SUMMARY REPORT
EVALUATION OF LYDIAN AMULSAR GOLD MINING PROJECT: ASSESSMENT OF ARD POTENTIAL AND EFFECTS ON SURFACE WATER AND GROUNDWATER

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1. What is Acid Rock Drainage (ARD)?

In mining operations, acidic drainage with associated dissolved metal species some damaging to human health and toxic to biota (e.g., Cd, Cu, Pb, Zn, As, Hg, Se), can result from the weathering of sulfide minerals in mine waste rock and process tailings. The waste-rock dumps from overburden and low-grade sections of the deposit, usually hundreds to millions of metric tons, constitute by far the largest source of acid drainage if they contain significant sulfide mineral content. Acid rock drainage (ARD) can continue for hundreds of years after a mine is closed and so has potentially long-term and serious environmental impact on downstream water quality, agriculture, fauna and flora. The iron sulfide mineral pyrite (FeS_2), found throughout the Amulsar deposit, is the main generator of acid drainage.

ARD is internationally the biggest environmental issue facing closed and abandoned mines and mine site rehabilitation. It presents an impending liability to current and future mining operations worldwide and also poses a challenge to the environmental and social acceptance of mining activities. Total cost estimates for remediating ARD-impacted sites in the USA and Canada combined runs into tens of billions of dollars.

For effective ARD control and mitigation the rates of release of acid must be understood *in advance*. Definition of the total amount of possible acid release is useful to characterise a mine waste as potentially acid forming or non-acid forming but it is only through understanding the evolution of the

rate of acid release that an effective and long-lasting environmental management plan can be put in place. This has not been done adequately in the Amulsar ARD planning.

2. Lydian and the Amulsar Project

The Lydian Amulsar project is situated in southern Armenia. With 40% of capex currently committed (lydianinternational.co.uk/home), this is the first mine Lydian will manage or operate. For Lydian's other mine under consideration (Kela, Georgia) license conditions still require submission of an Environmental Impact Assessment and interim report on potential resources. Geoteam (now Lydian Armenia as of 2016), responsible for preparation and/or consideration of all documentation relating to ARD in the Amulsar development, is a wholly-owned Lydian company registered in Armenia.

The proposed mine area forms part of the catchment of major Armenian waterways:

> "Groundwater within the Project area feeds springs and recharges the main rivers, which include the Vorotan, Arpa and Darb. Spring and river water is used variously for drinking and irrigation supply, in fish farming and for hydroelectric power generation." (from Non-technical Summary, Evironmental and Social Impact Assessment, June 2016, prepared by Geoteam).
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> "The Vorotan, Darb and Arpa rivers, located near the Project, are tributaries of the River Araks, which forms the border between Armenia and Iran and flows south-east to the Caspian Sea. These rivers are therefore not part of the natural Lake Sevan catchment. However, an operational tunnel links the Arpa River at Kechut Reservoir and Lake Sevan, to support declining water levels at the latter." (from Section 4.10, NI 43-101 Technical Report Amulsar Updated Resources and Reserves Armenia, March, 2017, prepared by Samuel Engineering)

3. What are the Geochemical Issues with the ARD Characterisation

- **Insufficient assessment**

  The reports reviewed (Section 9) acknowledge that the mine will produce ARD but lack sufficient, credible testing of the sources, amounts, rates of release or mitigation measures. There are significant contradictions with missing and inadequate information on the mineralogy, geochemical testing and modelling of surface and groundwater impacts.

  The geochemical assessment and modelling contains inadequate data on which to base planning for control of acid generation. No details on the geochemical modelling methodology are provided. These are incorrectly reported to be contained in Appendix G of the Amulsar Project Geochemical Characterization and Prediction Report – Update, prepared by Global Resource Engineering Ltd, August 2014) and have also not been found elsewhere.

- **Rates of acid release are not understood**

  Humidity cell tests for measurement of rates of acid release were conducted on only 5 Lower Volcanic (greater risk) and 3 Upper Volcanic samples (lesser risk) coinciding with 8 samples on which mineralogy had been carried out. This number of samples is manifestly insufficient to be acceptable in international practice.

  In control of ARD in the first 10 years, it is rates rather than total amounts that determine the mitigation required. This is not acknowledged in these reports and the humidity cell testing does not give reliable information on this (as they acknowledge, Section 3.9, Appendix 8.19, ESIA, 2016, prepared by Geoteam).

