Mine Closure 2012 — A.B. Fourie and M. Tibbett (eds)

doi:10.36487/ACG_rep/1208_59_Jones

Unintended consequences and mine closure

H. Jones *Golder Associates Pty Ltd, Australia*

D. Salmon *Golder Associates Pty Ltd, Australia*

Abstract

Many closure plans do not work out as originally conceived and, as a result, some unintended consequences may arise. These consequences can be a result of the techniques employed as part of the closure process, of legislative constraints and of social expectations. In some cases these unintended consequences have major long-term adverse environmental and social outcomes. Conversely in others they have resulted in enhanced environmental and social outcomes for the post-mining use of the mine sites in question.

Using examples from around the world the authors outline some unintended consequences and consider the factors that actually influenced the closure outcomes, as against those factors the closure planners apparently envisaged.

Based on these examples, the authors then draw conclusions of how the unwanted and unintended consequences could be reduced and the potential societal benefits of closure enhanced through an early, rigorous assessment of closure options.

1 Introduction

We live in a world where few, if any, of our actions (or lack of actions) do not affect other people and the general environment. We commonly make our decisions to act (or not) with little real understanding of all the potential consequences our decisions may have. The closure of a mine involves a considerable number of decisions being made by many individuals or groups of people, often looking at the closure of a particular mine from different (often narrow) perspectives. It should therefore be no surprise that many of the outcomes from the mine closure process result in some unintended consequences.

This paper outlines some of the unintended consequences the authors are aware of and from which they have drawn conclusions in the hope that some unnecessary adverse consequences of mine closure can be avoided and some of the opportunities presented by mine closure for positive outcomes can be enhanced.

2 Landforms

The landforms that remain when a mine is closed are the epitaphs to that generation's technical expertise and commitment to sustainable development. Almost all people associated with the industry, companies, regulators, the work force and shareholders who invest in the industry and the general community would like to see these remnant landforms as stable structures that emulate the surrounding landforms. Such structures, able to support a relevant ecology in perpetuity would be considered as making positive contributions to post-mining land use opportunities.

However the construction of post mining landforms and their performance in terms of retaining their shapes and functionality is not as well understood as we would like and the challenge to meet the objectives outlined above is considerable.

Table 1 below is a rough comparison of six features of landforms, namely construction material, voids, top surface, slope angle, slope configuration, drainage and vegetation, illustrating the considerable differences between a typical flat-topped, truck-built waste dump often seen at metalliferous mine in Australia (ziggurat landform) and a natural hill from the same climatic region.

Contact author: H. Jones; hjones@golder.com.au

Table 1 Comparison of waste dump landforms against natural hills (after Jones, 2008)

Feature	Waste Dumps	Natural Hill
Construction material	Loose, unconsolidated run-of-mine waste	Rock core with (usually thin) regolith cover
Voids	c. 20%	>1%
Top surface	Large, essentially flat	Very small, domed
Slope angle	Uniform (approximately 20°)	Concavo-convex
Slope configuration	Regular horizontal 'steps'	Smooth
Drainage	Poorly defined	Well developed, clearly defined
Vegetation	Initially uniform age	Mature, varied ages, co-evolutional with the landform

There is also a considerable difference in the time taken for the two landforms to attain their 'final' state. A natural hill will have attained its current stable configuration over many thousands (or even millions) of years, while mine closure requires that man-made landforms become stable in a much shorter timeframe. Waste dump designers (mine planners) are therefore faced with the challenge of developing landforms that emulate natural hills in a very short time, while simultaneously keeping mining and closure costs as low as possible.

Our observations of mining operations around the world indicate that very few waste dumps are shaped to emulate natural landscapes such as hills. Many of the resulting landforms show significant, unintended erosion which could probably have been reduced if the action of natural forces on the structure had been better understood during the design phase.

The long-term 'performance' of any landform depends very heavily on its composition (construction material in Table 1) as well as the general aspect and specific configuration of its surfaces and any protective cover. Unconsolidated run-of-mine waste with a high void ratio can never withstand the long-term weathering and erosive forces to the same extent as bed rock; however other aspects listed in Table 1 can be modified during waste dump construction, improving the stability of the landform. Top surface, slope angle, slope configuration and drainage are all elements that can be adjusted through enlightened mine planning design and well planned operational practices.

2.1 Upper surface

To reduce unintended erosion the top surface of any dump should be as small as practicable and domed, rather than essentially flat. This is because a large flat surface at the top of a dump acts as a temporary pond for incident rainfall. Eventually the accumulated water will find a low points on the rim where the ponded water could potentially discharge, causing the formation of deep erosion gullies (Figure 1). A waste dump with a very small upper surface such as the 40 year old coal waste dump at Dyffryn Rhondda in South Wales (Figure 2 example) has survived the local rainfall of 1.2 m per year, no vegetation establishment and angle of repose slopes without developing a similar, closely spaced gully system.

