DESIGN AND CONSTRUCTION OF LIMESTONE BLENDED WASTE ROCK DUMPS - LESSONS LEARNED FROM A 10-YEAR STUDY AT GRASBERG[1]

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Abstract. A ten-year acid rock drainage (ARD) mitigation program conducted by PT Freeport Indonesia at the Grasberg Mine, Papua Province, Indonesia has developed strategies to maximise the beneficial use of the mined limestone for ARD mitigation. Laboratory columns and field test pad investigations have examined limestone blends, layers and covers. Full-scale trial dumps comprising truck blends, conveyor/stacker blends and truck placed limestone covers have been constructed and monitored. Construction of an operational blended stacker built dump commenced in 2004 and is operated in accordance with blending specifications developed from the 10-year trial.

Trials have demonstrated that run-of mine truck constructed blended dumps are unlikely to be effective because the finer size fractions do not received adequate limestone. Stacker-built dumps can be effective provided the blend ratio is based on achieving adequate acid neutralising capacity within the finer fractions.

Operational experience with the large stacker-built dump indicates that there is no discernable segregation of sulfur or acid neutralising capacity down the slope. The scheduling of potentially acid forming waste and limestone to the in-pit crushers is determining the spatial variability within the dump rather than segregation of sulfur or acid neutralising capacity during the dumping process.

Additional Key Words: blending, ARD, acid rock drainage, leach column, test pad, ANC, ANC/MPA ratio.

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Introduction

The Grasberg operation is a large copper (Cu) and gold (Au) open pit mine operated by PT Freeport Indonesia (PTFI). The mine is one of many ore deposits located within PTFI's contract of works area in the Papuan Province of Indonesia and represents one of the most significant ore finds in mining history. Porphyry and skarn replacement types of Cu and Au mineralisation occur. Current underground mining operations focus on the skarn replacement deposits containing high carbonate ore types while the Grasberg is a porphyry mineralisation hosted within limestone and the overburden associated with mining of this ore body is the focus of this paper. The Grasberg ore body itself is very low in carbonate but a substantial amount of limestone will be mined to gain access to the ore. Copper in the ore is primarily in the form of chalcopyrite with some bornite, chalcocite and covellite.

The Grasberg mine is located at an elevation of about 3700m in the high equatorial mountains of the Indonesian province of Papua. The landscape surrounding Grasberg is extremely steep and rugged with deeply incised valleys and sharp peaks. The overburden stockpiles are being constructed adjacent to the mine with a final elevation range from about 3,500 m at the toe of the lowest stockpile to 4,500m at the final top surface.

The annual precipitation varies from about 3,000 to 5,000mm over short distances around the Grasberg, but in general an average daily precipitation of about 10mm per day applies and leaching of the overburden is continuous throughout the year. The climate is alpine/sub-alpine with little seasonal variation in temperature or rainfall. The daily temperature ranges from about 2 to 14^{o}C with an average of 7 ^{o}C.

Mining commenced in 1988 and approximately 1000 Mt of overburden have been placed in stockpiles adjacent to the mine pit. The mine pit is planned to continue to the year 2014 at which time approximately 2,750 Mt of overburden will have been produced. The current overburden production rate is about 0.5 Mt per day and ore is processed at a nominal rate of about 240,000 tonnes per day with about 90% of the ore derived from the Grasberg pit and 10% from the underground operations.

Initial overburden geochemical characterisation studies commenced in 1993 and as part of feasibility studies for the expansion of production from the Grasberg mine in1996 a program of ARD investigations was established building on the earlier studies. Rio Tinto, as part of the feasibility study team, assisted PT Freeport Indonesia with the planning, design and implementation of this program.

Characteristics of the Grasberg operation and waste rock geochemistry that have significant implications for ARD management include the following:

- Rainfall leaching of the overburden is continuous throughout the year.
- From mine start up to year 2003 the bulk of the waste rock was potentially acid forming (PAF) with a short lag period. The waste rock stockpiles currently generate significant quantities of ARD and a collection and treatment strategy is utilised.
- From 2003 to the end of mining of the Grasberg pit, more than 30% of the total waste rock production will be limestone.
- Both truck dumping and crusher/stacker dumping techniques are used for dump construction. The crusher/stacker operations potentially allow for implementation of

limestone blending and the truck operation allows for partial blending and placement of limestone cover zones.

- Underground mining operations are planned to continue for at least 25 years after completion of the Grasberg waste rock dumps and hence ARD collection and treatment facilities can be maintained, as needed, while mining and mineral processing operations continue.

Because of this combination of factors, a major focus of ARD investigations at Freeport has been aimed at developing strategies to maximise the beneficial use of the significant quantities of limestone mined from 2003 to the end of the open pit. A key objective is to put in place an overburden management plan that will result in progressive, effective and permanent ARD reduction with time so that at the eventual closure of mining and milling operations, any residual ARD load will be minimal and will not adversely impact rehabilitation works or the surrounding environment. Part of this strategy is to construct non-acid generating dumps in areas located outside the current seepage collection system and longer term underground mine capture zones This paper discusses the site investigations, design and operational performance of a 450 million tonne limestone blended dump for ARD control at Grasberg.

Investigation Program

Laboratory columns, limestone blended field test pads, an instrumented trial dump incorporating truck and stacker built limestone blends are being used to optimise methods of utilising run-of-mine limestone for ARD management at Grasberg.

