Summary of Findings:

ACMER Project 58, Sunrise Dam Gold Mine Sponsor's Report

December 2007

Citation
Donato, D.B. and Smith, G.B. (2007), Summary of Findings: ACMER Project 58, Sunrise Dam Gold Mine Sponsor's Report, Anglogold Ashanti Australia.

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1. Executive Summary

An industry-based study conducted by the then Australian Centre for Mine and Environmental Research (ACMER), numbered Project 58, involving mining operations in Australia and Africa was undertaken to assess the level and nature of the risk to wildlife from cyanide-bearing tailings in the goldmining industry. Anglogold Ashanti Sunrise Dam Gold Mine (SDGM) was a sponsor of this study. A site-specific sponsor's report describing wildlife cyanosis risks and protective mechanisms from cyanide-bearing tailings was produced. That report is titled "ACMER Project 58: A Risk Assessment of the Effects of Goldmining Cyanide-Bearing Tailings Solutions on Wildlife, Sponsor's Report to: Sunrise Dam Gold Mine Anglogold Ashanti Australia" (sponsor's report). The report found and successfully argued that the unique circumstances and management of the SDGM centrally discharged hypersaline system was benign to wildlife despite discharge cyanide-bearing tailings marginally above the prescribed threshold. The sponsor's report was subsequently peer-reviewed in accordance with requirements of the International Cyanide Management Code (the Code).

This report is a Summary of Findings of the sponsor's report.

ACMER consultants prescribed wildlife and cyanide monitoring protocols that were implemented in April 2004. Between 1 April 2004 and 26 May 2006 wildlife monitoring was conducted on 266 observation days with an average total survey time of about one hour per observation. The monitoring program is ongoing. This monitoring protocol was designed to determine if any wildlife cyanosis deaths were occurring, define the risk of cyanosis to wildlife by quantifying wildlife presence at and interaction with cyanide-bearing water bodies, identify at-risk species or guilds and provide techniques for simultaneous monitoring of the cyanide concentrations and salinity within these water bodies.

Monitoring of waste stream solutions revealed that the concentrations of weak acid dissociable (WAD) cyanide in the tailings dam were in excess of the 50 ppm guideline provided by the Code. Cyanide was discharged to the central-thickened discharge tailings system (CTD) in excess of 50 ppm WAD cyanide on 72% of sampled days. The mean (±SD) concentration of WAD cyanide at discharge during this period was 62.4 ± 22.83 ppm (n=114 samples). WAD cyanide concentrations of supernatant pooling at the decant pipes of the tailings dam was highly variable during this time and it exceeded 50 ppm WAD cyanide on 7 of 113 sampling days. These samples have been diluted by an inflow of ground water usually to below 5 ppm. Weekly sampling commenced from supernatant ponding on the eastern side of the tailings dam before dilution occurred from ground water inflows. From these pools, five out of the eight samples have exceeded 50 ppm WAD cyanide.

On the primary cyanide-bearing mine waste impoundment, 1096 visitations and no wildlife cyanosis deaths were recorded on the CTD, and 748 visitations and no wildlife cyanosis deaths were recorded on the stormwater/decant pond.

ACMER consultants conducted site visits at SDGM in March 2004, April 2005, September 2005 and November 2006 for a total of 14 days. During this time, intensive wildlife monitoring and replicate cyanide sampling was undertaken within the SDGM waste stream. No wildlife deaths or carcasses were recorded.

The methodologies used were implemented at all other case studies as part of the ACMER project. At other case studies of ACMER PROJECT 58 (fresh peripheral-discharge tailings systems) where mine waste solutions exceeded the accepted discharge threshold for WAD cyanide concentrations, the on-site staff and ACMER consultants were able to routinely detect wildlife deaths.

The CTD is an ecologically simple system, as it is hypersaline and contains minimal food provisions. It is deliberately managed to maintain simple habitats. Consequently, cyanide exposure pathways to wildlife have been identified for SDGM. Considerable observations of wildlife interaction with cyanide-bearing hypersaline solutions did not record an effect, as insufficient quantities of solutions are ingested to be acute at the cyanide concentrations experienced at SDGM. As wildlife interaction with cyanide-bearing habitats was documented, a toxicity threshold would exist for this system. Consequently, management procedures are required to maintain compliance with the Code.

Considering the recorded cyanide concentrations and the lack of recorded wildlife deaths (from the robust monitoring procedure), this system departs from recognised literature and assumptions.

This report does not contradict the currently described toxicity threshold of 50 ppm WAD cyanide concentration that was derived from fresh peripheral discharge tailings systems. This report demonstrates that there are protective mechanisms occurring at SDGM CTD that identifies limitations of applying the threshold to a central-discharge hypersaline system.

The protective mechanisms of reducing cyanide-bearing habitats (by management and tailings system design), hypersalinity, lack of food provisions and minimal water resulted in no observed effect on wildlife after 266 observations days, 1096 wildlife visitations and intensive observations by ACMER consultants.

The results of routine monitoring of wildlife and cyanide at SDGM and the analyses within this report have been collated to generate a series of 20 recommendations for operational strategies and procedures tailored to reduce risk, maintain existing protective mechanisms, provide a proactive approach to risk and address the Code compliance requirements.

2. Introduction

2.1 Background

Wildlife mortality on goldmine cyanide-bearing tailings storage facilities (TSFs) is a contentious matter [1, 2] that has been evident since the onset of cyanide tailings disposal and storage using these structures [3, 4].

Certification under the Code requires signatories to manage cyanide responsibly [5]. Responsible cyanide management requires understanding and monitoring as well as managing risks of wildlife exposure to cyanide-bearing tailings [6].

In a simplistic manner, three cyanide forms are common in goldmining process waste solutions: free, WAD and strong acid dissociable. Bioavailability and cyanide concentrations vary considerably in the tailings environment due to varying concentrations of metals in ore, gold extraction recovery targets, ore blending and changing tailings dam environmental conditions. WAD cyanide is somewhat resilient in the tailings environment and bioavailable, hence it is the most pertinent form to wildlife cyanosis.