Limiting the size of this upper surface to the minimum practical area will reduce this potential. Where this is not practical then a well defined and well constructed drainage system able to accommodate the probable maximum flood should be incorporated into the design of the upper surface. Other possible means of managing water on the upper surface include specially designed 'store/release' caps and extreme surface roughness. The store/release approach, which uses evapotranspiration of vegetation in combination with an engineered cap, is climate dependent while the extreme surface roughness is less so.

Figure 1 Gullies forming on two year old waste rock dump with flat upper surface in arid Western Australia. Slope angle 18° (photo: H. Jones, 2004)

Figure 2 40 year old dumps with small upper surface (photo: H. Jones, 2006)

2.2 Slope geometry

Three major factors that influence erosion of any slope are the slope length, the slope angle and the surface shear strength (or erosion resistance) of the slope material. While the erosion resistance, which results from the nature and configuration of the particles forming the slope surface, is not economically changeable in most mining operations, both slope angle and length are usually more easily varied.

Most natural hill slopes that are not bed-rock outcrops have a concavo-convex ('S' shaped) cross section, with hills shedding the majority of incident rainfall through progressively reducing slope angles. McPhail and Rye (2008) have demonstrated the influence of slope geometry on erosion potential which is summarised in Figure 3. These simulations of a 35 m high landform over a period of 100 years, assumes no discharge from the top surface and reports the results as a percentage against the base case (38°) slope.

The step pyramid or ziggurat shape often adopted by designers of waste structures and promoted in various guidelines around the world has some serious unintended consequences when applied to final landforms.

Many waste management practitioners now accept that narrow, horizontal or low-gradient berms or terraces constructed across the slope are of negligible long-term benefit for reducing erosion through breaking up slope length. They actually exacerbate erosion, because they concentrate down-slope flow at overtopping points, leading to rapid gully development (Willgoose, 2000; Loch and Lowe, 2008).

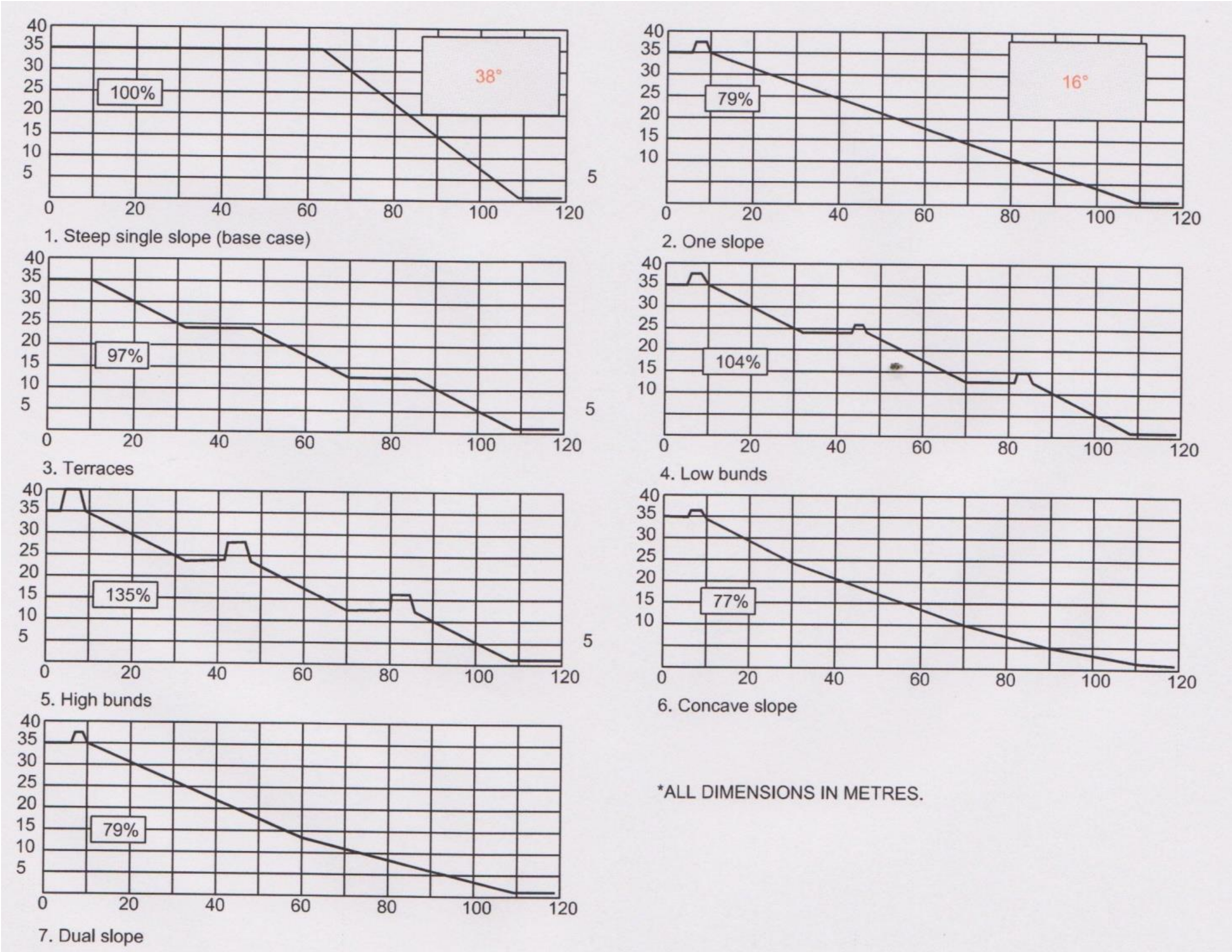

Figure 3 Summary of the Rye and McPhail erosion simulations (Jones, 2011a)