A description and findings of the columns and test pads set up and operation are presented in Miller et al. (2003a) and Miller et al. (2003b), respectively. The trial dump design is presented in Andrina et al. (2003) and Miller et al. (2003a). The columns and test pad programme commenced in 1996 and is ongoing.

Construction of the trial dump was completed in mid 2002 (referred to as the Batu Bersih dump) and decommissioned in December 2004. The dump measured 480 m in length by 80m in width with a depth of 20m. The trial dump was divided into 8 individual panels constructed with various select waste rock materials. A total of 24 high density polyethylene (HDPE) lined lysimeters measuring 12m x 12m were installed on the foundation of the dump (i.e. 3 under each panel) prior to the construction of each panel. Approximately 30 sets of thermister strings and O_2 sampling ports were installed at select locations in undisturbed waste rock along the tip face as each panel was advanced. Continuous flow measurements from the lysimeters have been recorded since the start of construction. At decommissioning, a dozer and excavator were used to expose vertical profiles from the crest of selected panels and back approximately 50m. The exposures were logged and photographed and samples were collected for analysis of acid base characteristics, extent of oxidation, in-situ pH and acidity, mineralogy and surface chemistry.

Detailed sampling and analysis of solid and leachate samples was carried out on all trials. All solids were assayed for total S, acid neutralising capacity (ANC), net acid generation (NAG) and total Cu. Selected samples were assayed for sequential NAG and kinetic NAG (methods described in Stewart et al, 2003), and multi-elements and mineralogical examination was carried out by the Ian Wark Research Institute, University of South Australia, Adelaide.

Leachate volumes were recorded for columns, test pads and the Batu Bersih trial dump. Routine monthly leachate assays include measurement of pH, electrical conductivity, alkalinity, acidity and dissolved Ag, Al, As, Ca, Cd, Cl, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Se, Si, SO_4 and Zn.

Overburden Geochemical Types

Four main overburden geochemical types are identified at Grasberg for segregation and operational purposes. These are labelled as Green, Blue, Red and Heavy Sulphide Zone (HSZ) overburden and are described as follows:

Green: Acid Consuming (AC) and non-acid forming waste (NAF). Limestone accounts for about 98% of this material and has a carbonate equivalent of more than 85% $CaCO_3$ and a net acid producing potential (NAPP) of less than minus 850 kg H_2SO_4/t. NAF overburden accounts for only 2% of the Green Waste and is non-limestone rock with a negative NAPP.

Blue: Potentially Acid Forming (NAPP positive and single addition NAG less than 35 kg H_2SO_4/t)

Red: Potentially Acid Forming High Capacity (NAPP positive and single addition NAG greater than or equal to 35 kg H_2SO_4/t)

HSZ: Heavy Sulphide Zone (greater than 20% Pyrite based on visual identification)

From 2004 to the end of the Grasberg pit operation 37% of overburden production is scheduled to be Green Waste, 24% Blue Waste, 29% Red Waste, 8% HSZ and about 2% is undefined at this stage.

Pyrite is the dominant sulfide mineral in both waste types with minor chalcopyrite and trace amounts of covellite and bornite. Magnetite is a significant component of the heavy fraction. Bulk gangue mineralogy is dominated by potassium feldspar with quartz, mica (biotite, chlorite and phlogopite) and plagioclase. Anhydrite ($CaSO_4$) is an important mineral component and becomes significant deeper in the deposit. At higher elevations in the ore body the anhydrite has been leached from the rock resulting in a friable rock type known locally as poker chip. Where anhydrite is present, the rock is more competent and known as hard-zone material.

Calcite is the dominant carbonate mineral in the limestone overburden although magnesium carbonate and some pyrite occur locally. The limestone overburden typically contains a carbonate equivalent of more than 85% $CaCO_3$.

Summary of Findings from Column, Test Pad and Trial Dump Programs

A summary of the key findings of the column and test pad programs in relation to limestone blends are presented in this section. Further details are presented in Miller et al (2003b). The column and test pad trials began in 1996, are ongoing and have been operating for 9 years. The test pad material was crushed to minus 300mm and column test consisted of samples crushed to minus 39 mm, minus 19 mm, minus 3mm and intermediate fractions of 3 to 19 mm and 19 to 39mm.

Table 1 summarises the ARD characteristics and performance of the limestone blend trials to date. Also shown are the ABA characteristics of the run-of-mine Blue and Red waste used in the trials.

Table 1. Summary of limestone blend characteristics and performance.

OB Type	Limestone Blend (%)	Total Sulfur %S	NAPP kg H_2SO_4/t	ANC/MPA	ANC*/NAG* (#)	Blend Performance
Blue	-	2.0	46	0.1	-	-
Blue	5	1.6	5	0.9	2	POOR
Blue	10	1.5	-50	2	5	POOR
Blue	25	1.4	-210	6.5	14	GOOD
Red	-	4.6	141	0.02	-	-
Red	10	4.2	15	0.9	1	POOR
Red	25	3.5	-170	2.6	4	UNCERTAIN
Red	50	2.4	-480	7.6	13	GOOD

(#): ANC* and NAG* are calculated values used for planning operational blends whereas ANC and NAG are laboratory determined values which apply to individual overburden types. MPA is the maximum potential acidity, in kgH_2SO_4/t, calculated from the total sulfur content by %S x 30.6. NAPP is the net acid producing potential and calculated by MPA - ANC. See text for further explanation.

