Minesite rehabilitation

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Abstract

Minesites in Australia are often developed on pastoral or cropping properties. Therefore, there is a requirement to return the mined land to a land use capability similar to that existing prior to mining. Unless the topsoil is returned to the area, the revegetation will encounter harsh soil and moisture conditions that will test the longer-term stability of the vegetation and the final land use. This paper discusses some of the issues involved and points to the principles that can be adopted from the vast pool of agronomic research that has been accumulated in the Australian tropics.

Introduction

The post-mining land use for many minesites involves either grassland for cattle and wildlife or bushland, or on the better soils, cropping. With this in mind it is useful to review the likely situations in which grasslands research can enhance the quality and speed of effective rehabilitation operations.

Rehabilitation of minesites is a legislative requirement throughout Australia and many parts of the world. In Queensland, that was the case for the better part of the nineteenth century, but was often not enforced effectively. Currently mining companies commit to a program of rehabilitation from the outset of operations. If the program is developed effectively, it incorporates the handling and storage of topsoil, waste rock and tailings in such a way that will assist in the final rehabilitation of the site. The benefits are that mine planners consider not only the movement of materials but also the most appropriate storage of benign and hostile materials in order that they minimise the disturbance area and minimise the work required to rehabilitate the site. Previously, planning focussed entirely on the most cost-effective means of extracting ore; time would repair the disturbance.

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Mining has a strange language that will be quite foreign to the ear of a grassland scientist (or anyone else for that matter), terms such as Tailings (finely ground waste from ore processing), Borrow Pits (place where earth is taken but never replaced), a ROM for Run-of-Minelife, a Void (pit or hole in the ground). However, rehabilitation is a term we all recognise, and it is rehabilitation that is the focus of this paper.

An extreme situation

Minesite rehabilitation, unlike farmland rehabilitation, often deals with extreme situations. Coarse waste rock dumped in mountains and covered with a mantle of top or subsoil or crushed rock is a harsh place for any sort of vegetation. Fertility and moisture supply are often restricted, and yet with time, a great deal of time in some situations, plants will colonise those mountains. It is the time factor that is crucial here. In past times when the majority of our population directly or indirectly earned their keep from mining or agriculture, and the population was spread even more thinly around the continent than it is now, society was content to allow nature to care for itself, perhaps with the knowledge that time would heal the situation. Gradually it did, at places like Mt Lyell (hard-rock mining of copper at Queenstown, Tasmania), Derby (alluvial tin mining in northern Tasmania), the Palmer River (alluvial goldfields in north Queensland) and Herberton (alluvial tin workings in north Queensland). There are obvious cases where the rehabilitation takes longer, for example Mount Morgan and sections of the Queensland coalfields.

Society attitudes

Nowadays, the predominant urban society has been convinced that disturbances should be repaired as soon as possible after the event at whatever the cost. Society seems to be unconcerned that the cost will be added to the products they consume or simply preoccupied with the appearance of their surroundings while giving little thought to the longer-term rehabilitation of the minesites. There are sites that will not rehabilitate naturally in the foreseeable future without some form of intervention.

Natural rehabilitation

Natural disturbances such as a landslip occur continuously in high rainfall, geologically active areas (Burma, Irian Jaya, and Bartle Frere, NQ) and natural rehabilitation commences quickly. The very active areas in PNG and Irian Jaya also have high sediment loads within the rivers due to natural disturbance. However, it is not necessarily the turbidity or sedimentation of the streams that is of primary concern, but the chemicals/metals that can rapidly devastate the aquatic/marine life. These systems will regenerate with time, but it is of concern that people and wildlife depend on that river for water and food.

The ability/speed to rehabilitate naturally is linked to site characteristics. Generally, the speed of regeneration is faster in wet temperate (the farm croplands of West Virginia vacated in the 1930s with depression, drought and acid soils) and tropical situations than in dry conditions (the seismic lines visible in the Omani desert after 40 years). The same can be said for the grasslands and woodlands that have been disturbed by agricultural and residential activities.