An example of this process in action is shown in Figures 4 and 5 where rainfall run-off has been concentrated at the base of a 1.5 m wall raise on a tailings storage facility and exited via the lowest point along the low berm. After just one rain event of 100 mm in 24 hours the resulting discharge has cut through the 'capping material' on the face of the starter embankment leaving a gully about 400 mm deep.

Figure 4 Horizontal berm on TSF (photo: H. Jones, 2006)

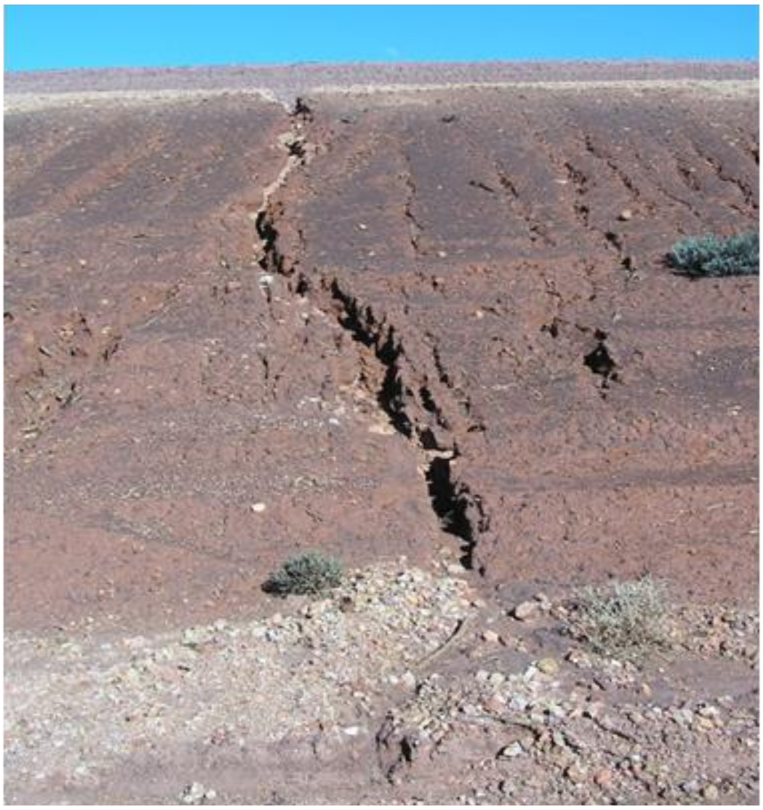

Figure 5 Erosion gully developed below that berm after one significant rain event (photo: H. Jones, 2006)

This concentration of rainfall run-off by horizontal terraces often results in the development of gullies that in turn can result in the relatively rapid exposure of material that may have been placed inside the waste landforms in a deliberate attempt to prevent them being exposed.

The terraces may be an important safety consideration while the waste dumps are being constructed, but as Figure 3 indicates they are not usually the optimal erosion minimisation configuration. The authors have observed examples of this process of gully development below horizontal terrace similar to that shown in Figure 6 in many countries and different climatic zones, ranging from mines north of the Arctic Circle to those in the tropics.

Figure 6 12 year old waste dump in central Western Australia (photo: H. Jones, 2008)

Figure 7 Successful 'moonscaping' in Western Australia, iron ore mine, after a major cyclone (photo: H. Jones, 1978)

2.3 Rainfall management

In designing many closure landforms, designers are faced with two apparently contradicory objectives to consider. One is controlling rainfall run-off in a manner that minimises erosion, the other is to maximise rainfall infiltration on the structure to assist in the developement of a sustainable vegetation cover.

These two objectives led to the develoment of the 'moonscaping' technique by Ken Walker (pers. comm.) at the Mt Whaleback mine in the 1970s, where it proved successful.

However, application of the same moonscaping technique to another iron ore operation was considerably less successful, with the combination of very different physical properties of the waste materials and the more intense rainfall over a long period resulted in major damage.

Figure 8 Failed 'moonscaping' northern Western Australia in the first wet season after construction, iron ore waste dump (photo: H. Jones, 1998)

These two unsuccessful examples of 'moonscaping' (Figures 8 and 9) illustrate the misconception of assuming that a technique which works in one situation will perform as well a in similar but different situation. The erosion damage on slopes can be minimised by investigating the macro-properties of the materials and adopting a slope configuration that can utilise those materials. This investigation could include using modeling techniques when designing the waste dumps to assess the relative performance of different slope configurations.