The results have shown that 5 and 10% limestone blends are not effective although they do reduce the overall acid and Cu loads. The 50% limestone blends have continued to perform as effective ARD controls in both Blue and Red waste and the 25% blend is effective on the Blue waste. Although the 25% limestone blended Red waste test pad is maintaining pH control, due to the failure of the column test blends and erratic nature of Cu solubility in the test pad, there remains uncertainty as to the longer-term performance of this blend.

Table 1 indicates that an ANC/MPA ratio of more than 2.5 and possibly at least 5 is necessary to provide an adequate factor of safety for ARD control in limestone blended overburden. Ratios of about 1.5 typically provide an adequate level of safety for specific rock types and tailings but for blended waste rock it is apparent that a much higher ratio is required to ensure effective blending throughout all size fractions even at the laboratory and field test pad scale.

Table 1 introduces a site specific parameter, ANC*/NAG* ratio, that is used to assist mine planning in evaluating the acid base balance of production schedules and mine operations for control of blends during construction of blended dumps. ANC* is the calculated acid neutralising capacity of the limestone component (in tonnes H_2SO_4) of the overburden and NAG* is the calculated total acid generating capacity of the non-limestone component (also in tonnes H_2SO_4).

These parameters are calculated as follows:

ANC* = Limestone production x ANC of limestone

NAG* = Blue Waste production x NAG of Blue Waste + Red Waste production x NAG of Red Waste

Production is the scheduled tonnes for the selected mining period and ANC and NAG are in kg H_2SO_4/t. The NAG of Blue and Red wastes are typically 30 to 40 kg H_2SO_4/t and 90 to 130 kg H_2SO_4/t, respectively.

The equivalent ANC*/NAG* ratios are shown on Table 1 and the findings to date support a target ANC*/NAG* ratio of at least 13 to provide long term ARD control from limestone blended waste.

At the Batu Bersih dump limestone treatments were evaluated in four of the face panels. Each trial consisted of 25% limestone and 75% Red/Blue run-of-mine waste. Three of the panels were truck dumped and one was constructed using a crusher and stacker system. The three truck panels were constructed as follows:

- Truck and Dozer Mixed: Three truck loads of run-of-mine Blue/Red waste and 1 load of run-of-mine limestone were tripped near the dump crest, dozer mixed and pushed down the face.
- Alternate Truck Dump: Three truck loads of Blue/Red waste and 1 load of limestone were tipped from the crest and down the tip face. This was alternated until the panel was completed.
- Truck Layers: Three metres of Red/Blue waste followed by 1 metre of limestone were advanced from the crest. The sequence continued until the panel was completed.

The stacked built panel was constructed using a crusher and stacker. The crusher was fed using a front-end loader, alternatively loading 42 cubic metres of Red/Blue waste and 14 cubic metres of limestone. This ratio was developed to approximate layer thicknesses that might occur on a full-scale stacker built dump with a 400 m face.

Figure 1 shows the pH trends for each of the limestone treatments. P4L1 is the truck and dozer mix; P5L1 is the alternate truck dump; P6L1 is the layered treatment and P7L1 is the

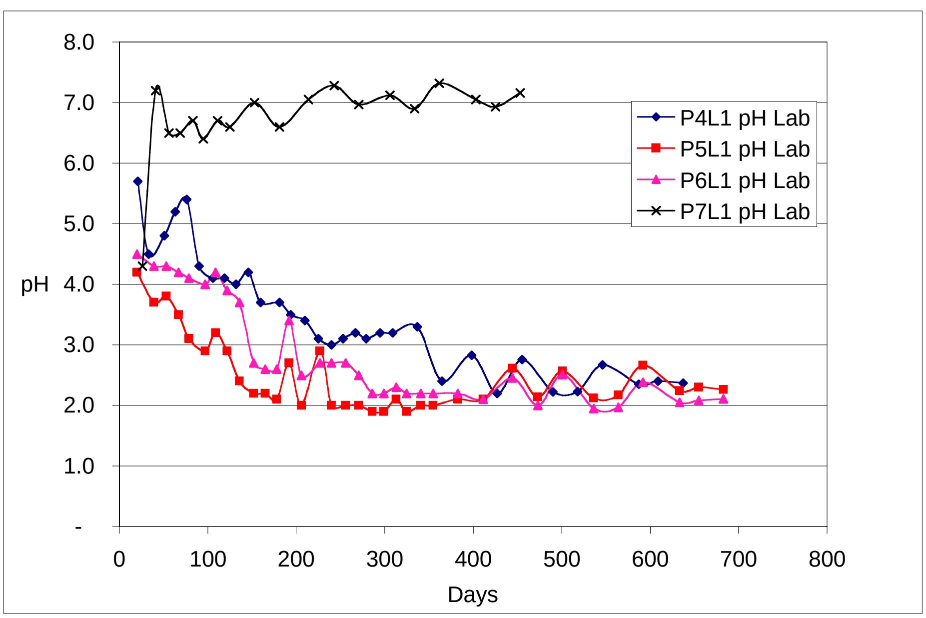

Figure 1. The pH trends in limestone treated face panels at the Batu Bersih trial dump.

stacker panel. The results show that all the truck treatments failed within a short period of time while the stacker built panel continued to perform effectively.

Samples were collected from the advancing dump face during construction of the panels and the results indicate an overall ANC*/NAG* value of 8. Samples were also collected from the stacker built panel at decommissioning and the results indicate a variable mix within the panel ranging from about 5% to 30% limestone. The average NAPP of the samples collected was only minus 15 kg H_2SO_4 and 40% of the samples were NAPP positive. These results indicate a relatively low factor of safety for long term ARD control within the stacker built trial dump.

