewood waste rock dump.

This recommendation is an **optional** step in Phase I. If it is not implemented in Phase I then it should definitely be included in Phase II. The Black Flag Beds rock is known to oxidise and result in localised acid drainage at KCGM, although the extent and impact of this is not known. Although the static test work will give more quantitative data on this, establishment of field kinetic tests would provide an opportunity for a long-term test (i.e. in the order of years) into the potential impacts of oxidation of Black Flag Beds rock. The tests would take place under natural field conditions. Rock can be placed in 200 L drums or similar that are left in the open and drainage monitored after rainfall events. A suitable design has been provided by HLA under separate cover.

HLA notes that field kinetic tests have been established at KCGM using weathered Black Flag Beds rock from the Lakewood waste rock dump and fresh material obtained from the Fimiston Pit. These materials have been placed in 1,000 L IBC containers and left exposed to natural climatic conditions. In almost two years since these were established no drainage has appeared from the base of the rock beds. This is most likely a result of the continuing low rainfall regime at Kalgoorlie.

6.1.3 Scheduling of Potential Acid Generating Waste Rock

The results of the static acid base accounting should be incorporated into the KCGM geological model.

The geological model and database is currently the repository for information on the geochemistry of rock types and, therefore, it is logical that the results of the acid base accounting be incorporated into this.

KCGM should undertake a "first-pass" assessment of the volumes and distribution of the different waste rock lithologies, classified according to their acid drainage potential, that will be produced over the remaining life of the mine.

Data from the life of mine plan have been used to produce an annual schedule of sulphide and oxide waste rock that is used in the life of mine rehabilitation plan to identify potential shortfalls of required materials for rehabilitation. A mine waste model using the acid drainage characteristics of the waste rock lithologies can be used to define the distribution of the potentially acid generating (PAG) waste rock will be mined. Preferably, the model should be based on sulphur concentration rather than Net Acid Production Potential (NAPP) as this will ensure that all sulphides are encapsulated. This model can be used to generate the mining waste schedule that would define when the PAG rock will be mined and so assist in planning and implementation of acid drainage control measures.

6.1.4 Further Assessment of Fimiston TSFs

KCGM should conduct hydrogeological and geochemical investigations to confirm the possible explanation for low pH values recorded in boreholes and piezometers around the Fimiston TSFs.

Low pH water is consistently recorded in monitoring bores around these facilities. This could be the result of acid seepage from the TSF, or the result of dryland salinity acid sulphate resulting from groundwater mounding or oxidation of monosulphides developed in the near surface environment by hypersaline groundwater. This has been proposed as an explanation for low pH water recorded under a TSF at another mine in WA but has not been confirmed as the explanation at KCGM (see Section 4.4 for more discussion on this).

6.1.5 Administrative Controls

Develop and implement a Standard Operating Procedure that sets out specific controls on the placement of Black Flag Beds rock in the Fimiston waste rock dump as soon as possible.

Geologists in KCGM's Mining Division confirmed that there is an informal procedure to prevent Black Flag Beds waste rock from being dumped within 50 m of the final face of the waste rock dump. A procedure should be formalised and implemented as soon as possible to ensure that this does occur.

Identify clear internal responsibility for acid drainage investigations, possibly through establishment of an acid drainage taskforce.

Specialist investigations such as acid drainage studies need to be coordinated and managed in order to obtain the best value from them. In addition, there may be value in establishing an "acid drainage taskforce", with external independent peer review, to oversee this work.

Ensure that all relevant internal and consultant reports are incorporated into SECRIS to ensure free exchange of all available information.

A report database (SECRIS) has been established at KCGM to record all important documentation and make it available readily to staff. It is overseen by the Safety and Environment Department. During preparation of this report, some important reports that were not recorded in SECRIS were identified at the operation. All relevant reports should be captured in this system.

6.1.6 Environmental Monitoring

Undertake a thorough assessment of monitoring data in the environmental database to determine any spatial or temporal patterns in the pH of water being monitored.