Wildlife readily absorbs cyanide compounds [7], and poisoning may occur due to inhalation of dust and mist, ingestion of solution, absorption through mucous membranes and absorption through direct contact with intact skin [1, 8-11]. In the tailings environment observational data indicates that ingestion of cyanide-bearing solutions appears to be the primary pathway of wildlife cyanosis (ACMER Project 58, unpublished data).

Consensus suggests that cyanide will generally not kill wildlife at a concentration of less than 50 ppm WAD cyanide [1, 12], although this is based on field observations of fresh (non-saline) peripheral-discharge tailings systems. This cyanide concentration should be viewed as a management trigger figure rather than a toxicity concentration threshold for wildlife [4]. This takes into account that cyanide degrades in all tailings dams, and wildlife is therefore exposed to concentrations less than that at spigot discharge, depending on the habitat.

The natural degradation of cyanide is a complex process that is influenced by many variables. Consequently, the rate of degradation is likely to be different at each mine site and should be evaluated on a site-by-site basis. The rate of cyanide degradation will strongly influence the cyanide concentration and therefore toxicity of habitats within the tailings system.

Full compliance with the Code requires the development of formally documented wildlife monitoring procedures. Only trained staff can be considered to adequately document the risk and impact to wildlife [4]. It is apparent that at cyanide discharge concentrations known to be 50 ppm WAD cyanide or greater then the onus is upon the mine operator to prove that their operation is safe [13].

2.2 Sunrise Dam Gold Mine Operations

The climate in the SDGM region is described as arid with an average annual rainfall of 231 millimetres. Vegetation in the region is dominated by mulga woodlands (*Acacia aneura*) over mixed understorey shrubs including species of *Eremophila*, *Maireana*, *Atriplex*, *Senna*. Ground cover comprises a suite of grasses and daisies, typically species of *Eragrostis*, *Eriachne*, *Triodia* and *Sclerolaena* [14, 15].

The ecology of the saline lakes and the waterbirds (and general ornithology) are in part described by Smith [16]. These works provide a basis for determination of site-specific at-risk wildlife species [3, 17].

The SDGM operation is located 55 kilometres south of Laverton, Western Australia. The operation comprises an open pit and underground mining as well as processing. SDGM has an annual processing rate of 3.6 million tonnes. The tailings dam is currently a 320 hectares single-cell CTD facility. Under normal operational conditions there is minimal or no supernatant liquor or associated ponding from tailings discharge. The tailings dam and associated decant water dam were constructed above the surrounding flat terrain and the CTD system results in conical stacking of dry tailings. The CTD has a circular footprint and a stock and wildlife-proof electric fence surrounds the perimeter of the structure.

Tailings out of the spigot are discharged with WAD cyanide concentrations in excess of 50 ppm.

An open drainage system around the periphery of the CTD removes excess liquor to the perimeter of the CTD for use as dilution and it flows to the adjacent decant water dam. This water contains less than 1 ppm WAD cyanide. The clay-compacted lined decant pond walls are armoured with coarse rock material. The decant pond is square in shape (45 x 45 metres). The decant water is usually less than 20 ppm WAD cyanide and is transferred by pumping and underground carriage to the process water dam, which is located in close proximity to the mill.

Unique to the Kalgoorlie and surrounding districts, including SDGM, is that ore milling, gold extraction processing and tailings deposition occur under hypersaline conditions. The SDGM tailings are hypersaline, up to three times more saline than seawater, usually recorded well in excess of 150 000 total dissolved solids (TDS).

SDGM is unique in the gold industry being a hypersaline CTD tailings system that has undergone extensive wildlife and cyanide monitoring.

3. Project Methodology

This report collates and illustrates the routine data collected by trained on-site staff and data collected during site visits by ACMER consultants.

3.1 Routine Monitoring by On-site Personnel

3.1.1 Routine Wildlife Monitoring

The routine wildlife monitoring regime employed at SDGM as part of the ACMER project, collected data to assess the risk of cyanide-bearing water bodies to wildlife. It was designed to fulfil the requirements for wildlife monitoring as outlined in Standard of Practice 4.9 of the Code. Routine wildlife monitoring using the methodology described below commenced at SDGM in April 2004.

The wildlife-monitoring regime prescribed by the ACMER consultants for the SDGM environment department and technical staff, recommended monitoring of all cyanide-bearing water bodies two to three times per week. Initially, monitoring was conducted at the process water dam, however, due to the low level of wildlife visitation, ACMER consultants advised SDGM to cease formal monitoring of this facility and focus all available time on the CTD, stormwater/decant pond and CTD ground water interception trenches (dewatering trenches). Observations are generally conducted in the morning within three hours of sunrise.

Each monitoring session has a set observation period of 30 minutes, however observation times varied and were usually 40 to 60 minutes, which included the adjoining stormwater/decant pond.

Employing a set observation period as a standard practice largely removes observer bias of different staff members and leads to the collection of more consistent data. Recording observation time effort allows for time-effort normalisation of observational data and also allows for time-series analysis to be performed on wildlife monitoring data.

During each monitoring session the observer continually inspects the CTD and associated trenches using binoculars with 8x magnification. Any wildlife (alive or dead), species (or guild) and number observed during the set observation period are recorded on a data sheet.

On-site process technicians and environmental staff also collected behavioural and habitat data associated with wildlife observations in accordance with ACMER consult methodology. This information was provided in descriptive terms, which was standardised by ACMER consultants according to the following behaviour categories:

- resting (R);
- locomotion (L);
- feeding (F);
- drinking (D); or
- patrolling by raptors (P).