Mine scale

The scale of mining activities has also changed so disturbances can be on a greater scale than in the past 100 years. Even so, the amount of disturbance on any one mining operation is usually <800 ha, which is relatively small in comparison with pastoral properties, or indeed suburbs in Australia. Mechanisation of many smaller mining operations such as opal, alluvial gold and tin has increased the speed of mining and scale of disturbance, and should have also increased the speed of the rehabilitation process. Mechanisation and the exhaustion of near-surface oxide ore bodies has led to large-scale open-cut mining often associated with sulphidic rock at greater depth. Sulphidic waste rock and tailings pose greater problems for rehabilitation.

Rehabilitation requirements

The increasing stringency of environmental regulation of the mining industry is focussed to a large extent on the rehabilitation of the disturbance to a state that ensures a long-term, stable land use in keeping with the land use in the surrounding country. In many respects, the legislative requirements facing the mining industry will also have an impact on grazing and cropping industries in the future.

The States and Territories of Australia require that the post-mining landscape is stable and non-polluting, and this generally involves some form of revegetation. The basic principles for minesite rehabilitation are as follows:

- agreement on a long-term land use for the mined land;
- progressive rehabilitation of the site;
- prevention of the spread of weeds and pests;
- minimising the disturbance;
- reshaping the mined land for stability and drainage;
- minimising long-term visual impact; and
- reinstating drainage.

In many respects, what happens on minesites and subsequently on rehabilitated sites will become a legacy that will eventually become grasslands, woodlands or forests. In this forum, however, we are considering minesites that become grazing land for livestock and wildlife. The legacy may comprise poor fertility, erosion, salinity, soil acidity, metal levels above the background landscape levels, poor moisture-holding capacity, weeds, a lack of diversity; many of the issues currently encountered in grazing lands throughout the tropics. Mine pits stay as holes in the earth or create a water body that is of use to man, wildlife and livestock, in much the same way that Tinaroo or Somerset Dam does.

Constructed landforms

Internal/External/No-drain landforms

Waste rock and overburden dumps require rehabilitation to an agreed land use, whether that is native bushland, timber plantation or pasture. The traditional method of landform reconstruction involved reprofiling the dump by knocking down the angle-of-repose batters to angles less than 33%, and creating contour banks and drains to reduce erosion. This method of rehabilitation has been successful at South Blackwater mine and other mines in central Queensland. However at that site, they go a step further and remove the contour banks once vegetation is fully established in an effort to remove any source of water retention that could possibly cause erosion.

The problem of erosion on reformed mine surfaces such as coal spoil or waste rock dumps has stimulated experimentation with alternative landforms. The internally drained landform used by Mount Isa Mines at several coal mines in CQ (Pocknee *et al.* 1999) was trialed to reduce the amount of minespoil reshaping required, external drainage and associated erosion as part of the rehabilitation process. Indeed, catching and holding rainfall within the landform may enhance leaching of salts from the root zone and water use by the vegetation on spoil which has a low moisture-holding capacity. It can be argued that this form of water harvesting is needed in the semi-arid climates of central-western Queensland. Attempts to drain the structure externally often result in erosion and extensive maintenance. In saline spoil, however, encouraging internal drainage through the structure may eventually lead to salting at the toe of the structure or in the surface aquifer. Kidston gold mine has a similar strategy for the rehabilitation of its waste rock dumps (Williams *et al.* 1997), which caps the bench surface with a thick layer of oxidised material. It differs from other landform strategies by having a cap that acts as a sponge to absorb rainfall for use by the vegetation. Research at Kidston has shown that a cap covered with pasture has reduced infiltration to less than 0.4% of annual rainfall, and that in extreme rainfall years (1 in 100 wet season) some 5-26% of rainfall would infiltrate to the waste rock below (Currey *et al.* 2000).

Waste rock dumps should blend with the surrounding landscape, and develop a vegetation cover similar to the surrounding landscape; that can be difficult in some situations. For example, at Earnest Henry mine on the black, flat plains of north-west Queensland, mining has opened up a cavernous hole in the earth, and created a waste rock mountain of huge proportions. In effect, it has sculptured its own landscape, and yet, in the far distance, there are natural landscapes of similar proportions. Very often, the reconstructed landform can be found in surrounding country. In the steep landscapes of Irian Jaya and PNG, the only place to put waste rock is in the adjacent valley. In many mining situations there is sufficient variation in the natural landscapes which miners can effectively mimic with their constructed landforms.