Figure 9 Failed 'moonscaping' in central Western Australia, following one cyclone (photo: H. Jones, 2006)

Managing sheet flow, through variations of slope angles, works to a certain point beyond which it is necessary to manage the run-off water using defined drainage channels. Robust landform drainage design approaches, using deliberate landform shaping to produce a drainage pattern analogous to those on hillsides, with careful consideration to the relationship between catchment area and the size of drainage channel, should be adopted. The 'hardening' of the channel bases (provided by bedrock, stream bed debris and vegetation in the natural terrain) could be provided by preferential placement of selected, rocky spoil, rather than by deliberate rock lining. The rocky spoil used for 'hardening' should be carefully selected to ensure no potentially acid generating materials are incorporated in the channel.

Engineered chutes are often unsuccessful in the very long-term, because inadequate design/construction leads to bypassing and rapid gullying. It is important that these channels are appropriately sized and the profile of the channel bed designed to accommodate the predicable volume of water. Many designs adopt the 1:100 flood event as their design standard for drainage, including diversion channels. This is totally unacceptable for a closure design, as it has a 20% probability of being exceeded in just 25 years! Closure design should adopt the probable maximum flood (PMF).

An example of designing drainage patterns on a waste landform to roughly mimic the natural drainage system is described by Myres et al. (2001). This 'learning by observation' approach is less likely to produce unintended consequences in the long-term than the practice of using of concrete channels.

2.4 20 degree slopes

While the negative consequences of imposing sub-optimal slope configurations and slope angles for closure through regulation (or de facto regulations-government guidelines) are often noted, there is one case, namely the stability of tailings embankments in Western Australia, where this has inadvertently resulted in better closure outcomes on some mines.

Publication of State government guidelines in 1996 (Department of Minerals and Energy, W.A. Government (DME, 1996)) were intended to promote the establishment of vegetation on post mining landforms and reduce the potential erosion. The subsequent application of these guidelines to all waste landform slopes, including tailings facility embankments (often via strict mining tenement conditions), resulted in some tailings embankments being ‘over designed’ with their external batters being shallower and their bases wider than the conventional tailings embankment designs of that period would have recommended. These more conservative designs have contributed to the fact that there is no reported case of any embankment failure of a tailings embankment in Western Australia since that time (I. Misich, DMP, pers. comm., April 2012). Given that many tailings facilities in Western Australia are upstream constructions, often built with limited professional supervision this is a ‘good outcome’ story, but like so many good news stories concerning mining and the environment, is often overlooked.

2.5 Ecological considerations

Funded research into the challenge of recreating the vegetative cover on newly constructed waste landforms was initiated in the mining industry using the very cost effective technique of seeking natural analogues in the form of areas disturbed by other activities. Building on this information, the mining industry funded further research into such things as plant succession, understanding of the ecological cycles for those disturbed lands and developing practical methods of replicating natural processes.

However, the vegetation on the majority of waste dumps is still often the result of a single planting, with a resulting uniformly aged ‘crop’, unlike the mixed ages observed in natural vegetation communities. This makes such vegetation susceptible to natural events (fire) and excessive feral animal grazing, as shown in Figure 10.

The adoption of more than one seeding event, combined with the protection of vegetation until it has reached maturity would increase vegetation survival. However, this aspect is often not addressed by closure plans, so the well meant efforts to establish native vegetation can be destroyed by too early a declaration of successful vegetation establishment and the withdrawal of active site management.

Figure 10 Impact of goats on rehabilitation, Western Australia, 2005 (photo: H. Jones)

Covers are placed to reduce the infiltration of moisture and oxygen. In coal mine waste they may be used to prevent the heating of carbonaceous and coaly material by the considerable reduction of oxygen ingress. This relatively loose cover material is easily excavated by burrowing animals and the creation of these new habitats results in degradation of cover effectiveness. If there is remnant heating within the dump material these animals find an even more attractive centrally heated home. Increased burrowing intensity allows more oxygen to pass through the cover stimulating more heating and increased vulnerability to surface water erosion and infiltration.

3 Social aspects

Closure planning is often considered to be the domain of the environmental scientists and civil engineers. However, the socio-economic aspects of mine closure can be very dramatic in terms of long term impacts on communities and they should be given more consideration during the project feasibility evaluation process and particularly during the closure planning process.

3.1 Closure impacts

One of the author's personal experience with the unintended consequences of mine closure, the systematic closure of some 256 coal mines in South Wales over an approximately 15 year period (mid-1960 to early-1990s), resulted in him being faced with the choice of changing his profession or relocating his family. He elected the latter and migrated to Australia. Other members of his extended family were faced with the same choice; one family migrated to Africa, one to Canada, one to a temporary job (five years) in the Middle East. Of the family members who remained in South Wales, two changed their professions and one has never worked since! The local unemployment in his village immediately rose from about 2% to 35%, with most shops and even three of the four pubs being permanently closed almost overnight.