And the following habitat categories:

- supernatant open water (S);

- supernatant beach/wet tails interface (B/WT);
- supernatant beach/dry tails interface (B/DT);
- supernatant beach/natural landform interface (B/NL);
- dry tails (DT);
- wet tails (WT);
- aerial (A);
- infrastructure (I);
- dam walls (W);
- islands (Is); or
- vegetation (V).

Other information recorded on the data sheet included the weather conditions during the survey and an estimation of the size of the supernatant pond as a percentage of the entire CTD surface area.

When no wildlife was present at a water body, a zero is recorded on the data sheet. A search for the presence of carcasses within all cyanide-bearing water bodies was also conducted as part of the routine monitoring.

After the monitoring session was completed, the data was entered into a Microsoft Excel© spreadsheet. This electronic database is stored in-house and maintained by the SDGM environment department. The spreadsheet is emailed to the ACMER consultant on a monthly basis for quality control and the analysis of patterns of wildlife visitation and mortality.

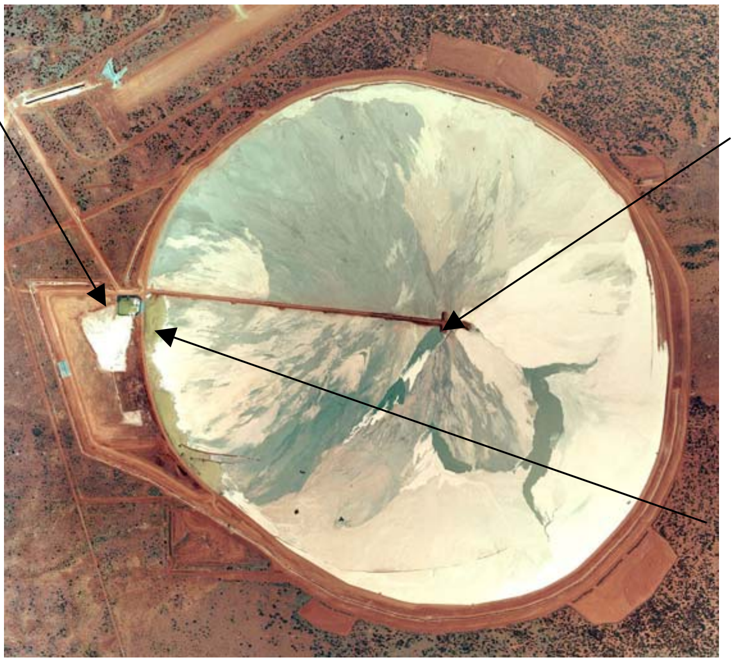
3.1.2 Routine Cyanide Monitoring

The accurate determination of cyanide concentrations in the field is difficult [20-22] due to sampling techniques and analytical error [23]. The interference of oxidising agents and sulphide agents requires field samples to be stabilised [24]. Testing for oxide and sulphide interference according to Noller and Schulz (1995) was conducted at SDGM in 2004 and no oxide or sulphide oxidising agents were recorded.

Additional guidelines for sampling procedures are outlined in the Code 'Cyanide Sampling and Analytical Methods for Goldmining' [25]. This document was provided to SDGM environment staff.

Weekly samples are currently taken at SDGM from the discharge spigot, tailings dam supernatant pond (decant pipes), decant pond and process water dam. Samples are sent to an off-site NATA-accredited laboratory and analysed for total, WAD and free cyanide concentrations.

Figure 1: Cyanide samples are taken from the CTD spigot discharge point and the decant pipes



3.1.3 On-site Staff Training

Mill process technicians are trained in-house in cyanide sampling techniques, as part of their employment duties. Prior to the commencement of routine wildlife data collection at SDGM, a training workshop was conducted for the environment and technical staff by the ACMER consultant to develop skills in the area of wildlife monitoring and data collection. It should be noted that members of the environment staff who performed wildlife monitoring do have previous experience with similar methodology associated with scientific fieldwork and are receptive to training in this field. Refresher training was provided during the coarse of the study and subsequently ongoing.

3.2 Intensive Wildlife Monitoring by ACMER Consultants

Intensive wildlife monitoring data was collected by ACMER consultants to examine wildlife habitat contact and behavioural interaction at cyanide-bearing water bodies. ACMER consultants conducted intensive wildlife surveys at the CTD and stormwater/decant pond during March 2004, April 2005, September 2006 and November 2006. Intensive wildlife monitoring was conducted continuously from sunrise to sunset using binoculars with 8x magnification and a telescope with 60x magnification.

During intensive surveys, observations were conducted at one-hour intervals and documented:

- species identification;
- number of individuals present;
- contact time with the TSF;
- TSF habitat usage and interaction;
- signs of stress (for example excessive eye rubbing and lethargy);and
- general behaviour.

The habitats with which wildlife interacted within the CTD and process water pond and its behaviour were allocated to the same set of categories described for routine in-house monitoring (described above).

3.3 Aquatic Macroinvertebrate Survey

Sampling of aquatic invertebrates in the CTD supernatant and CTD ground water interception trenches was conducted in September 2006. Several species of native wildlife will attempt to forage in hypersaline waters if food resources are present (e.g. Australian Shelduck, Banded Stilt, Black-winged Stilt) [26]. This represents the most likely pathway of cyanide exposure under hypersaline conditions.

To investigate the availability of food resources for waterbirds, the CTD decant pond, CTD ground water interception trenches and stormwater/decant pond were surveyed in September 2006 to obtain a measure of the aquatic macro-invertebrate assemblage. Four separate samples were taken from supernatant pooling around the CTD decant pipes area. One sample was taken from the stormwater/decant pond. Two samples were taken from different locations within the southwest CTD ground water interception trench and one sample from the north CTD ground water interception trench.

Invertebrate sampling was done using a standard 250 µm mesh dip net with a 350 by 250 mm (triangular shaped) opening, 50 cm net depth and 1 to 1.5 m aluminium extension handle. Invertebrates were collected by vigorously sweeping the net through the water column, for a minimum period of two minutes, using short vertical lifts to disturb the substrate and catch the suspended organisms [27]. This method was employed to ensure that both nektonic and benthic invertebrate species were collected.