For these rehabilitation landforms, grazing by livestock may not be an option due to inaccessibility and tree density. It can best be defined as bushland in the long term. Trees have a greater capacity than grasslands for removing water from the landform surface, and from a capped landform such as that at Kidston mine. It is expected that trees will help to reduce salinity levels in the surface soil and minimise deep infiltration of rainwater into the spoil, particularly that which has an acid-forming potential or is highly saline. Further research is needed to demonstrate the benefits of trees in these situations.

Tailings dams are an integral part of most mining operations which process ore. At the end of mine life, they are required to be non-ponded, stable structures. Often they contain chemically or physically hazardous particles that need to be buried or capped and revegetated for long-term stability. Undoubtedly, it is difficult to ensure the integrity of the cap: cracking as a result of wetting/drying episodes, and penetration by tree roots will eventually allow some water infiltration. Fire can be used to restrict tree development and maintain grassland in the long term. In pastoral country, a common feature of rehabilitated tailings dams is the heavy grazing pressure by cattle and wildlife, attracted by the soil disturbance, the new growth, fertiliser, and possibly the elevated levels of metals in the vegetation. As with pastures anywhere, cattle need to be controlled to maintain vigour and stability of the vegetation. For this reason, it is important for mine operators to solicit the co-operation of neighbouring graziers in managing the rehabilitated land.

Erosion

Erosion is an important matter for rehabilitation of minesites. The standards set have been likened to those on agricultural land, and where mined land is to be returned to farming/grazing that is appropriate. The rule should be that erosion on the rehabilitated land should be no greater than that from surrounding land of similar land use.

Erosion potential is closely linked with the landform design, slope angle and length, material characteristics, cover and of course, the climate. While many mines in Australia are located in dry parts of the continent, the intensity of rainfall in many tropical areas is high. Consequently, the risk of erosion during minesite rehabilitation is severe. Conventional landforms incorporate contour banks, restrict slope length, and introduce drainage systems in an effort to minimise erosion. As with the agricultural industries, vegetation cover and drainage control are the key factors to consider in minimising minesite erosion. Relationships derived from grasslands are useful in describing how vegetation cover will reduce soil erosion (McIvor *et al.* 1995).

Fertility

Ideally, topsoil should be stored for use in rehabilitation of mining disturbances. Often there was little topsoil to begin with; highly mineralised country is characterised by a paucity of topsoil and often vegetation. In many cases miners will use any benign material available as a growing medium for vegetation. Subsoil or overburden material has low nutrient status compared with topsoils. Unless topsoil is stored and replaced on the mined area, fertility problems can be encountered. Typically, these materials are also low in phosphorus and have a low Ca:Mg ratio, which can be overcome with fertiliser, but little is known of the longer-term effects on grassland stability. The mining industry needs to learn something from the pastoral industry.

Unfortunately, soil fertility analysis does not feature highly in the rehabilitation plans for the mining industry. Despite the huge amounts of money expended on earthmoving contracts, mining companies appear ignorant of the benefits of getting fertility right prior to revegetation. Many a revegetation program has failed or performed poorly because of poor fertility, with resultant erosion, maintenance earthworks, and non-compliance with rehabilitation schedules. Often, inexperience is the primary reason.

The aim of good minesite planning is to ensure that the relatively nutrient-rich topsoil is saved for use as the final surface layer on the rehabilitated landform. Comalco, Weipa has a mine stripping and replacement program which does just that. Simply replacing topsoil, however, is often not enough, because soils in many mining areas are nutrient-deficient. Speed of re-establishment is of critical importance. Therefore, fertiliser should be applied to optimise fertility for the emerging vegetation.

Seed/Fertiliser application

Fertiliser is applied at sowing to give the greatest benefit to the developing seedlings. In level country, fertiliser is applied by truck or tractor-mounted spreaders, but as the degree of difficult country increases there is greater efficiency in aerial application by helicopter or fixed-wing aircraft. Some people claim to have experienced uneven distribution from aerial application, which runs counter to experience in the pastoral industry. To improve the ballistic characteristics of the seed and provide some fertiliser to the seedling, fertiliser coatings have been used. Coated seed, however, is more expensive based on the value of the seed and fertiliser. The small amount of fertiliser added as the seed coating will have little long-term effect on fertility of the rehabilitated minesite.