Limestone Blending Specifications for Construction of the Lower Wanagon Dump

At Grasberg, a 450 million tonne waste rock dump is being constructed downstream of the current seepage collection systems. This dump is referred to as the Lower Wanagon Dump and is being constructed with rock that is crushed in pit and conveyed to a large boom stacker for placement into the headwaters of the Wanagon River valley. To develop operational guidelines for construction of a limestone blended waste rock dump for ARD control, the results of the columns, tests pads and trial dump have been utilised. To scale up to the full size dump, it was necessary to consider the particle size distributions in each rock type and the geochemistry of each size fraction. A key finding from scale up test work was the importance of ensuring all size fractions in a blend, particularly the finer size fractions, contained excess ANC (i.e., NAPP negative).

Sieve analyses were conducted on samples of Red, Blue and limestone waste after crushing. The particle size distribution (PSD) for typical samples are shown below on Fig. 2.

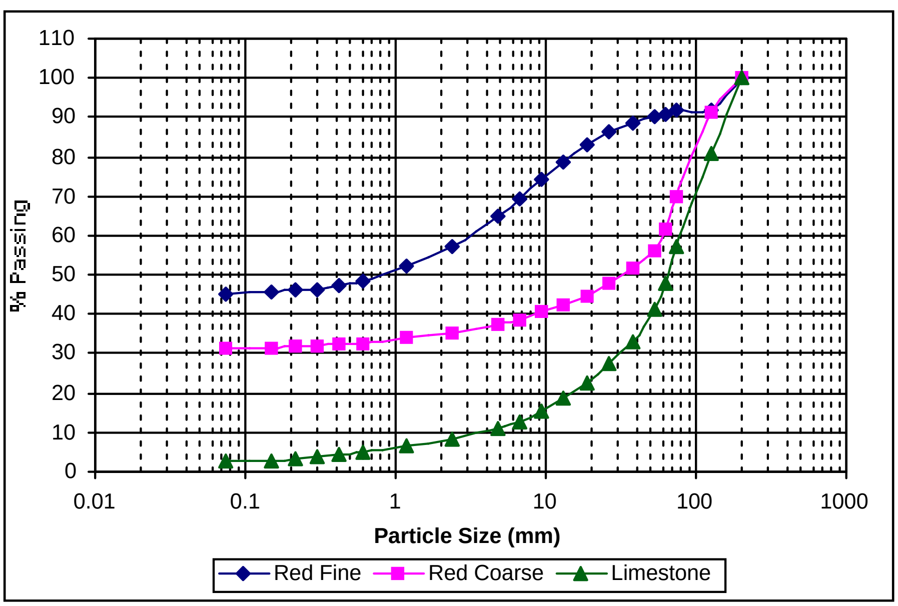

Figure 2: Particle size distribution for Red Fine, Red Coarse and Limestone samples from OHS-3 Conveyor.

Figure 2 shows the lack of fines in the limestone compared to the Red waste. Although Red Coarse contains significantly more cobble sized material (63 to 200 mm) than Red Fine, they both contain significant amounts of fines. Red Fine and Red Coarse have 45% and 31% passing 75 micron, respectively. This contrasts with the limestone with only 3% passing 75 micron.

To evaluate the theoretical distribution of limestone and Red waste when these materials are mixed, three size ranges were used and calculations made for different bulk ANC*/NAG* values.

The three size fraction were as follows:

- 63 to 200 mm (Cobbles)
- 2.36 to 63 mm (Gravels)
- Less than 2.36 mm (Sand-Silt-Clay)

The distribution across the size fractions for mixes of Red Fine Waste and Limestone, Red Coarse Waste and Limestone and Red Waste and Limestone at a Coarse to Fine ratio of 2 to 1 were calculated. A minimum coarse to fine ratio of 2 to 1 is a geotechnical constraint. The results for ANC*/NAG* ratios of 15 to 1, 10 to 1, 8 to 1 and 6 to 1 for the Red waste and limestone mix at a coarse to fine ratio of 2 to 1 is shown on Figure 3 and indicates that the material is uniformly distributed between Cobble, Gravel and Sand-Silt-Clay fractions.

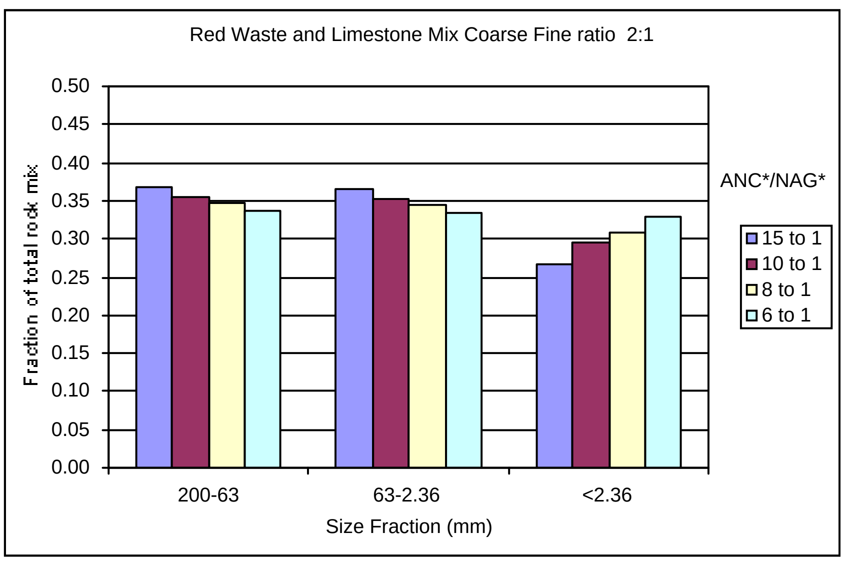

Figure 3. Relative amounts of rock within each particle size fraction for the Red waste and Limestone mixes at a Coarse to Fine ratio of 2:1 for different bulk ANC*/NAG* ratios expressed as a fraction of the total rock mass in the mix.