All invertebrates collected during sampling were preserved in 70% ethanol. In the laboratory, specimens were identified using a stereomicroscope at 10x and 50x magnification. Most macroinvertebrates were identified to family level, with the exception of Chironomidae that was identified to subfamily, and water mites (Acarina) to order.

Differences in macro-invertebrate assemblages among CTD decant pipes and CTD ground water interception trench samples were examined by calculating the number of taxa per sample (taxa richness) and the number of individuals (abundance) per sample. For this analysis the stormwater/decant pond and CTD ground water interception trench samples were grouped together (combined total number of samples: n=4) and compared with the CTD decant pipes samples (n=4). For health reasons no sampling of the sewerage solutions was conducted. Visual observation of the sewerage pond solutions revealed a number of obvious macroinvertebrates.

3.4 Bat Monitoring

Bat presence and activity was monitored using anabat detectors. These were placed at the CTD supernatant, dry tails, CTD interception trenches and nearby sewerage ponds.

3.5 Criteria for Establishing a Causal Relationship

Causal relationships are required to establish if the mechanisms proposed actually reduce wildlife exposure to the cyanide hazard. Since data collection of the SDGM tailings system is observational-based, not experimental design, causation is discussed in this context using Hill's Criteria.

Hill's criteria has been widely used to determine causal associations that exist and is used in this study as an ecological and toxicological context for the study. The rationale for extending the application of Hill's criteria to other applications is supported by the US Agency for Toxic Substances [28] and Disease Registry *A Quick Guide to Evaluating Environmental Exposures* [29].

4. Results

The following is a summary of the results derived from monitoring at SDGM. A comprehensive description, critical review and discussion of all results obtained from wildlife and cyanide chemistry monitoring during this project is provided in the sponsor's report Appendix B: Results of this study.

4.1.1 No Observable Effect (No Deaths) on Wildlife

No wildlife cyanosis deaths were detected during on-site routine monitoring (266 observations between April 2004 and May 2006) at SDGM CTD. No observational evidence of carcass scavenging or removal was recorded. A total of 1096 wildlife visitations were recorded at the CTD or in the airspace above the system.

In addition ACMER consultants did not record wildlife deaths (n= 36 hours of intensive wildlife observations at sunrise and sunset) over four separate observation periods.

The methodologies were implemented at all other case studies as part of the ACMER project. At case study A and B (fresh peripheral-discharge systems) where mine tailings solutions exceeded the accepted threshold for WAD cyanide concentrations, the on-site staff and ACMER consultants were able to routinely detect wildlife carcasses and deaths. At these case studies wildlife deaths occurred in-situ at the source of the toxicant, as expected, with cyanide an asphyxiant.

4.1.2 Cyanide Concentrations of the Process Tailings Solutions

Weekly cyanide samples have been taken from all cyanide-bearing water bodies at SDGM during the period of wildlife monitoring (April 2004 to May 2006) and continues. Cyanide was discharged to the CTD in excess of 50 ppm WAD cyanide on 72% of the sampled days. The mean (±SD) concentration of WAD cyanide at discharge during this period was 62.4 ± 22.83 ppm (*n*=114 samples taken) with 90% of the samples between 32 to 100 ppm WAD cyanide concentration.

WAD cyanide concentrations of supernatant pooling at the decant pipes of the tailings dam was highly variable during this time and exceeded 50 ppm WAD cyanide on 7 of 113 sampling days. These samples have been diluted by an inflow of ground water usually to below 5 ppm. Samples from the CTD to the decant pond via the pipes have not exceeded 50 ppm WAD cyanide since 12 February 2005, however in May 2006, weekly sampling commenced from supernatant ponding on the eastern side of the tailings dam before dilution occurred from ground water inflows. From these pools, five out of eight samples exceeded 50 ppm WAD cyanide with values ranging from 35 to 59 ppm.

4.1.3 Sunrise Dam Gold Mine: Deviation from Expected Results

Considering the recorded cyanide concentrations and the lack of recorded wildlife deaths (from the robust monitoring procedure), this system departs from recognised literature and assumptions.

To develop a hypothesis of this result, the following mathematical expression describes wildlife cyanosis impact (or lack of impact) as:

Impact = f Exposure (wildlife interaction) x Hazard (CN concentration) eqn. 1 [30].

Since the cyanide code specifies no wildlife deaths and that 50 ppm WAD cyanide is the recognised hazard threshold then the equation above can be further described. Consider that the 50 ppm WAD cyanide concentration threshold is derived from fresh peripheral discharge tailings systems [4, 9, 31]. Therefore the risk can be described as:

$Impact_o = f \, Exposure_{fpd} \times <50$ ppm [CN WAD] eqn 2.

Where $Impact_0$ is no wildlife deaths, $Exposure_{fpd}$ is the extent of wildlife exposure at fresh peripheral discharge system and the hazard is expressed as the toxicity threshold or less.

At SDGM impact was recorded as zero ($Impact_0$) and the hazard as above 50 ppm WAD cyanide concentration. Therefore wildlife exposure (for whatever mechanism) at SDGM CTD ($Exposure_{SDGM}$) must be less than experienced at fresh peripheral-discharge systems.

To explain this phenomena of reduced or eliminated exposure the following four mechanisms are hypothesised:

1. There are minimal habitat provisions containing bio-available cyanide (supernatant and wet tails) for at-risk species.
2. The management procedures are maintained to minimise and reduce structural habitat diversity in the CTD.
3. The minimal food provisions in cyanide-bearing substrates reduces the inadvertent ingestion associated with feeding in solutions and wet tails.
4. Hypersalinity eliminates the drinking of solutions.