In the past, miners have adopted fertilisation rates used in the pastoral industry. This has been a mistake because of the inherently low fertility of many minesite rehabilitation areas, and the risks involved. By far the greatest cost in minesite rehabilitation is earthmoving; seeding and fertiliser are relatively low cost. Yet, the consequences, in terms of maintenance earthworks, of poor initial revegetation, due to low fertility are great. The rule is to get the fertiliser mixture right and use high fertiliser rates that will have a long residual value, and stimulate nutrient cycling. Reapplication is often impractical on a regular basis except by aircraft.

Generally, the fertiliser and seed can be sown together. Experience in the pastoral industry indicates that mixing should be done within 1-2 hours of application to minimise seed burn from the fertiliser.

When sowing mixtures of tree and grass-legume seed, some miners delay sowing the groundcover species to improve the establishment of tree seedlings. This practice is more costly and has an associated risk of soil erosion owing to the poor cover provided by tree seedlings. Generally, I favour mixing the species and applying the seed and fertiliser at the one time.

Salinity

Some coal spoil and reject from coal beds is extremely saline, which presents a significant problem for revegetation. There are several possible solutions. The first involves capping with benign material, and the second involves the use of salt-tolerant vegetation. Clearly it is preferable to use a capping layer; but this is not always possible owing to the lack of available capping materials. There is the additional problem where salts rise through capillary action in areas where evaporation exceeds rainfall. In the no-cap option, the spoil dumps should be allowed to drain, as they age, into dedicated evaporation dams. As salinity levels in the spoil fall, salt-tolerant species can be sown. Queensland University (Centre for Mined Land Rehabilitation) and the Central Queensland University have been engaged in this research in the central Queensland coal fields for the past 10 years. Hoy *et al.* (1994) have identified a number of tree species that are highly tolerant of saline, alkaline conditions, and have adapted a number of seedbed preparation practices (from horticulture), such as plastic mulching, which greatly enhances the establishment of trees and shrubs on saline coal tailings dams.

The best advice on salinity is to avoid it, but otherwise develop a system which leaches salt from the profile and either delivers it to the groundwater (if it is already saline) or delivers it to a sump such as a saline water dam. The internally drained landform has the potential to do that, but the fate of the saline water needs to be predicted and monitored with confidence if it is not to be a long-term liability to future landholders.

Acidity

Ore bodies associated with sulphides have the potential to produce acid drainage once they have been exposed to air and water. This particularly applies to some waste rock, coal spoil and reject and tailings. A prime example is the copper and gold mine at Mount Morgan in central Queensland where both tailings and waste rock material have produced a large volume of acid water in the pit, which previously drained to the Dee River. Most vegetation is intolerant of acid conditions in association with high concentrations of metals such as aluminium, copper, lead and zinc. In these situations, the material must be capped with benign material to limit infiltration of air and water, and to provide a rooting medium for vegetation. Kidston mine constructs a wide barrier of benign waste rock to encapsulate sulphidic waste rock so as to limit the amount of rainfall and oxygen that can infiltrate the sulphidic material.

Invariably, an acid-forming characteristic in sulphidic ores is linked with high levels of one or more of the following elements: aluminium, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel and zinc. Minesites affected by acid drainage will also have elevated levels of metals. Recent developments have shown that the red mud from the refining of bauxite can be used to effectively reduce the level of contaminants in mine waters (McConchie *et al.* 1999) so that they are suitable for consumption by livestock. Such a material may also be useful for reducing the availability of contaminants in soils.

Bioaccumulation

Mineralised areas generally have elevated levels of metals in the surrounding soils, but the metals tend to be in a highly oxidised state. Mining and processing expose and distribute much higher levels of metals over a wider area in the vicinity of the minesite, so there is the potential for metals to accumulate in vegetation or deposit on vegetation as dust. Cattle or wildlife grazing that vegetation will ingest the material and there is the potential for adverse effects on animal health. Higher-than-normal levels of metals in waters may also be associated with the mining operation. If livestock were to be fenced on to that water as their sole source of drinking water, a problem would develop. As a general rule when a minesite is being rehabilitated, there is a requirement on the mining company to prove that the soils and water will not adversely affect livestock. If metals are at elevated levels, a risk assessment is also required to determine the potential for contamination of livestock based on the likely duration of exposure to the contamination.

