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CYANIDE ECOTOXICITY AT HYPERSALINE GOLD OPERATIONS

Executive Summary
Volume II – Phase II (Definitive Investigation)

Results of research carried out by [1]Mutis Liber Pty Ltd, [2]Donato Environmental Services and [3]Roger S Schulz (consultant) as MERIWA Project No. M398 I and II

by

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Executive Summary

Wildlife interaction and ingestion of saline (>14,000 mg/L total dissolved solids – TDS) and hypersaline (>50,000 mg/L TDS) cyanide solutions in gold plant tailings in the Central Goldfields of Western Australia is reputedly less than that experienced at other gold minesite tailings facilities, with more rapid degradation of weak-acid dissociable (WAD) cyanide in the tailings storage facility (TSF). The objective of this definitive Phase 2 of the M398 project is the compilation and review of sufficient additional data to quantify the nature and to establish the scientific validity of the 'hypersaline cyanide ecotoxicity' hypotheses that were supported by the Phase 1 field data and literature review. This report is a compilation of the Phase 2 data collected, along with comments on hypothesis validity and limitations in the dataset and recommendations.

The research programme comprised an intensive chemical sampling and wildlife observation exercise at two nominated hypersaline sites, Barrick Kanowna Belle (BKB) and Goldfields St Ives (GSI) and one saline site, Barrick Granny Smith (BGS), between January and June 2008. One further saline site, Barrick Darlot (BD), was selected as a limited data set comparison during January 2008. In addition, the buildup of individual site data sets at the three primary sites has been ongoing via site monitoring programmes and site data is included up to 31 May 2008. Laboratory testwork and modelling activities were also included to help meet the overall study objectives. Available reported chemical sampling and wildlife observation data from a previously operational fresh water site, Case Study D (CSD), was also closely examined to provide a further comparative basis to help in the development of the scientific rationale supporting the considered hypotheses.

Two of the nine hypotheses considered by the authors in the preliminary Phase 1 component of the work reported in Volume 1 of this report are strengthened by the data presented in this report; the other seven hypotheses arre not considered to be supported by the data. Hypothesis 7, although modified and extended in light of the definitive data analysis in this study, has been documented as **valid** and causation inferred:

> **Hypothesis 7A:** Hypersalinity (>50,000 mg/L TDS) provides a natural barrier for wildlife exposure to WAD cyanide contained in tailings solutions because at this salinity the solutions are outside the physiologically safe drinking range of wildlife and wildlife seek to avoid its ingestion while foraging.
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> **Hypothesis 7B:** Salinity (>14,000 mg/L TDS) provides a partial barrier for wildlife exposure to WAD cyanide contained in tailings solutions because at this salinity wildlife are either unable to drink solutions or preferentially drink fresh water if it is available.

Hypothesis 8 has been documented as **valid** and causation inferred:

> **Hypothesis 8:** WAD cyanide in hypersaline waters is lost at rates sufficient to have a substantial beneficial impact on the physical area of wildlife exposure to contained WAD cyanide (levels and profiles are to be determined on a site-specific basis).

No wildlife deaths attributable to cyanide were recorded at the BGS, BKB or GSI TSFs during the 1319 observation days conducted by on-site monitoring or during the 91 days by third-party experts. A total 5710 live wildlife visitations to the TSFs were recorded. The lack of recorded deaths appears to reflect a lack of actual deaths despite observed interaction (including foraging behaviour) with tailings at all three sites.

Causation for the lack of wildlife deaths could not be established through experimentation without the risk of incurring unnecessary wildlife deaths, despite the support for the hypotheses. Establishing causation in observational (non-experimental) studies is difficult and especially so for this project where the toxicity threshold has not been breached. Hill's criteria have been used to aid the establishment of causation. WAD cyanide toxicity thresholds are not given but must exist because wildlife do interact with these systems.

Process waters at BKB and GSI are hypersaline (~200,000 mg/L TDS and ~50,000 mg/L TDS, respectively), while BGS and BD were considered to be saline at ~20,000 mg/L TDS. Some of the protective measures identified (particularly TSF solution palatability as a wildlife drinking source) may not be applicable at BGS and BD, where wildlife are theoretically capable of drinking the tailings solutions.