4.2 Wildlife Exposure

4.2.1 Tailings Dam Habitats and Wildlife Presence

Determining habitat provisions on a tailings system allows prediction of expected wildlife species presence. On visual inspection the following habitats within the SDGM CTD are present:

1. supernatant (S);
2. supernatant beach/dry tails interface (B/DT);
3. supernatant beach/wet tails interface (B/WT);
4. wet tails (WT);
5. dry tails (DT);
6. infrastructure (I);
7. dam walls (W);
8. islands (Is);
9. vegetation (V): or
10. Aerial (A).

Habitats 1 to 4 were found to contain bioavailable cyanide and consequently only species that interact with these habitats have the opportunity to ingest cyanide. The remaining habitats are benign to wildlife.

There is minimal extent of cyanide-bearing habitats on the CTD. The surface area of supernatant and wet tails determines the extent of habitats 1 to 4. The supernatant and wet tails surface areas (as a percentage) of the entire CTD were estimated concurrent with wildlife surveys and found to average 1%(<1Ha) and <5% (2Ha) respectively. These habitats are small compared to peripheral-discharge systems, which can have these habitats comprising 50 to 90% of an entire tailings dam [32]. Of importance at SDGM is such solutions and wet tails are at least 70 and at times over 1000 metres from any extant native vegetation. This removes the connectives of vegetative habitats and the CTD water source (and bioavailable cyanides).

Supernatant surface area minimilisation has been documented in ACMER Project 58 case study A as a protective measure to reduce wildlife visitation and deaths. The visitation rates at SDGM CTD are significantly lower (0.23 and 1.27 wildlife present per hour to supernatant and beach habitats) than that recorded on fresh peripheral-discharge systems [4] and case study A and D [32, 33]. This concurs with literature that documents a positive correlation of visitations and diversity of waterbirds with water body size [34]. Furthermore the CTD is managed to exclude structural diversity, which decreases species numbers and visitation [35]. Minimal supernatant means the number of species and individuals that have long contact time with habitats containing bio-available cyanide (i.e. ducks floating on supernatant) are less than expected on fresh peripheral-discharge tailings systems. To substantiate this, only 6.6% of visitations by ducks to the tailings system (Figure 2), compared with 29 to 60% recorded elsewhere [2, 4]. This is crucial as ducks are probably the most susceptible guild because of high drinking rates and long contact time with supernatant habitat, and they suffer deaths near the 50 ppm threshold [4, 9, 36].

It should be noted that large visitations of ducks, other waterbirds, granivorous species (parrots and pigeons) (217 wildlife visitations per hour) and insectivorous bats to the SDGM sewerage ponds (a non-saline system) some 5 kilometres away from the CTD have been observed throughout the project period by the ACMER consultants (see sponsor's report Appendix B). This demonstrates that wildlife is present in the region but has deliberately chosen not to inhabit the SDGM CTD in any significant number or length of time. It also demonstrates that those species dependant on fresh water sources for drinking can discriminate between saline and fresh water sources (see sponsor's report Appendix B).

Wildlife visitations to the CTD recorded by SDGM environment and technical staff included 35 species in nine different wildlife guilds. Waterbird guilds comprise over 62% of these visitations (Figure 2). Over half of these visitations are waders, mostly Red-capped Plover, a non-migratory wader probably resident on the CTD and surrounds (see sponsor's report Appendix B).

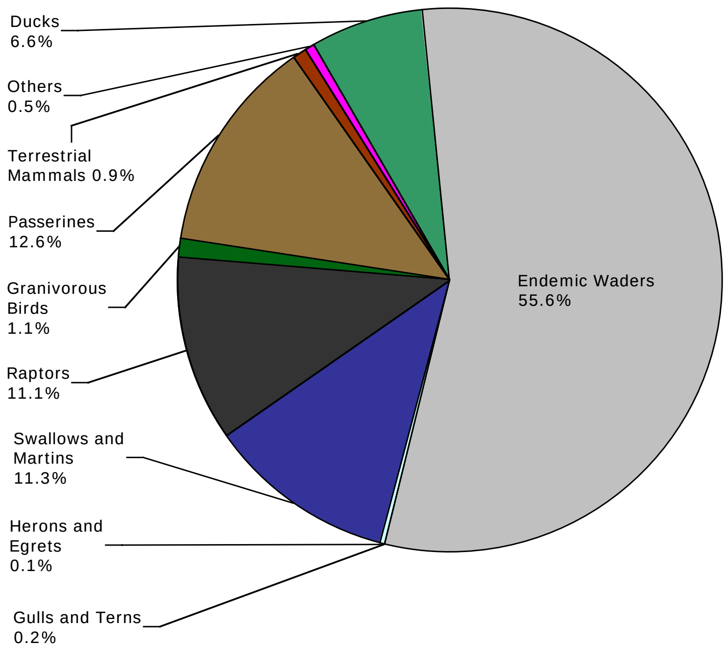
The remaining visitation records are of wildlife guilds that normally have a secondary association with aquatic habitats (Table 1, Figure 2).

Table 1. Mean wildlife presence recorded by on-site staff between 1 April 2004 and 26 June 2006

	CTD tailings dam	CTD supernatant habitat	CTD beach habitat	Stormwater/decant pond	Dewatering trenches	Process water dam	Sewerage ponds
Wildlife presence per survey	4.1	0.23 (2.48)	1.27 (0.24)	2.8	4.1	0.3	(217)
Species	35	6 (3)	8 (3)	32	31	5	(33)
Guilds	9	2 (1)	3 (2)	10	7	3	(6)

* Data in parentheses is derived from intensive monitoring by ACMER consultants. Wildlife presence figures are mean wildlife present per hour of monitoring.

Figure 2: Wildlife visitations by guild recorded by environment technical staff at SDGM CTD between 1 April 2004 and 26 June 2006 (*n*=1096 visitations, 266 surveys)



The proportional composition of the species recorded on the SDGM CTD is presented in Figure 2.