It is certain the governments of the day (the closures happened under both of the U.K.'s major political parties (Cabinet Papers, 1971)) did not wish to deliberately inflict social hardship or export a well educated and trained work force. Similarly the author and his migrating cousins never intended to leave the land of their birth but these were the unintended consequences of those mine closures.

Now, some 40 years later, all the emigrants are happily and successfully established in new lands, with no thoughts of ever permanently returning to the land of their birth, but the scars in the form of missing houses, boarded-up shops, dilapidated public buildings still greet them when they visit their remaining relatives, proof that the lives of those who remained have also been irrevocably changed.

3.2 Fringe benefits tax

The introduction of the Fringe Benefits Tax (FBT) in Australia in 1986 was one factor that changed the approach of mining companies to the manner in which they accommodated their employees. Prior to that time it had been common practice for mining companies to construct towns near their proposed developments, such as the towns of Newman, Kambalda and Tom Price. In other cases, the companies built their own accommodation in existing towns, such as Port Hedland. To attract workers to these then very remote areas, companies offered the accommodation to their employees at subsidised rentals of around one dollar per day in the early 1970s. However the FBT, defined by the Australian Tax Office (ATO), states:

> *"If you provide an employee with the right to use a unit of accommodation and that unit of accommodation is the usual place of residence of the employee, the right to use the unit of accommodation is a housing fringe benefit."*

This effectively put an end to the practice of companies developing towns in remote locations.

In terms of the social impacts of mine closure this is probably a very good outcome, as the trauma and social disruption resulting from closing down the prime source of employment in any town can be extreme. The replacement of residential accommodation for employees and their families on site with the fly-in-fly-out (FIFO) work rosters has its own social challenges, but the closing of a particular mine under these circumstances does not require the employee to relocate his/her home to remain in the industry. This, from one of the author's personal experience of having to relocate his family in order to remain in the industry, is a very positive unintended consequence of the FBT.

3.3 Anthropogenic impacts on rehabilitated land

The rehabilitation of coal mine waste dumps in developing countries with large under privileged populations has sustainable uncertainty post-closure. A common unintended consequence is the provision of fertile lands, enhanced by regular application of fertilisers to stimulate and maintain vegetation growth for soil stabilisation reasons. These areas offer attractive grazing for animals belonging to informal settlers and local communities. Uncontrolled grazing results in loss of the stabilising vegetation and trampling by animals can quickly change slope profiles with the creation of preferred surface drainage paths and concomitant erosion.

Although in commercial terms dumps are composed of waste, old coal mine waste dumps are perceived as a resource by the underprivileged; poor quality discarded coal burns can be and is used as a fuel source for heating and cooking. The dump becomes a target for informal reworking that removes top soil covers, as many small excavations are dug in the hunt for residual coal in the waste.

In a similar manner, artisanal miners are attracted to waste dumps and particularly tailings storage facilities associated with gold operations with the resulting damage to covers, which, over time can have serious impacts on the long-term stability of the covers.

The social aspects associated with mine closure in developing countries are often made more acute because the mine workforce becomes redundant but cannot afford or may be unwilling to relocate. Some companies have reduced these anthropogenic impacts by endeavouring to set up post-mining alternative industries (Roldan and Purvance, 2011).

4 Open pit voids

There are many examples around the world of closed mines that have become social assets, however, very few are the result of forward planning by the miners or the governments. They have often evolved almost by accident. Some of the more well known examples are given below.

The oldest well known example is England's largest area of wetlands, the Norfolk Broads which were a source of peat for many centuries up to the end of the 14th century when the 2,000 ha site, comprised of deep excavations, was flooded to form over 30 lakes and interconnect several rivers to form about 200 km of waterways creating a now popular tourist destination (Bradshaw and Chadwick, 1980).

Reconfiguring open pits and quarries into concert venues is a popular option in many parts of the world including the Dalhalla theatre in Dalarna, Sweden, and the Quarry Amphitheatre in Perth. Other such closed mines have become botanical gardens (Butchart Gardens in British Columbia, Canada, and Eden Project, England); a football stadium (Braga, Portugal); motor racing track (Gotland Ring, Storugns quarry, Sweden) and rock climbing routes (Landschaftspark, Duisburg-Nord, Germany) (Pearman, 2009).

When the open pits voids have retained permanent water they have also been turned into a social assets such as diving at Tidenham quarry, England; canoeing at Markkleeberger See, Lausitz, Germany; hydroelectricity generation at Dinorwig, Wales (Pearman, 2009); and general boating activities at Collie, Western Australia (McCullough and Lund, 2006). Water retaining pit voids are also used for aquaculture as at Premier Coal, Western Australia (Kumar et al., 2011); wildfowl conservation at Capel and Kemerton Lakes, Western Australia (Lund and McCullough, 2011); and river water quality management at Chicken Creek, Western Australia.

Many of the above were unintended consequences of closure but all are positive outcomes. In several cases, the positive outcomes were not part of the original planning for the mines but late in the life of the operations the positive outcomes were recognised and actively pursued, proving that even late changes to closure plans can develop good outcomes.