- **Scientific inaccuracies**

It is agreed that the Lower Volcanics (LV) formation that will be excavated in the Amulsar pits will be acid generating. However, it is stated that this formation:

> "shows resistance to the formation of strong ARD and resistance to ARD created by ferric iron oxidation of sulfides." (from Section 6 Conclusions, Appendix 8.19, Environmental and Social Impact Assessment, June 2016, prepared by Geoteam)

There is no evidence for this recurring statement justifying an incorrect conclusion of "mild" ARD. The samples chosen to justify this conclusion simply had low sulfide content whereas other LV samples produced strong acid (pH <3) in a few weeks.

- **Acid producing minerals not correctly identified/assessed**

Jarosite and alunite are found in the LV and UV mineralogy. Acid generation from alunite leaching is discounted as not being significant. More importantly, acid generation from jarosite leaching is not recognised at all. On-going lime treatment will be required to neutralise acid release from jarosite and alunite in the barren rock storage facility until they are exhausted, as recognised by major international companies. This process is likely to take more than 20 years at this site.

- **Inadequate survey of local neutralising materials**

In the Barren Rock Storage Facility, there is no effective natural neutralisation capacity in the rock material. However, no mention is made of either sourcing or utilising local neutralising materials which may be available according to:

> "Locally, those [deposits] flanking Amulsar, consist of multiple fining-upward cycles of volcanogenic conglomerate and mass flow breccia, fining-upward to volcanogenic and marly mudstones and locally, thin **calcilutite limestone**." (from Section 1.4 Geology and Mineralization, NI 43-101 Technical Report Amulsar Updated Resources and Reserves Armenia, March 30, 2017, prepared by Samuel Engineering, our bolding)

4. What is the Proposed ARD Control?

- **Incorrect definition of materials for encapsulation strategy**

> "LV mine waste will be encapsulated within the BRSF to minimize contact with infiltration, seepage, and oxygen. A minimum five-meter-thick NAG buffer zone serves as the basal encapsulation layer. The upper volcanic NAG waste material also serves as a buffer between the encapsulated waste and all final side slopes, benches and top surfaces." (from section 10.2.1.1 Encapsulation, The Amulsar Project Geochemical Characterization and Prediction Report – Update, 31st, August 2014, prepared by Global Resource Engineering)

According to the geochemical assessments of the Upper Volcanics in the GRE Geochemical Characterization report, these are assessed as being uncertain to potentially acid generating. There is no NAG, not acid generating, material. **This suggests that the encapsulation material itself may be acid generating.**

- **Incorrect interpretation of ARD from Soviet era waste rock piles**

> "The LV formation has been demonstrated to produce ARD with pH>3.0, sulfate concentrations less than 100 mg/L and total acidity of ~100 mg/L $CaCO_3$ equivalent even after decades of exposure to the ambient environment."

and

> "As a result, the goal of the ARD mitigation plan is to encapsulate the LV material before it can develop the conditions required to generate stronger ARD. This will be accomplished by creating LV encapsulation cells in the BRSF [barren rock storage facility] that are isolated from groundwater, surface water, and precipitation. The BRSF will also be rapidly capped as a concurrent reclamation measure. The LV in pit backfill will be managed with rapid placement of a closure cover. As a result of these measures, the predicted intensity of ARD on site will be mild – on the order of what has been observed in the field discharging from the Site 13 and Site 27 Soviet-era exploration adit waste piles." (both quotes from Section 6 Conclusions, Appendix 8.19, Environmental and Social Impact Assessment, June 2016, prepared by Geoteam)

These statements, in relation to the previous Soviet processed waste dumps Sites 13 and 27, are misleading and illustrate the inadequacy of the assessment. **ARD with pH 3.5 is found *after 65 years of storage and weathering*. This is strong ARD that contains dissolved toxic heavy metals under in situ conditions confirming the requirement for proper management as set out in the INAP GARD Guide (http://www.gardguide.com) and international practice.**

- **Treatment capability likely to be inadequate**

The only treatment proposed for BRSF seepage and runoff is a Passive Treatment Water System (PWTS) to be constructed in 2019. There are major concerns that this PWTS will not be able to neutralise and treat the release from the BRSF, particularly as this has been inadequately characterised, with consequent ARD and metal release to the streams, rivers and water storage below the mine.