In addition to the routine in-house monitoring, ACMER consultants intensively monitored the CTD and stormwater/decant ponds at SDGM for a combined total of 36 hours on ten different days over four separate visits (March 2004, April 2005, September 2006 and November 2006).

During intensive monitoring, ACMER consultants recorded visitations of 21 wildlife species in seven guilds. This measure of wildlife diversity and guilds compares favourably with in-house data over the full monitoring period from

1 April 2004 to 26 June 2006. This provides a level of confidence of guild composition recorded by in-house data.

There is no data to suggest that SDGM (or the broader region) is on a migratory fly path although migratory species are found in the district (Bird Data, Birds Australia www.birdsaustralia.com.au).

The SDGM CTD, inherent in its design and management (supernatant and structural diversity minimisation), reduces visitations to cyanide-bearing habitats compared to peripheral-discharge tailings systems.

4.2.2 Wildlife Cyanide Exposure Pathways

There are four main cyanide exposure pathways for wildlife visiting and interacting with TSFs:

1. Absorption through epidermal exposure.
2. Inhalation.
3. Drinking.
4. Attempting to feed [8, 9, 37].

Data shows from other ACMER Project 58 case studies that only those species ingesting cyanide-bearing supernatant by drinking or feeding have been recorded dead on the tailings system.

While the natural ecology of wildlife guilds visiting goldmine TSFs is known, these systems are very much artificial habitats. Habitat and behaviour information collected by mine environment and technical staff and ACMER consultants during routine and intensive monitoring provides a more meaningful understanding of the risk to wildlife by cyanide-bearing mine waste solutions. Specific exposure pathways are unique to each wildlife guild according to its behavioural ecology. Furthermore, these pathways and the relative abundance of different wildlife guilds are likely to vary between mine sites according to the amount and types of habitats available.

4.2.3 Epidermal Exposure

Cyanide can be absorbed through the skin especially when the skin is wet [8, 12]. Acute cyanosis of wildlife due to skin absorption has not been reported in the literature [9] or observed in the field [4]. While it is possible that some cyanide is absorbed through the skin there is no evidence that there is an effect on wildlife. Birds roosting on supernatant have epidermal exposure through their feet, consequently limited surface area contact. Birds' feet have low epidermal exchange with the external environment [38]. Effects of cyanosis through this avenue will be the same as for other exposure avenues, such as lethargy, tameness, gulping, yawning and mortality, which has not been observed in the field or reported in literature. Considering the cyanide concentrations, literature and field observations, it follows that this pathway poses little or no risk to wildlife.

4.2.4 Inhalation

Cyanide gas on tailings systems results from the liberation of free cyanide as it volatilises from the surface of tailings dams [1, 18, 19, 37, 39-45], although atmospheric concentrations immediately above tailings solutions are not considered toxic [37]. Pertinent to SDGM, cyanide volatilisation decreases with increasing salinity [46]. Monotox monitors used for safety reasons during the coarse of the study did not record gas concentrations greater than 2 ppm.

Considering the literature, cyanide data collected, field observations and the lack of recorded deaths, this exposure pathway is dismissed as a risk to wildlife at the concentrations expected at SDGM CTD.

4.2.5 Feeding in Cyanide-bearing Habitats

The matrices below outline the guilds of species at cyanide-bearing habitats and their behaviour (inferring possible ingestion) while in that habitat. Two guilds (ducks and endemic waders) use the supernatant and beach (including wet tails) habitats that contain bio-available cyanide. Each guild's habitat preference and behaviour are presented below.

Table 2: Habitat preference and behaviour of endemic waders expressed as percentage of all endemic wader visitation records

	Supernatant	Beaches (incl. wet tails)	Dry tails	Islands	Bare Ground	Infrastructure	Mud	Wall	Aerial	Habitat not recorded	Total
Foraging	1.5	38.4 (2)	13.1 (2)	0.0	1.6	0.0	0.0 (19)	0.0	0.0	0.3	55.0 (23)
Locomotion	0.3	8.0	10.0 (6)	0.0	4.4	0.0	0.0	0.0	0.0 (4)	0.0	22.8 (10)
Resting	3.6	4.1 (1)	0.3 (20)	0.0	2.6 (33)	0.2	0.0 (13)	1.0	0.0	0.0	11.8 (67)
Behaviour not recorded	0.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.4	10.3
Total	5.6	51.4 (3)	23.5 (28)	0.0	8.7 (33)	0.2	0.0 (31)	1.0	0.0 (4)	9.7	100.0

Notes: Figures in parentheses are sourced from ACMER consultant data. Percentages are rounded. Routine data: n=609 records, ACMER consultant data: n=96 records.

Table 3: Habitat preference and behaviour of ducks expressed as percentage of all duck visitation records

	Supernatant	Beaches (incl. wet tails)	Dry tails	Islands	Mud	Wall	Aerial	Habitat not recorded	Total
Foraging	0 (2)	0	0	0	0	0	0	0	0 (2)
Locomotion	18	0	4	0	0	0	31 (11)	0	53 (11)
Resting	11 (59)	10	13	1 (11)	0 (9)	0 (4)	0	0	35 (82)
Behaviour not recorded	8 (5)	0	0	0	0	0	0	4	13 (5)
Total	38 (66)	0 (10)	17 (28)	1 (11)	0 (9)	0 (4)	31 (11)	4	100

Notes: Figures in parentheses are sourced from ACMER consultant data. Percentages are rounded. Routine data: n=72 records, ACMER consultant data: n=94 records.

Tables 2 and 3 identify the guilds that interact (inhabit and forage) with habitats (and substrates) that contain bio-available cyanide. Feeding in cyanide-bearing habitats is presented here in two subsections, supernatant and beaches.