Open pit voids also have negative outcomes such as physical instability resulting from the pit being excavated to an operating standard of safety rather than a closure requirement. This has resulted in some pit wall failures. In addition adverse impacts may result from the weathering of sulphide minerals left exposed by the excavation of the pit (McCullough, 2007).

Figure 11 Result of failing pit wall in central Western Australia in 1996 (photo: H. Jones)

The potential for pit walls to collapse (Figure 11) can be managed by the establishment of a buffer zone around the pit rim sufficiently wide enough to allow for the pit wall to fail to the maximum probable extent, based on the maximum credible earthquake for the site.

The oxidation of sulphide minerals is a much more complex issue depending on the nature of the minerals exposed and ground water response to the development of the open pit. In Western Australia, the Minister for Environment has sometimes placed prescriptive Ministerial Conditions (EPA, 2009a) on development proposals which require open pits to be partially backfilled on closure in order to protect ground water resources. However, where the pit walls have exposed sulphide minerals backfilling to above the pre-existing water table, a through-flow pit could result, which would in turn increase contamination of the groundwater down gradient from the pit (McCullough et al., 2012). Another consequence of these types of ministerial condition is the additional greenhouse gas emissions required to load, haul and dump the waste needed to backfill to the extent the Ministerial Conditions require. At other times the Ministerial Conditions (EPA, 2009b) have been worded in a more enabling tone by stating the required Ministerial outcomes, rather than prescriptively directing the company's actions.

5 Role of guidelines

Guidelines are a mechanism for assisting individual companies plan and operate more effectively in order to attain specific closure outcomes (Jones, 2008; Jones and McCullough, 2011). Guidelines may be prepared by governments, industry groups, academic institutions, financial organisations and individual companies. Some of the guidelines are intended to be used internationally, while others are prepared for specific jurisdictions.

However, guidelines, particularly those developed by governments or international organisations, are often considered as design standards by both operating companies and the regulating authorities. The site specific nature of mining means that it is almost impossible to draft closure requirements that meet all situations. For example, (Figure 12) the 'moonscaping' guidance was published in a State government guideline (now no longer on that State's web site) and incorporated into a Federal government guideline (Environment Australia, 1998). Yet experience shows (Jones, 2010) that many closure landscape engineering techniques only work in some situations (Figures 8 and 9) and the authority such guidance gains by being a government publication could potentially cause serious damage to some closed landforms.

There are potentially misleading guidelines at an international level. For example, the current International Finance Corporation's (part of the World Bank Group) guidelines published as part of the 'Environmental, Health and Safety Guidelines for Mining' (IFC, 2007) recommends the following for Waste Rock Dumps:

"Dumps should be planned ***with appropriate terrace and lift height specifications (highlighted by the authors)*** *based on the nature of the material and local geotechnical considerations to minimise erosion and reduce safety risks."*