For the Red Coarse and Limestone mixes approximately 20 to 25% of the material reports to the sand-silt-clay fraction (less than 2.36 mm) compared to slightly higher values of 30 to 40% in the Red Fines and Limestone mixes.

To evaluate the ARD potential for the different mixes and bulk ANC*/NAG* ratios, the average maximum potential acidity (MPA) of 115 kg H_2SO_4/t was used for the Red Waste and the average acid neutralising capacity (ANC) of 900 kg H_2SO_4/t was used for limestone.

The ANC/MPA ratio provides an estimate of the likelihood of ARD generation. A value of 1 means that the acid potential (MPA) and the neutralising potential (ANC) are in balance. Values greater than 1 indicate that the ANC exceeds the MPA and values less than 1 indicate that the ANC is less than the MPA.

When considering an individual rock sample where the ANC is inherently associated with the sulphide, an ANC/MPA value of 1.5 is likely to provide an adequate factor of safety to prevent ARD. Similarly, a ratio of 1.5 is generally appropriate for a well mixed material such as tailings. However, very little data are available for individual size fractions within a mixed waste rock dump. Given the heterogeneous nature of dumps, and the level of uncertainty due to lack of data, higher ratios are likely to be needed to ensure adequate safety. Therefore ratios greater than 2 are recommended for the Sand-Silt-Clay fraction, and ratios greater than 3 for larger size fractions.

Figure 4 is a graph of the calculated ANC/MPA ratio of the Sand-Silt-Clay fraction plotted against the ANC*/NAG* value for Red Waste and Limestone mixes.

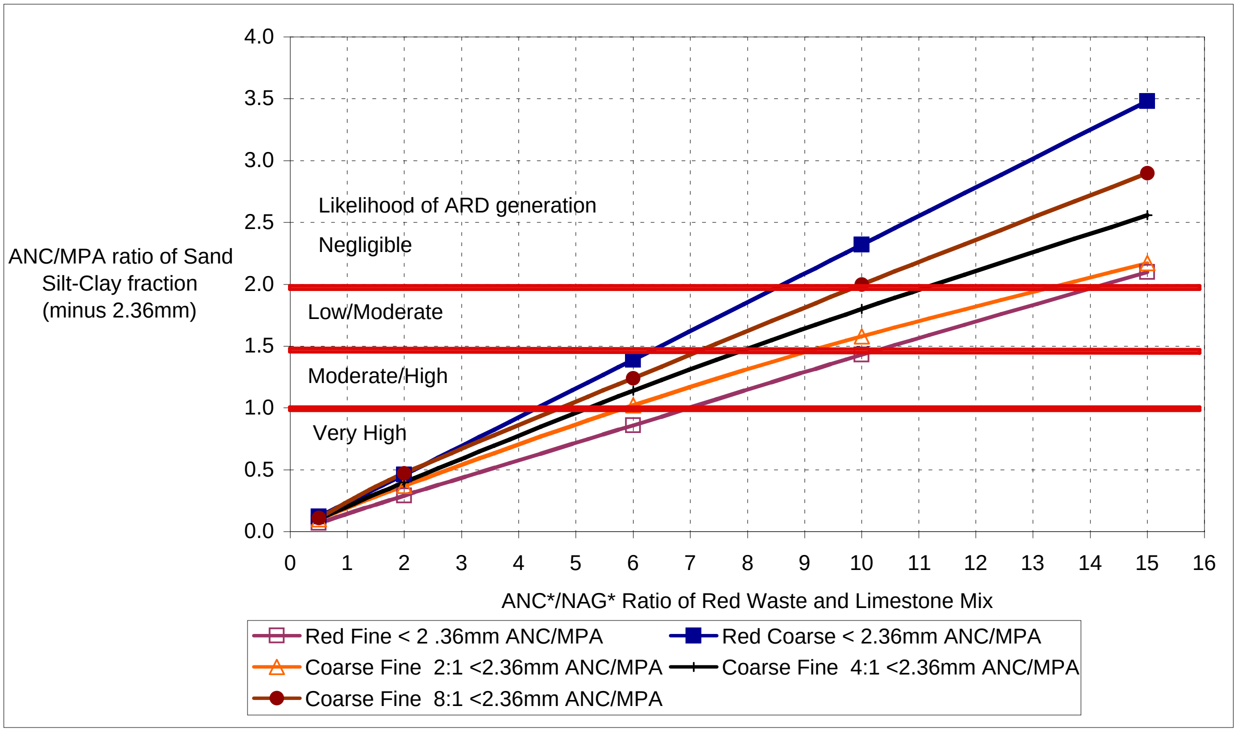

Figure 4. ANC/MPA value of the Sand-Silt-Clay fractions (< 2.36mm) as a function of the ANC*/NAG* and Coarse to Fine ratio in the limestone and Red waste mix.