- **No treatment for ARD seepage from the mine pits**

On closure of the two major mining pits, ARD is recognised in runoff but no treatment or mitigation is proposed before release to local streams or drainage to springs. It is stated that:

> "The pit backfill and open pit seepage will discharge a low volume of ARD to seeps and springs that are impacted by naturally occurring ARD with no net impact to baseline water quality." (from Section 6 Conclusions, Appendix 8.19, Environmental and Social Impact Assessment, June 2016, prepared by Geoteam)

However it is also stated that

> "The predicted pH is acidic, with mean values over time of 4.3 and 2.9 for the average and maximum case, respectively." (from Section 5.4 Erato Seepage, Appendix 8.19, Environmental and Social Impact Assessment, June 2016, prepared by Geoteam)

Given the lack of appropriate characterisation of relevant acid producing mineralogies these predictions cannot be assumed to be reliable but they indicate serious ARD after closure. **This drainage should be pumped or directed for remediation in the same manner as seepage from the barren rock storage facility prior to discharge to waterways.**

- **Unclear management responsibilities**

  In the Lydian ESMP [Environmental and Social Management Plan] to "operationalise" the commitments to environmental and social (as well as occupational health and safety) management and mitigation, there is no mention of direct responsibility for ARD control in the document. There is no assigned responsibility for implementation of the management plan described Appendix 8.19.

  Specifically there is no assignment of responsibility for ensuring that the identification and dumping of the higher risk ARD Lower Volcanic barren rock during operation takes place as specified in Appendix 8.19. This fault is common in poor ARD control in many mines where the Mine Manager, with primary focus on production, can and does override the Environmental Manager in correct dumping, encapsulation and dump management. This is a serious omission requiring correction.

- **Inadequate government oversight and responsibility**

  The Armenian government Environmental Impact Report on the project (Amulsar State Expertise Conclusion on Environmental Impact.pdf) does not mention ARD in any form, the need to prevent or control ARD, the potential long-term pollution of streams, rivers and water supplies or the environmental or health consequences found downstream of ARD release. This compounds the problem of Lydian as the operator. It appears that there is no expertise within the Armenian Government to recognise, assess, monitor the Amulsar ARD mitigation or control this potential release for the Armenian people.

- **Insufficient monitoring and maintenance post-closure**

  It is assumed that this PWTS is to remain effective in perpetuity but the planning for this is clearly insufficient:

  > "It is anticipated that periodic maintenance (approximately 20-year intervals) to replace substrate in some components of the PWTF may be required. Geoteam will develop a monitoring plan during final design to determine when maintenance is required." (from Appendix 8.18, Preliminary Mine Reclamation, Closure and Rehabilitation Plan, ESIA, 2016)
  >
  > > "Effluent monitoring from both the BRSF and HLF will continue for a period of 5 years following construction completion of the respective ET covers." (from section 24.4 Reclamation, Closure and Rehabilitation Plan, NI 43-101 Technical Report Amulsar Updated Resources and Reserves Armenia, March 30, 2017, prepared by Samuel Engineering)

  Given that acid seepage is likely to peak after this 5 year interval and may continue for decades or centuries, this duration of monitoring is insufficient. As pit seepage will make its way into spring waters these also should be monitored both off and on-site. Moreover, it is not stated what will be done and by whom if these waters fall to below acceptable standard.

- **On-going costs post-closure**

  This cost of treatment is likely to fall to the Armenian Government. In closure phase, the risk from hundreds of examples internationally is that the company profits decline to below debt level and the local (Armenian) company declares bankruptcy leaving the ARD control for many decades to the government. We note:

> "Lydian owns 100 percent of the Amulsar Project and holds all of the titles, rights, benefits and obligations to the Amulsar Gold Project through their wholly-owned subsidiary Lydian Resources Armenia. In turn Lydian Resources Armenia owns 100 percent of Lydian Armenia CJSC ("Lydian Armenia"), previously Geoteam CJSC ("Geoteam"), an Armenian-registered Closed Joint Stock Company (CJSC), which holds 100percent of the current site related prospecting license and mining license." (from section 1.1 Introduction, NI 43-101 Technical Report Amulsar Updated Resources and Reserves Armenia, March 30, 2017, prepared by Samuel Engineering)

The major issue shown by these examples is that the on-going cost to the Government of Armenia after life of mine may exceed income to the State during operation. Fifty to sixty tonnes of acid per kT of barren waste will require on-going neutralisation. **Estimates of acid generation and neutralisation rates, not just amounts based on sulfide assays, as assessed in these reports, are required to quantify treatment costs.**

- **In summary**

  The reports on the geochemical testing suggest that Lydian lacks the experience and expertise to adequately define the ARD risk, and to construct and operate the geochemical and engineering required to control the ARD that will result from the Amulsar mine.