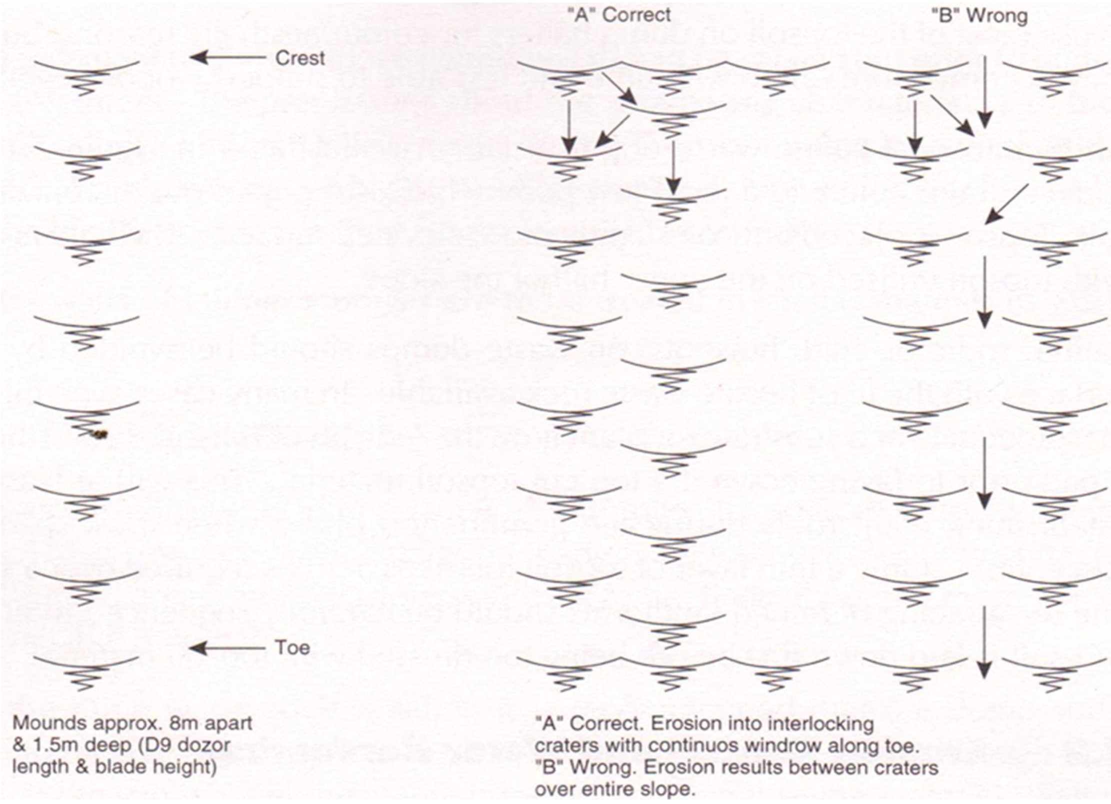

Figure 12 Part of Figure 7.2 from DME, 1996

This recommended use of terraces will almost certainly increase the erosion potential at most mines. Companies would be better advised to follow the earlier guidance given by the World Bank Group in July 1998 (Word Bank Group, 1998) in their section on Base Metal and Iron Ore Mining contained in the Pollution Prevention and Abatement Handbook which states, in part:

"The closure and restoration plan should cover reclamation of tailings deposits, waste rock deposits, any open pit areas, sedimentation basins, and abandoned mine, mill, and camp sites. Mine reclamation plans should incorporate the following: Contouring of slopes to minimize erosion and runoff." (highlighted by the authors)

The intention of the guidelines is to assist in the attainment of good closure outcomes. They should be printed with a clear disclaimer that they are guidelines and NOT regulation standards that must be followed. Without this advice, the publication of simple, clear diagrams such as Figure 12 can lull the poorly informed mine operators into using inappropriate designs, particularly when the regulators insist that 'one-size-fits-all'.

A very significant difference between these two guidelines which are both intended to cover closure aspects is the introduction of "appropriate terrace and lift height specifications" in the newer guideline. This particular advice is clearly not sound advice when applied to designing a final landform that is being designed to remain essentially 'stable' in perpetuity. This advice should be seen as an operational safety measure rather than a closure design, as terraces will result in a landform requiring continuous maintenance to repair erosion gullies, an unintended closure consequence.

6 Single issue fixation

A number of the unintended consequences at closure have happened because the objectives of closure design and implementation on a particular project becomes focused on a very small number of the closure aspects, in some cases the focus may even have been on a single issue.

Closure planning in Australia in the 1970s focused on the establishment of vegetation cover on the landforms with little or no consideration being given to the development of suitable drainage on the structures or the impact of geomorphological processes on the landforms. This parochial view to mine closure encouraged designers to create landforms with large flat areas and horizontal terraces, as the potential unintended consequences of such landforms in the form of increased long term erosion were not understood. Because of the different time frames for the biological cycle and the geomorphological cycle, it is only when these landforms reach their 10 year plus age that the unintended consequences are being recognised (Jones, 2011b).

7 Conclusions

Life is a series of learning experiences and the unintended consequences outlined above should be considered as just that, learning experiences, in much the same way as the Tacoma Narrows Bridge collapse in 1940 is considered as an important step in building knowledge about understanding suspension bridges (Petroski, 2012).

Understanding those lessons should enable the incidence of unintended consequences to be reduced. In particular, the adoption of landform construction techniques should be done following a detailed assessment of the available materials, the climatic regime of the site and the selected post mining land use. Every mine is unique. Selecting a technique just because it works at another mine site is simply inviting potential unintended consequences.

The design life of a closed mine is almost infinite and therefore the acceptable design standards adopted should be similarly long-term, such as probable maximum flood (PMF) and maximum credible earthquake (MCE).

Ecological and geomorphological processes require different timeframes to reach maturity. An understanding of all of these processes is essential to avoiding negative unintended consequences.

The social aspect of mine closure is much less well understood than the physical aspects and yet often has much greater consequences for communities. It is hoped that this aspect of mine closure is more fully researched so that unintended consequences can be minimised.

Based on the ‘good news’ examples of unintended consequences of closure good mine closure planners should seek positive post mining land uses outcomes through consultation with other stakeholders. Even if the potential land use is as basic as using open pits as landfill sites for nearby urban areas, this consultation will lead to more acceptable (and sustainable) closure outcomes through realising potential opportunities.

References

Australian Tax Office, www.ato,gov.au/businesses.

Bradshaw, A. and Chadwick, M.J. (1980) The restoration of land: the ecology and reclamation of derelict and degraded land, Blackwell Scientific Publications, Oxford, 317 p.

Cabinet Papers (1971) Conclusions of Cabinet meeting 30 April 1971, National Archives (U.K.) Reference CAB/128/45.

Department of Minerals and Energy (1996) Guidelines for mining in arid area environments, June 1996, 44 p.

Environment Australia (1998) Landform design for Rehabilitation, One booklet in a series on Best Practice Environmental Management in Mining, Department of the Environment, Commonwealth of Australia, ISBN 0-642-54546-4 of the series 0-642-19418-1.

EPA (2009a) Windarlind W2 pit, Ministerial Statement No 802, Published on 18 August 2009.