The comparative freshwater TSF at the previously operational CSD site, for which data had been made available, revealed the apparent lack of some protective mechanisms, with mortalities recorded at spigot WAD cyanide levels similar to those found on the hypersaline and saline sites that recorded no mortalities.

Wildlife seasonality was considered, with ecological data being collected during various climatic seasons and migratory seasons for wader species.

Several special investigations were carried out to help clarify aspects of saline tailings systems. Cyanide levels in both dry and wet beach solids were low and deemed not to be toxic to wildlife. Results also indicate that the pH of wildlife digestive tracts, quantity of digestive juices and salinity (particularly hypersalinity) can all strongly influence the quantity of free cyanide liberated on ingestion. Over the pH range tested, spigot solution provided lethal doses of free cyanide (>50 mg/L free cyanide) at all sites when the ratio of tailings solution to stomach liquids was 1:1 or greater. This appears not to be the case for supernatant solution, which contained much lower WAD cyanide levels.

The hypersaline sites showed significantly greater cyanide degradation in the spigot-to-supernatant flowing beach zone than the saline sites. The major contribution to degradation in WAD cyanide in all four process plants was across the carbon-in-leach (CIL) circuit, with the strongest effect being observed for the highest salinity water.

Utilization of a radio-controlled boat (RCB) enabled sampling of supernatant in areas close to inaccessible shallow parts of the supernatant simultaneously with avian wildlife observations both from the decant pier and via onboard wireless camera feed to a laptop computer. This work was extended in the May/June site visit to include instrumented real-time monitoring and logging of supernatant pH, oxidation-reduction potential (ORP), salinity, temperature and depth at logged global positioning system (GPS) points at the three TSFs under investigation.

The two hypersaline plants (GSI and BKB) share both lower operating pH ranges and higher gaseous HCN emissions compared with the two saline sites (BGS and BD). HCN volatilization is therefore an important contributor to the degradation system, particularly in hypersaline waters.

Cyanide degradation testwork was carried out under controlled laboratory conditions on synthetic and plant solutions, enabling the determination of first-order rate constant data for the systems and validation and extension of the cyanide degradation effect against literature data. The enhancing effect of salinity on cyanide degradation rate was validated and the limiting effect of copper on degradation rate and extent quantified.

The data set for the three primary sites was successfully tested against two discrete mathematical models for cyanide degradation extended to allow for the effect of copper, to predict WAD cyanide levels in TSF supernatants. This enabled the further support and substantiation of the scientific basis underlying the relevant hypothesis that was shown to be consistent with the data.

Key recommendations for maintaining inferred protective mechanisms through control of TSF spigot and supernatant chemistry (WAD cyanide, salinity, pH and copper) are presented on a site-specific basis for the two hypersaline sites (BKB and GSI) and one saline (BGS) site under primary investigation. The secondary saline site (BD) had not been included in the detailed investigation and the dataset was small, comprising one 3-day site visit only; however, the data was consistent with that of the primary saline site at BGS and served to provide further validation of the beneficial saline effect on cyanide ecotoxicity observed at BGS. Recommendations are presented with a view to Code compliance requirements. These recommendations have been developed on the basis of the formulated hypotheses and supporting scientific bases, as applied to the body of data collected for each site in this study. Process control mechanisms to achieve the recommended outcome targets are not specified here but have been shown to be achievable based on the current data set and should be reviewed after (i) periods of extension of the data set and (ii) anticipated substantial changes in feed ore mineralogy, process setpoint parameters or tailings deposition techniques that could reasonably be expected to impact on the outcomes determined in the current body of work.

This work is of potential substantial benefit to the sponsoring companies, insofar as providing a non-chemical means of controlling and maintaining hypersaline or saline TSFs that are essentially non-toxic to wildlife. The resultant upside in both capital and operating cost savings is likely to be significant. The improved understanding of salinity effects on chemical and wildlife aspects is of value to the broader research community and to the various other gold minesites in the Eastern Goldfields of Western Australia that are utilizing saline process water in their process. Indeed, the economic benefits from improved control of reagent consumption have already been observed at one site. The clear environmental benefits resulting from this body of work should also provide assurance to the general public that the gold-mining industry is taking proactive steps to maintain rigorous protective mechanisms for wildlife to target the current status of zero mortalities at these sites.