KCGM maintains an extensive database of water monitoring results, primarily from boreholes and piezometers around the TSFs. HLA understands that the main purpose of this database is to comply with regulatory requirements. However, it is also a valuable resource to demonstrate the quality of water leaching from these facilities. A review of these data would form part of the preliminary investigation into the presence or absence of acid drainage at KCGM.

Expand the environmental monitoring program to ensure that rainfall runoff and seepage from the Fimiston waste rock dump is sampled and analysed (for a range of appropriate indicators that includes at least pH, EC, acidity, alkalinity and sulphate) during and following rainfall events.

The environmental water monitoring program appears to be almost entirely focussed on sampling seepage collection trenches, boreholes and piezometers around the TSFs. There are virtually no data on the quality of runoff or leachate from the waste rock dumps. The monitoring program needs to be extended to include sampling of this runoff or leachate. As rainfall at KCGM is erratic, this program should be based on sampling runoff when it occurs and leachate for some time afterwards rather than being based on a temporal sampling regime.

The analytical suite for groundwater is focussed on understanding the salinity of the groundwater mounds and the potential for cyanide contamination of the groundwater under the storages. This analytical suite needs to be extended to incorporate parameters that are applicable to acid drainage investigations.

Undertake a regular review of the environmental monitoring data to detect any changes in analytical parameters.

In addition to the recommended review of historic monitoring data, regular review of the data collected under the recommended revised and expanded program is necessary for early detection of acid drainage and confirmation of whether it is occurring at KCGM's Fimiston operations.

6.2 Phase II – Quantification of Risk

The Phase I program outlined above could be completed within three to four months. At the end of this program there should be a formal evaluation of the data to determine whether there is a need to proceed with further test work. If justified, this Phase II program would be focussed on quantifying the level of risk at Fimiston from acid drainage and developing appropriate control measures. It is not appropriate at this time to provide a detailed work program, but the Phase II program could include the following:

- Kinetic test work on waste rock and tailing by establishing columns of these materials under controlled laboratory conditions;
- Further refinement of the waste rock scheduling for management of potentially acid generating waste rock;
- Design and construction of the waste rock dump for the controlled management of potentially acid generating rock;
- Investigations into appropriate decommissioning and rehabilitation techniques for waste rock dumps containing potentially acid generating material;
- Studies into the potential for acid drainage to occur from exposed Black Flag Beds in the Fimiston open pit either during mining or following closure of the mine;
- Review of tailing deposition and management of TSFs to account for potentially acid formation in the repositories; and
- Further refinement of environmental monitoring programs to enable better investigation of the potential for or occurrence of acid drainage at KCGM.

If not done so in Phase I, establishment of an “acid drainage taskforce” to oversee and manage the work would be an appropriate step at the commencement of Phase II.

7 ASSESSMENT OF RESIDUAL RISK

The previous section proposes a program of work to provide quantitative information on the potential for acid drainage at KCGM and an understanding of the magnitude of the resultant environmental risk. The scope of work for this project specifically required an assessment of projected residual risk if KCGM undertakes the scope of work for Phase I and Phase II. This section provides a brief assessment of this residual risk.

The risk of acid drainage occurring at KCGM is considered to be moderate to low. Based on knowledge from other mines in the region, acid drainage is most likely to occur from Black Flag Beds waste rock and sulphide ore tailing.

The recommended Phase I test program is aimed at confirming the potential for acid drainage to occur at Fimiston on a semi-quantitative basis. Implementation of this program will provide greater certainty into the likelihood of acid drainage occurring and the extent of the environmental impact of this. As mining at Kalgoorlie has been taking place for decades and there has apparently been no overt evidence of extensive acid drainage, failure to undertake this program, or delays in its implementation, would lead to minimal extra risk. The primary purpose of undertaking the Phase I program is to conform to current practice at Australian mining operations.

Completion of the Phase I program would enable a more certain evaluation of the risk from acid drainage at KCGM. An appropriate response to this could then be developed. If the likelihood of acid drainage is confirmed, design and implementation of a Phase II program would be a logical step to quantify further the level of risk.

contact us www.hla-enviro.com.au

BRISBANE • MACKAY • MELBOURNE • NEWCASTLE • SINGLETON • SYDNEY