SDGM CTD is hypersaline, averaging 158, 000 TDS. Several species of native wildlife will attempt to forage in hypersaline waters if food resources are present. Some species are capable of, and regularly do, feed in hypersaline waters, particularly in Australia [16]. In one study on nearby Lake Carey, eleven species of birds were recorded foraging in a hypersaline environment [16]. These species may attempt to feed within the supernatant or beach habitats of the SDGM CTD. Some inadvertent ingestion of solution while attempting to feed is likely to occur.

Supernatant
No ducks were seen foraging in the supernatant at the SDGM CTD during routine in-house monitoring (see sponsor's report Appendix B). However, three Grey Teal (ducks) on one occasion were observed foraging in the supernatant during intensive monitoring by ACMER consultants (see sponsor's report Appendix B). No effect was observed and the ducks where recorded leaving the system at sunset.

Red-capped Plover was recorded feeding in this habitat on 1.5% of the time. Some inadvertent ingestion of solution during feeding attempts is likely to occur. Results of aquatic invertebrate sampling from the SDGM CTD supernatant indicate that the supernatant is essentially abiotic and does not contain food resources to sustain foraging by waterbirds or waders (see sponsor's report Appendix B).

Macroinvertebrates are abundant in the surrounding hypersaline trenches (see sponsor's report Appendix B).

Macro-invertebrate abundance and diversity comparison, section 1.3.4: Aquatic Macro-invertebrate Survey), correspondingly ducks (48%), endemic waders (23%) and migratory waders (50%) were recorded feeding in these solutions (see sponsor's report Appendix B).

Consistent with Hill's criteria, the lack of feeding observations is caused by the lack of food resources and consequent inadvertent exposure to cyanide.

Winged insects have been observed floating (dead) on the supernatant surface. Swallows and martins, while on the wing, do pick insects from the surface of open water bodies such as supernatant. This has been rarely observed at SDGM CTD with no effect. This observation has also been recorded at case study A [32]. These observations demonstrate insufficient cyanide is ingested through this pathway at the cyanide concentrations experienced at SDGM CTD.

Insectivorous bats have been recorded in the airspace above the CTD. They are recorded in minimal numbers compared with the sewerage pond system (see sponsor's report Appendix B). Their hunting technique (echolocation) suggests that picking dead insects from the supernatant surface is extremely unlikely. This is unlikely to be sufficient exposure pathway of cyanide at the concentrations experienced at SDGM CTD.

Beaches
During routine monitoring, endemic waders were seen to predominantly use beach habitats (51%), and were foraging in these beach habitats 38% of the time (Table 2). Nine of these foraging waders were on supernatant habitat and 234 were foraging on beach habitats. The remainder were recorded foraging on dry tails or bare ground substrates. ACMER consultants also recorded endemic wader species foraging on beaches, dry tails and mud at the CTD.

Only endemic waders (probably Red-capped Plover) were recorded foraging in a beach habitat that contains bioavailable cyanide by on-site staff. This guild of species pick wind blown insects from wet substrates (supernatant or beaches) [26] and pers. obs.).

No deaths of this species were recorded and the species has been observed on 23% of observation days (with a total count of 348). Immature and adults (in breeding plumage) were observed on the CTD. This probably indicates breeding and long-term habitation of the SDGM CTD and surrounds. Banded Lapwing has a similar feeding behaviour and was recorded breeding on the CTD in April 2004. Long habitation time provides circumstantial evidence of the benign state of the tailings system to this guild.

Intensive observations conducted by ACMER consultants, identified that this species frequently feeds in the beach habitats. It feeds in the expected manner, picking up small insectivorous food items from dry tails, wet tails and the edge of the supernatant (n=96). The species frequently leaves the SDGM CTD and walks to the adjoining stormwater/decant pond only to return some hours later. Essentially the species (typical of the family *Charadriidae*), hunts by sight for small insects and seeds trapped in wet substrate [26]. Consequently this species has minimal contact time with the bioavailable substrate, and does not filter feed in the substance. The avoidance of salinity loading inadvertently reduces ingestion of cyanides. These field observations demonstrate this exposure pathway under hypersaline conditions does not provide sufficient cyanide to cause death or observable effects at the concentrations experienced at the SDGM CTD.

The literature and data from this study illustrates that the feeding behaviour of this guild of species in wet tails and supernatant habitats is not a toxic exposure pathway at the cyanide concentrations and salinity experienced at SDGM.

4.2.6 Drinking (and the Influences of Salinity)

No wildlife of any kind was seen drinking at the CTD during routine monitoring by environment and technical staff or intensive monitoring by ACMER consultants.

The salinity of the mine waste solutions in the CTD, decant ponds and dewatering trenches was recorded weekly along with cyanide sampling. TDS in the CTD averaged 158, 322 ± 3 847 ppm (±SE) at tailings discharge (four to five times more saline than seawater) and averaged 133, 722 ± 9 256 ppm in supernatant pooling at the decant pipes. In water pooling on the CTD, TDS averaged 163, 429 ± 9 008 ppm. Solutions in the decant pond averaged 82, 000 to 89, 000 ppm and in the dewatering trenches, between 57, 742 ± 772 ppm (south trench) and 86, 097 ± 1 135 ppm (east trench).

The extremely high salinity of the tailings solution at SDGM is due to the use of hypersaline ground water, unique to the eastern goldfields of Western Australia.

Some species have adapted to saline conditions and can tolerant (for drinking purposes) concentrations similar to sea water (35, 000 TDS), a quarter of that experienced at SDGM CTD. Wildlife exposure is significantly reduced as they are physiologically incapable of drinking the solutions [47] and therefore are unlikely to ingest sufficient quantities at the concentrations experienced at SDGM CTD.

Table 2 and 3 demonstrates that drinking as an exposure pathway is eliminated at this site.