Also shown on Fig. 4 are relative ratings with respect to the likelihood of ARD generation based on the ANC/MPA values. The plot indicates that the generation of ARD is unlikely with an ANC*/NAG* value of 15 for a Red Fine Waste mix and a value of 8.5 for a Red Coarse Waste mix. This result is consistent with the findings of the column test pad and trial dump investigations. Table 1 indicates that the blending performance is good at ANC*/NAG* values of about 15. The Batu Bersih trial dump indicated that although an ANC*/NAG* value of 8 in the stacker built panel performed effectively for the duration of the trial, there is some uncertainty as to the long term performance.

Since measurement of the ANC/MPA ratio of the fine fraction of a blend is not practical as an operational tool, it is necessary to predict the ratio from the ANC*/NAG* of the blend and the particle size distribution (PSD) of the individual components of Red waste and limestone. Figure 4 was therefore used by PTFI to assist with planning and scheduling waste rock to the Lower Wanagon Stockpile. In addition, it is not practical to blend rock types prior to loading the crusher and hence an operational time period needed to be considered. Based on practical and achievable operational considerations, the following specifications were developed for the initial operation of the dump and are part of the standard operating procedures (SOP) for construction of the Lower Wanagon Stockpile.

- The predicted weekly ANC/MPA ratio of sand-silt-clay fraction should not be less than 1.5.
- The predicted quarterly ANC/MPA ratio of the sand-silt-clay should not be less than 2.

Blast hole testing is carried out ahead of mining to determine the acid generating capacity of each block and limestone requirements to meet the material specifications listed above

Performance Evaluation

The first sampling and performance evaluation of the Lower Wanagon Stockpile was carried out in February 2005. Samples were collected at 8 locations down the angle of repose slope representing the surface 500 to 1000mm. The sample locations are shown on Fig. 5.

The particle size distribution was determined on all 8 samples. For geochemical testing, the bulk sample and 3 particle size groups were prepared as follows:

Bulk sample

63 to 9.5mm

9.5 to 2.36mm

<2.36mm

The grading curves for each sample are shown on Fig. 6 and the ARD characteristics are summarised on Table 2.

Figure 6 shows that samples from locations 1, 7 and 8 are coarser grained, comprising 93 to 98% gravel sized material, than the well graded samples from locations 2, 3 and 4. The sample from location 5 has no gravel and is much finer than other samples. This sample possibly reflects material eroded from the slope. Sample 6 also comprises a high content of coarse gravel sized material.

The results indicate that the coarser fraction is preferentially reporting to the bottom of the slope and the material higher in the stockpile is well graded with a D50 (diameter which 50% passes) of about 5mm and D10 (diameter which 10% passes) of 0.5mm. These contrast with the coarser samples from locations 1, 7 and 8 which have D50 and D10 sizes of 20mm and 10 mm, respectively.

Table 2 presents the overall statistics for total Sulfur, ANC, NAPP and ANC/MPA ratio for the 8 samples

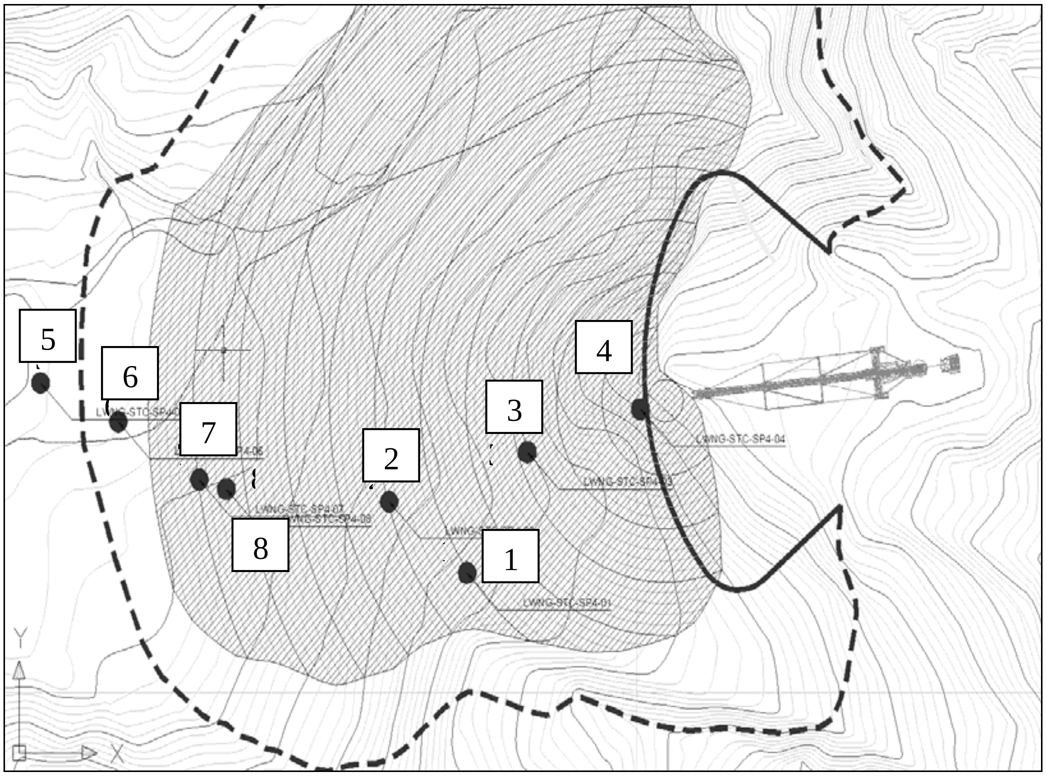

Figure 5. Plan view of Lower Wanagon Stockpile showing surface sampling locations.