  In this combination of inadequate testing, planning and operation by Lydian with absence of government oversight and control, a primary risk is not only extensive pollution of streams, rivers and agricultural practice but also class actions by groups of stakeholders who have been misled (as in the action against BHP Billiton at Ok Tedi).

5. The Potential Impact of Failure to Control Acid Rock Drainage

The potential impacts of improperly-controlled ARD on streams, agriculture, fish, other biota and, in some cases, human health are well known. **Based on international examples, the scale of cost to the Armenian Government from post-closure control of ARD release could be in the hundreds of $M.**

In the assessments made of ground and surface water impact it has been assumed that leachate from the BRSF will be effectively treated to acceptable standards for release by the passive treatment system. The acceptability of such an assumption is questioned as the pH and dissolved solids content of the in-flow to the PTS is based on in-correct and in-complete analyses. Failure of the PTS would have very significant detrimental impacts on down-steam catchment.

- **Disruptive changes in groundwater levels**

  In the key findings of their post-closure model many of the changes in groundwater levels (e.g. up to 60 m lower, Section 6.9.6, Chapter 6, prepared by Golder and Associates, Environmental and Social Impact Assessment, June 2016), redirection and reduction in springs and streams predicted within and around the mine site are of considerable magnitude.

  > "Throughout the Project construction, operation, and closure there are some predicted total losses of springs due to construction of the BRSF and the HLF. These impacts are considered significant. However, the impacts cannot be avoided as the facilities are optimally located." (from Section 6.9.7 Mitigation Measures, Environmental and Social Impact Assessment, 2016, prepared by Golder Associates).

- **Unacceptable potential impacts on water quality due to pit leakage**

> "Significant impact to water quality at springs located around the pits is predicted with respect to beryllium, cobalt, nickel and nitrate as a result of leakage from the pits. The increase in beryllium, cobalt and nickel are a result of the release of these constituents from the backfill. These constituents are naturally present in this mineralised area." (from Section 6.9.7 Mitigation Measures, Environmental and Social Impact Assessment, 2016, prepared by Golder Associates).

These elements are present in the minerals but are ***released*** by the acid reactions in the pits and BRSF. **These major additions to apparently already high levels should not be acceptable.** Design mitigation measures are proposed, *i.e.* encapsulation, to limit the leakage from the pits but no further groundwater mitigation options are presented.

> "There is also a significant impact predicted to groundwater quality adjacent to the Vorotan River as a result of leakage from the pits. The change in groundwater quality is high, and the moderate sensitivity of this receptor results in the significant impact. As noted previously, the end receptors of the predicted change in groundwater quality are surface water and ecology. Therefore, **no additional mitigation is presented here to limit or avoid this impact**." (from Section 6.9.7 Mitigation Measures, Environmental and Social Impact Assessment, 2016, prepared by Golder Associates; our bolding).

> "There is a potentially significant predicted impact to groundwater input to the Spandaryan-Kechut Tunnel. However, groundwater inflow is not intended to be the main source of water in the tunnel that provides supply to the Kechut Reservoir, so this reduction in quality should not be considered as a material impact to water resources in the area. Therefore, **no additional mitigation is presented to limit or avoid this impact.**" (from Section 6.9.7 Mitigation Measures, Environmental and Social Impact Assessment, 2016, prepared by Golder Associates; our bolding)

Given the inadequate characterisation of ARD potential and rate there is potential for these impacts to be greater than stated in the Lydian assessments.

6. What is Missing?

- **Lower Volcanics ARD Characterisation**

Mineralogy: The mineralogy of the Lower Volcanics is not complete nor is it matched to acid base accounting, sulfide S or humidity cell testing (as carried out to date). Mineralogy is required on both low and high sulfide S samples with corresponding acid base accounting and standard kinetic leach column tests over at least 1 year for international acceptance of ARD potential.