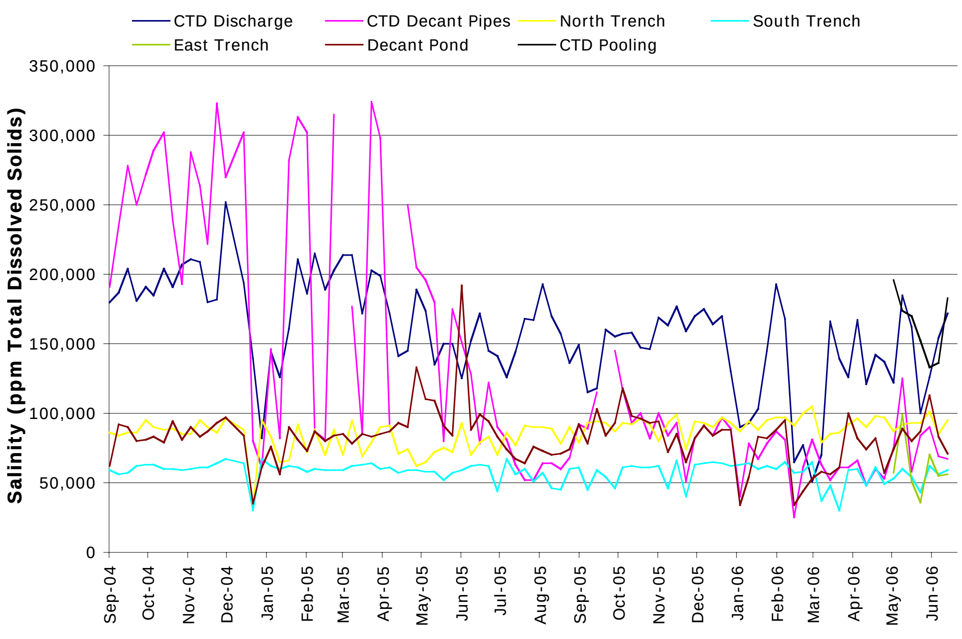
Parrots and pigeons are rarely recorded at the SDGM CTD, although they have been extensively recorded drinking at the sewerage ponds during concurrent wildlife observations. Their presence at times, in excess of 396 individuals per hour, again indicates that wildlife can differentiate between water sources and selectively avoid the hypersaline solutions of the SDGM CTD as a drinking source (see also sponsor's report Appendix B). The sewerage ponds are inhabited by species that are required to drink frequently (granivorous species) (see sponsor's report Appendix B).

Insectivorous bats have been recorded in the airspace above the CTD, although they preferentially inhabit the sewerage pond system significantly more frequently (see sponsor's report Appendix B). This supports the proposition that it is not conceivable that insectivorous bats are capability of drinking the hypersaline solutions experienced at the CTD. Consequently it can be deduced that insectivorous bats prefer to occupy and drink from the sewerage pond system to the CTD. Considering the lack of live macroinvertebrates in and on the supernatant and hypersalinity there is no plausible pathway of lethal cyanide concentration ingestion for insectivorous bats at the SDGM CTD.

Comparisons of wildlife drinking rates with other ACMER case studies that are 'fresh' cannot be made as all wildlife died that drank fresh tailings solutions in excess of 50 ppm WAD cyanide at discharge.

Literature, lack of drinking observation at the CTD, observations of drinking at fresh sources and differing species composition between the sewerage ponds and CTD establishes the obvious causation that hypersalinity experienced at the SDGM CTD eliminates wildlife drinking and reduces inadvertent solution ingestion by feeding attempts.

Figure 3: Salinity (TDS – ppm) recorded at the CTD, dewatering trenches and decant pond at SDGM during the wildlife-monitoring period



5. Discussion

The protective mechanisms as outlined provide protective measures to reduce wildlife exposure compared to fresh tailings systems.

This report does not contradict the currently described toxicity threshold of 50 ppm WAD cyanide concentration that was derived from fresh peripheral discharge tailings systems. SDGM discharges cyanides at the spigot marginally above this prescribed threshold. This report has demonstrated that protective mechanisms occur at SDGM CTD and have identified the limitations of the applying the threshold to a central-discharge hypersaline system.

The protective mechanisms of reducing cyanide-bearing habitats (by management and tailings system design), hypersalinity, lack of food provisions and minimal water have resulted in no observed effect on wildlife after 266 observations days,1096 wildlife visitations and intensive observations by ACMER consultants. This study has hypothesised that mechanisms provide protective measures by eliminating and reducing the wildlife exposure pathways to otherwise toxic solutions.

Wildlife at SDGM interacts with bio-available cyanide-bearing habitats and therefore a toxicity threshold exists. It should be noted that if these protective mechanisms cease or reduce in effectiveness then the risk of cyanosis may occur. Consequently to maintain minimal wildlife risk and compliance with the Code management recommendations were provided.

A toxicity threshold was not breached during two years of monitoring and therefore an alternative threshold specific to SDGM CTD cannot be provided.

Proposed mechanisms to reduce wildlife exposure at SDGM have resulted in no observable impact. They have been developed through close scrutiny of data collected during extensive monitoring over a two-year plus period. It is not suggested that the exposure-reducing mechanisms detailed at SDGM occur at other mining operations thereby automatically equating to wildlife protection and resulting in no observable impact to wildlife.

6. Management Recommendations

Detailed management recommendations were presented in the sponsor's report Appendix C. The recommendations are provided in the context of the relevant standards of practice specified in the Code, address any perceived risks of wildlife cyanosis at SDGM and identify requirements for compliance with the Code.

The recommendations address the following key aspects:

- Monitoring and maintaining the identified protective measures;
- Maintaining the tailings system, including but not limited to salinity, cyanide concentration, supernatant size and management within the identified environmentally safe parameters; and
- Detailed and comprehensive on going wildlife and cyanide monitoring regime.

In addition several recommendations relating to emergency management, training of wildlife and cyanide chemistry monitoring staff and public dissemination of information relating to the use of cyanide.

The recommendations are in the context of an adaptive management process and should be continually reviewed with new information and on-site data collection.

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