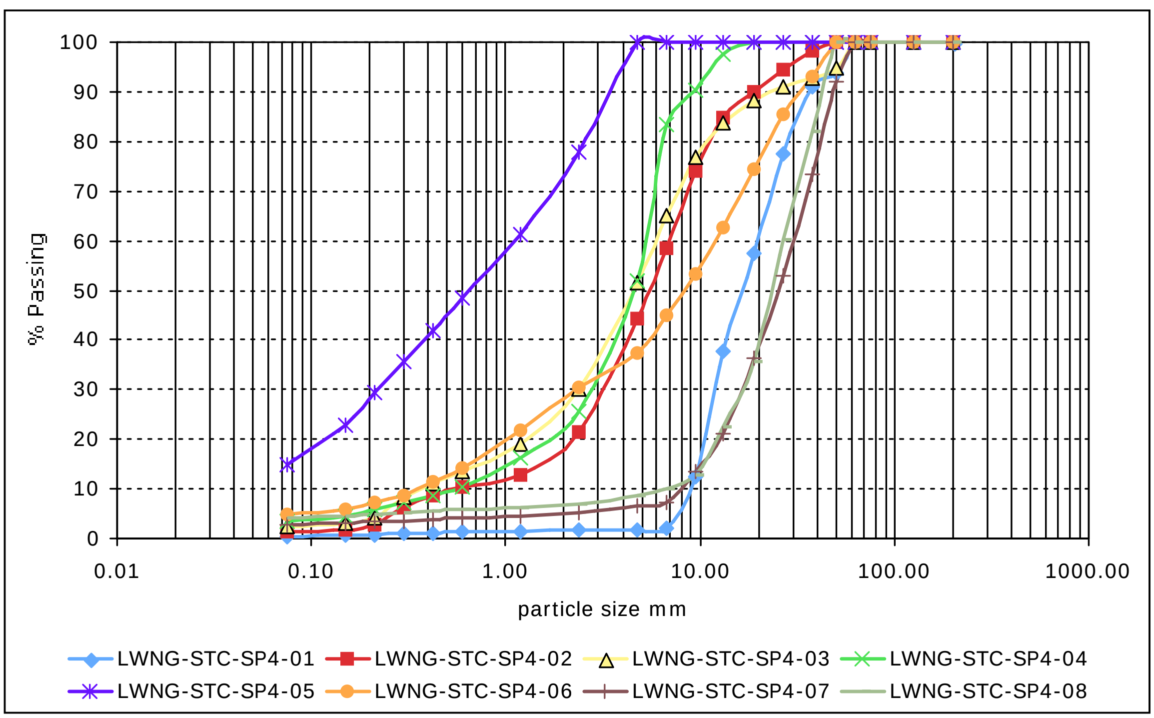

Figure 6. Particle size distribution curves for Lower Wanagon Dump surface samples.

Table 2. Summary Acid Base Characteristics for the Bulk Samples from the Lower Wanagon.

	Total Sulfur %S	ANC kg H_2SO_4/t	NAPP kg H_2SO_4/t	ANC/MPA
Average	2.84	249	-162	5.3
Median	2.78	172	-46	1.5
Std. Dev	1.23	185	211	8.7
Minimum	0.8	104	-623	1.1
Maximum	5.0	648	-19	26.5

The results show that the overall average ARD characteristics for the bulk samples indicate an excess of ANC, equivalent to about 15% $CaCO_3$, and a high ANC/MPA ratio of 5. However, the results also show that the median ANC/MPA ratio is 1.5 indicating only a low factor of safety in 4 of the 8 bulk samples. The high standard deviation for ANC, NAPP and ANC/MPA ratio is due to the variable distribution of ANC.

Figure 7 presents box plots for total S, ANC and the ANC/MPA ratio for the three size fractions. The top and bottom of the shaded boxes are the 75th and 25th percentile, the 50th percentile (or median) is indicated by the solid line within the box and the 10th and 90th percentiles are indicated by the extended bars.

The box plots show that the total sulfur content increases with decreasing particle size, and that the ANC is relatively consistent across particle sizes. Due to the increasing sulfur content, the ANC/MPA ratio decreases with decreasing particle size,

As outlined previously, the critical factor for ARD control in the Lower Wanagon dump is the acid base characteristics of the sand-silt-clay fraction. Table 3 presents these data and the results indicate that there is substantial ANC within the sand-silt-clay fraction ranging from a limestone equivalent of about 12% to 50% $CaCO_3$. The average for the 8 locations meets the ANC/MPA target of greater than 2 however, only 2 of the 8 individual samples have ANC/MPA values greater than 2.

Table 3: Total S, ANC and ANC/MPA Ratio for the Sand-Silt-Clay Fraction (minus 2.36 mm).