Leach Studies: More extensive leach studies (number and placement in the deposit) must be undertaken to more directly assess the high risk (*i.e*. high pyritic S) samples and to correlate the leach behaviour against mineralogy to establish predictive assessment. These leach studies should be in the form of kinetic leach columns (not humidity cells as has been undertaken to date). This would provide a reasonable measure of net acid generation ***rate*** since it is this (not nett acid generating potential) that will determine requirements for initial and on-going treatment. This is not measured or discussed. **In addition on-site drum tests should be initiated immediately to definitely ascertain the effect of local climatic conditions on rates of acid and species release.**

Timing: The pH of the effluent from humidity cell testing of two Lower Volcanic samples was <3 after 12 weeks. These two samples contained the greatest pyrite concentration of the samples tested (8 and 10 wt.% respectively). Testing of these samples was only carried out for 20 weeks which is insufficient as they state:

> "it is generally accepted that a year of kinetic [humidity] cell testing will demonstrate with high confidence that a rock sample will or will not generate acid. The test is a logical extension of the static testing because it demonstrates empirically whether the potential determined in the ABA testing will be realized in the field. Geoteam will start this testing as soon as bulk samples of ROM material are available" (from Section 3.9, Appendix 8.19, Environmental and Social Impact Assessment, 2016, prepared by Geoteam).

This testing will be too late to modify waste rock dumping practice and needs to be done now using the more relevant conditions of kinetic leach columns rather than the humidity cell test procedure, most particularly on the Lower Volcanic wastes.

- **Upper Volcanics**

  As for the Lower Volcanics, proposed management of Upper Volcanics, which are Uncertain to PAG (potentially acid generating) in ARD classification (not NAG as stated in several places)also requires much more complete information on mineralogy and kinetic leach column testing on higher sulfide S containing samples (>0.5 wt.%S).

- **Non-sulfide ARD**

  The findings (by XRD and petrology) of alunite and jarosite, which are recognised ARD generators, needs to be incorporated into the mitigation and treatment design. Further examination of the leach rate of alunite and jarosite and their impact on pH are warranted. The percentages of alunite and jarosite in both Upper Volcanics and Lower Volcanics samples needs to be properly analysed and incorporated into ARD control estimation.

- **Sources of neutralising materials**

  It appears that evaluation of the local sources of neutralising materials has not been considered even though they may be present in the local geology. An assessment of the viability and availability of these materials should be carried out.

7. Recommendations

There is a lack of understanding of the rates and amounts of ARD release from this mine site with potentially serious downstream consequences. Without proper definition it is not possible to ensure that adequate mitigation is in place to ensure minimal impact on the environment and human endeavours including potable water, agriculture and tourism. **All of the missing tests and data specified in Section 6 (above) should be obtained before proceeding with ARD planning.**

The Recommendations in Chapter 26 of the Samuels Report NI 43-101 to Lydian (March 30, 2017) make this incomplete characterisation and detailed planning completely clear.

- Thirteen tasks are identified to be required to advance the HLF to detailed design level.
- Fourteen tasks, several major and long-term, are identified for the detailed BRSF design. In Section 26.5 Geochemistry **T**
- **Three tasks, two of which are long-term,** will be required to advance the geochemical characterisation and ARD management to the detailed design level. **These and our**

recommendations show that the geochemical characterisation and ARD management are not acceptable in present testing and documentation.

- In Section 26.6 Water Treatment

  "Unlike active treatment systems, a Passive Treatment System (PTS) must be designed to function under site-specific conditions. **To date, no studies have been performed to ascertain the performance of PTS methods on Amulsar ARD. A process verification study must be performed. This study includes benchscale and pilot-scale tests. The process verification studies are long-duration tests that will start during final design and continue into production."** (our bolding)

  This is not acceptable. This should be complete before production. Changes after production have carry-over consequences for ARD control.

- In Section 26.7 Water Balance

  "Additional studies are required to verify predictive models that were used within the water balance. **Site runoff, evaporation, seep and spring flow, surface water flow, and pit dewatering models all require additional model verification against field data.**"(our bolding).

The mine should not have been approved until these tasks and verification were complete. The detailed ARD assessment and control design has not been done. **Finding out after starting the mine that very high cost on-going treatments are required may seriously alter the value to shareholders and the Armenian Government.**

Our recommendation is therefore that mining is not started until these outstanding areas are properly investigated by independent bodies/consultants with the findings incorporated into an ARD management plan incorporating both government and company responsibilities and liabilities.