EPA (2009b) Southdown Magnetite Proposal, Ministerial Statement No. 816, Published on 25 November 2009.

IFC (2007) Environmental, Health and Safety Guidelines, Mining (December, 2007) International Finance Corporation, 28 p.

Jones, H. (2010) Environmental Compliance, in Proceedings First International Seminar on the Reduction of Risk in the Management of Tailings and Mine Waste (Mine Waste 2010), A.B. Fourie and R.J. Jewell (eds), 29 September – 1 October 2010, Perth, Australia, Australian Centre for Geomechanics, Perth, pp. 309–317.

Jones, H. (2008) Closure objectives, guidelines and actual outcomes, in Proceedings Third International Seminar on Mine Closure (Mine Closure 2008), A.B. Fourie, M. Tibbett, I.M. Weiersbye, P. Dye (eds), 14–17 October 2008, Johannesburg, South Africa, Australian Centre for Geomechanics, Perth, pp. 245–254.

Jones, H. (2011a) Three "R's" for mine closure – responsibilities, regulations and results, Plenary address to Sixth International Conference on Mine Closure (Mine Closure 2011), PowerPoint presentation, 19–21 September 2011, Lake Louise, Canada.

Jones, H. (2011b) Three "R's" for mine closure – responsibilities, regulations and results, in Proceedings Sixth International Conference on Mine Closure (Mine Closure 2011), A.B. Fourie, M. Tibbett and A. Beersing (eds), 19–21 September 2011, Lake Louise, Canada, Australian Centre for Geomechanics, Perth, Vol. 2, pp. 29–38.

Jones, H. and McCullough, C.D. (2011) Regulator guidance and legislation relevant to pit lakes, in Proceedings Mine Pit Lakes: Closure and Management, C.D. McCullough (ed), Australian Centre for Geomechanics, Perth, pp. 137–152.

Kumar, R.N., McCullough, C.D. and Lund, M.A. (2011) Use and water quality remediation of acidic coal pit lakes by adjacent aquaculture, Report number 2011-10, Mine Water Environment Research Centre/Centre for Ecosystem Management, Edith Cowan University, Perth, Australia, 104 p.

Loch, R.J. and Lowe, S.M. (2008) A logical framework for the design, construction and rehabilitation of mine site waste dumps, in Proceedings First International Seminar on the Management of Rock Dumps, Stockpiles and Heap Leach Pads (Rock Dumps 2008), A.B. Fourie (ed), 5–6 March 2008, Perth, Australia, Australian Centre for Geomechanics, Perth, pp. 257–267.

Lund, M.A. and McCullough, C.D. (2011) How representative are pit lakes of regional natural water bodies? A case study from silica sand mining, in Proceedings of the International Mine Water Association (IMWA) Congress, Aachen, Germany, pp. 529–533.

McCullough, C.D. and Lund, M.A. (2006) Opportunities for sustainable mining pit lakes in Australia, Mine Water and the Environment, Vol. 25, pp. 220–226.

McCullough, C.D. (2007) Approaches to remediation of acid mine drainage water in pit lakes, International Journal of Mining, Reclamation and Environment, Vol. 22, pp. 105–119.

McCullough, C.D., Marchand, G., Unseld, J., Robinson, M. and O'Grady, B. (2012) Pit lakes as terminal sinks: a new approach to best available practice mine closure, in Proceedings of the International Mine Water Association (IMWA) Congress, Aachen, Germany.

McPhail, G.I. and Rye, C. (2008) Comparison of the erosional performance of alternative slope geometries, in Proceedings First International Seminar on the Management of Rock Dumps, Stockpiles and Heap Leach Pads (Rock Dumps 2008), A.B. Fourie (ed), 5–6 March 2008, Perth, Australia, Australian Centre for Geomechanics, Perth, pp. 277–289.

Myres, K.L., Espell, R. and Burke, K. (2001) Reclamation and closure of the AA heap leach pad at Barrick's Goldstrike Mine, Society for Mining, Metallurgy and Exploration Transaction.

Pearman, G. (2009) 101 things to do with a hole in the ground, Post-Mining Alliance, Cornwall, 138 p.

Petroski, H. (2012) Failure follows success, Materials World, Vol. 20, No. 4, Institute of Materials, Minerals and Mining, April 2012.

Roldan, C.F. and Purvance, D. (2011) San Martin mine in Honduras – from closure to sustainability, in Proceedings Sixth International Conference on Mine Closure (Mine Closure 2011), A.B. Fourie, M. Tibbett and A. Beersing (eds), 19–21 September 2011, Lake Louise, Canada, Australian Centre for Geomechanics, Perth, Vol. 2, pp. 461–470.

Willgoose, G.R. (2000) in Proceedings Planning for Mine Closure – An Operator's Guide, ACG Seminar No. 2009, 7–8 December 2000, Perth, Australia, Australian Centre for Geomechanics, Perth, Section 11.

World Bank Group (1998) Pollution, prevention and abatement handbook, pp. 267–271.