Location	Total Sulfur %S	ANC kg H_2SO_4/t	ANC/MPA
LWNG-STC-SP4-01	1.43	528	12.1
LWNG-STC-SP4-02	6.96	200	0.9
LWNG-STC-SP4-03	3.60	376	3.4
LWNG-STC-SP4-04	4.35	151	1.1
LWNG-STC-SP4-05	4.00	123	1.0
LWNG-STC-SP4-06	4.67	207	1.4
LWNG-STC-SP4-07	5.56	228	1.3
LWNG-STC-SP4-08	6.00	239	1.3
Average	4.57	300	2.2

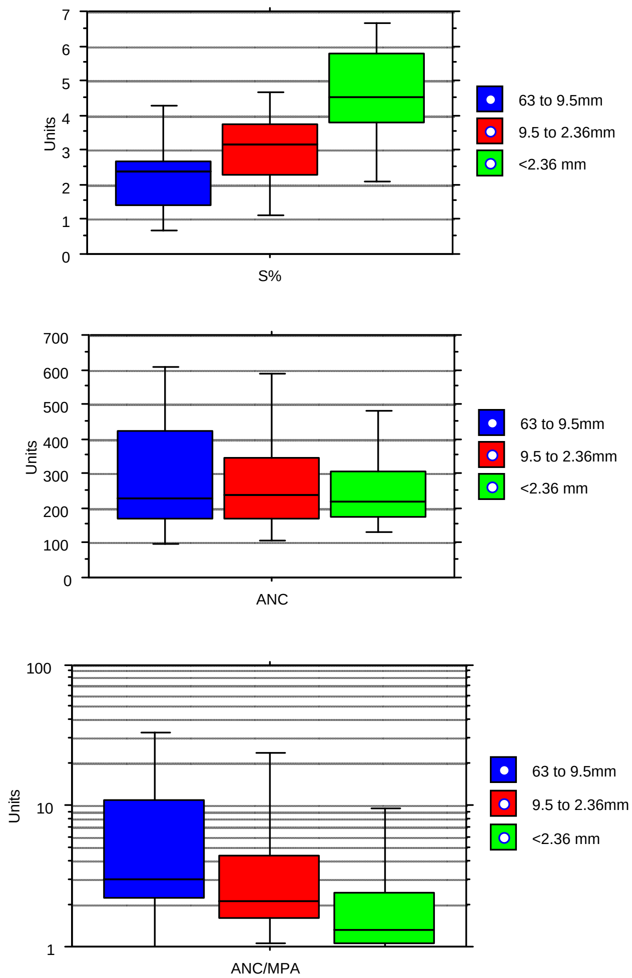

Figure 7. Box Plots for total sulfur, ANC and ANC/MPA
for each size fraction.

The results of the initial sampling programme are summarised as follows:

- There is no discernable segregation of ANC down the slope or between size fractions.
- There is no discernable segregation of sulfur down slope but a significant segregation between size fractions. The total sulfur content increases with decreasing particle size.
- The results suggest that down slope segregation of ANC and S is not significant and that overall there is abundant ANC within the whole dump with an average ANC/MPA ratio for bulk samples and the sand-silt-clay fractions of 5.3 and 2.2, respectively. However the median ANC/MPA values are only 1.5 and 1.3 for the bulk and sand-silt-clay fractions, respectively, indicating that spatially, the factor of safety for the prevention of ARD varies from low to high.
- The results suggest that it is more likely the scheduling of Red/Blue waste and limestone to the in-pit crushers is determining the spatial variability rather than segregation of ANC and S during the dumping process.

Although the target ANC/MPA ratio in the sand-silt-clay fraction was only being met at 2 of the 8 sample locations, the results of this initial sampling event demonstrate that a significant amount of ANC was being distributed across all size fractions. Also, there is abundant ANC within the dump and refinements to the scheduling of limestone and Red/Blue are being evaluated to further increase the factor of safety for long term prevention of ARD from the Lower Wanagon Dump.

Sampling of the dump is planned on a quarterly basis to determine trends through time and to continue to refine and improve operating procedures.

Conclusions

PT Freeport Indonesia is conducting a laboratory and field based program to evaluate the performance or limestone blends and covers for long term ARD control. The programs and trials have been operating for 10 years and the results have been used to develop and refine material specifications for constructing blended overburden stockpiles for ARD control.

The results have demonstrated that although limestone blending is effective, it is necessary to ensure that all size fractions within the blend receive adequate acid neutralising capacity to buffer the potential acidity. Because the sulfur content increases and the acid neutralising capacity decreases with decreasing particle size in limestone blends at Grasberg, the amount of limestone required greatly exceeds the stoichiometric requirement. Blending specifications have been developed for Grasberg overburden and are described in the paper. Trials have confirmed that run-of mine truck constructed blended dumps are unlikely to be effective with ARD generation occurring within a relatively short period of time.

Operational experience with stacker built dumps can be summarised as follows:

- There is no discernable segregation of ANC down the slope or between size fractions.
- There is no discernable segregation of sulfur down slope but a significant segregation between size fractions. The total sulfur content increases with decreasing particle size.
- The results suggest that down slope segregation of ANC and S is not significant and that overall there is abundant ANC within the whole dump with an average ANC/MPA ratio for bulk samples and the sand-silt-clay fractions of 5.3 and 2.2, respectively. However the median ANC/MPA values are only 1.5 and 1.3 for the bulk and sand-silt-clay fractions, respectively, indicating that spatially, the factor of safety for the prevention of ARD varies from low to high.
- The results suggest that it is more likely the scheduling of Red/Blue waste and limestone to the in-pit crushers is determining the spatial variability rather than segregation of ANC and S during the dumping process.

Although the target ANC/MPA ratio in the sand-silt-clay fraction was only being met at 2 of the 8 sample locations, the results of this initial sampling event demonstrate that a significant amount of ANC was being distribution across all size fractions. Also, there is abundant ANC within the dump and refinements to the scheduling of limestone and Red/Blue are being evaluated to further increase the factor of safety for long term prevention of ARD from the Lower Wanagon Dump.

Sampling of the dump is planned on a quarterly basis to determined trends through time and to continue to refine and improve operating procedures.

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