8. Documents Reviewed

Nine documents from the Environmental and Social Impact Assessment (ESIA, 2016) were reviewed: Non-Technical Summary June 2016, Wardell Armstrong International; Environmental and Social Review Summary; Chapter 8 Environmental and Social Management Plan, Wardell Armstrong; Appendix 8.19 Acid Rock Drainage Management Plan, Geoteam; Appendix 3.1 Amulsar Passive Treatment System (PTS) Design Basis, Sovereign Consultancy Inc. 9th Dec 2015; Section 6.9 Groundwater Resources, Golder Associates; Section 6.10 Surface Water Resources, Golder Associates; Appendix 8.22 Surface Water Management Plan, Geoteam; Section 6.22 Impact Assessment Summary, Intersocial.

The Amulsar Project Geochemical Characterization and Prediction Report – Update, 31st, August 2014, Global Resource Engineering was also reviewed. This document contains the full geochemical acid rock drainage (ARD) characterisation completed to date.

In addition the sections of NI 43-101 Technical Report Amulsar Updated Resources and Reserves Armenia, March, 2017 Samuel Engineering, have been reviewed as they pertain to ARD characterisation, mitigation and management. We note this report is a compilation of previous data with respect to ARD and does not appear to contain new information.

We also note sections 4.8 Groundwater Resources and 4.9 Surface Waters Composition by Golder Associates in Chapter 4 Environmental and Social Baseline (ESIA, 2016) as these provides baseline existing water quality and pH data. Of further interest is the The Preliminary Mine Reclamation, Closure and Rehabilitation Plan (including costs analysis) which is presented in Appendix 8.18, ESIA (2016).

9. Our Expertise and Role

The Principals (Dr. Andrea Gerson, Dr. Roger Smart) of Blue Minerals Consultancy (BMC) have a combined experience of 45 years in minerals processing and acid rock drainage R&D working directly with company staff for process and remediation improvement and enhanced efficiency.

Dr. Andrea Gerson is the Managing Director in BMC. She is an Honorary Professor at the Research School Earth Sciences, ANU and an Honorary Professorial Fellow at the Department of Physics, Melbourne Uni. She obtained her PhD from the University of Strathclyde (Scotland) in 1991 and thereafter was an Exxon Research Fellow at King's College (London, UK) until she joined the Ian Wark Research Institute, University of South Australia in 1991. She was the Director of the Applied Centre for Structural and Synchrotron Studies (2004–2010) and then lead the research group Minerals and Materials Science & Technology within the Mawson Institute. In 2015 she left UniSA to form the Blue Minerals Consultancy.

Dr. Roger Smart is Senior Consultant in BMC and Emeritus Professor in Minerals and Materials Science and Technology, University of South Australia where he founded the SA Surface Technology Centre in 1987 and was Deputy Director of the Ian Wark Research Institute from 1995 to 2002. He graduated from the Universities of Western Australia (BSc Hons) and East Anglia (PhD). At UniSA, he has been led teams on the AMIRA P260, Fine Grinding and five 3-year Acid Rock Drainage prediction and control projects (2002-2017) as well as single company projects.

The role of BMC is:

- To implement and develop initiatives, improvements and corrections in ARD assessment.
- The design and implementation of advanced estimations of acid generation rate and acid neutralisation rate, not only in the acid waste material, but also in identifying suitable neutralising mineralogy on site.
- Methods for passivation of pyrite and pyrrhotite oxidation in rock dumps and tailings reducing the AGR by more than 90%.
- Rapid assessment of ANR from both short-term carbonates and reactive silicates using methods alternative to long-term kinetic leach columns (with confirmation in kinetic leach columns if required).
- Determination of AGR/ANR ratio for estimation of approach to matching and any required additional neutralisation.
- Site testing in test pads, trial dumps, TSF treatments to verify planning.
- Advice to site consultants and environmental managers on options for dump and TSF design, remediation and management.

Companies we have undertaken ARD related work for: AMIRA International (6 Projects, 2002–2017); BHP Billiton (Iron Ore, Cannington); Caloundra Environmental P/; Environmental Geochemistry Int. (EGi, Sydney); Harmony Mining (Morobe Joint Venture) (Papua New Guinea); Kennecott Utah Copper (USA); MMG/Pasminco; Newcrest Australia; Newmont Mining; Northern Territory Dept. Mines and Energy; Oz/Zinifex; PT Freeport (Indonesia); Rio Tinto (Australia); RGS Environmental Services P/L; Savage River Rehabilitation Program (EPA Tasmania); Teck Resources (Canada); Elementos (Australia); North Queensland Gold (Australia).