Greenhouse gases

As evidence of a will to *do the right thing*, mining companies have moved to rehabilitation with trees, though there is also a perception in the mining industry that it is difficult to manage pasture in a rehabilitation program. While it is a good idea to grow trees on a mined area that does not have an immediate use in grazing and farming, field survey data from woodland communities (Burrows 1999) indicate that the sequestration of carbon in the rehabilitation vegetation is inconsequential compared with the quantity of carbon released when the coal is burnt. Nevertheless, it serves two purposes, one of demonstrating what appears to be the right thing to do environmentally for CO_2 balances, and the other of recreating a vegetated landscape. If it is greenhouse gases that concern us, then how much do grasslands lock away? Burrows (1999) again calculates that grasslands tie up above ground some 1-5 t/ha, compared with 15-50 t/ha in woodlands; below ground the differences will be similar but of different magnitude. For rehabilitated minesites the before/after scenario is that rehabilitation with trees and grassland may put the disturbed landscape in a carbon status similar to that which existed prior to mining. The difference lies in the material that has been mined, and the carbon expelled in mining (haulage and seam gases) and processing (crushing/concentration) the material. It should be remembered that the vast majority of greenhouse gases are expelled in the cities during power generation, manufacturing and transportation.

Drought

In many tropical areas seasonal drought is a fact of life, and the materials used in rehabilitation of minesites have poor moisture-holding characteristics. These conditions make it extremely difficult for revegetation. Reprofiled waste rock dumps, and capped tailings dams often have a poorly structured medium with little or no organic matter to assist in retention of moisture, or indeed nutrients. Compaction and salinity are further problems that can reduce rainfall infiltration and use by plant roots.

Grazing

During mining operations it is difficult to incorporate grazing into the rehabilitation program, and, given the fragile state of the rehabilitated land, there is good reason to proceed carefully. Wet season spelling is used effectively in restoring over-grazed pastures in the tropics (Cooksley 2000), and will have an even greater benefit during the minesite rehabilitation process. It is often left to the post-rehabilitation stage before there is any serious grazing of minesites, but even then there is a need for careful management of the site. Light grazing will stimulate the vigour (tillering) of grassland and assist spread and nutrient cycling. In the long term, much of the mined land will be grazed by domesticated stock (cattle, goats and sheep) and/or wildlife.

Fire

During the rehabilitation process, mining companies need to assess the resilience of the grassland or woodland to fire. Lessons can be taken from the grazing industry on the use of fire to alter grass and woodland composition and structure. Cooksley (2000) used fire in the early wet season to effectively reduce the composition of Seca stylo in native grasslands in north Queensland. Similarly, fire is often used to reduce the density of young trees and shrubs in open woodland country. In rehabilitation programs involving the use of pioneer species such as acacias (or indeed exotic legume species), there is a tendency for the pioneering species to dominate the vegetation in the absence of fire. A cleansing fire can be used to reduce dominance of these species and allow the development of the primary forest species such as the eucalypts. Fire has been used in this way at Comalco's bauxite mine, Weipa (N. Dahl, personal communication).

Weeds

In much of the mining and grazing landscape, weeds are present. Mining companies have a responsibility to ensure that weeds are controlled on mining leases and exploration areas. This may lead to a situation where the minesite is relatively free of weeds, but is surrounded by weedy grazing and cropping lands. Mining companies need to ensure that topsoil stockpiles are maintained weed-free, and this can be achieved by maintaining a vigorous tree and ground vegetation cover. Similarly, this applies in the rehabilitation program.

Other beneficial uses for mines

In areas with little remaining bushland due to excessive clearing, minesites can be rehabilitated to bushland landscape in which there is little or no grazing value for domestic livestock. There may be reason to dedicate the bushland to a national park status. Other uses include urban landfill, toxic waste storage, and tourism (strangely, tourists are attracted to a ravaged site such as Queenstown, Tasmania). Open days at Red Dome mine were very popular with the community in showing the mining processes and the value of a rehabilitation program. Mining wastes can have beneficial uses in industry. Coal tailings may be useful in improving long-term cation exchange capacity of impoverished agricultural soils. Waste rock can be used as road base or for erosion control. Therefore, there are situations where it is not advisable to rehabilitate. Current research is assessing the value of bauxite red mud in decontaminating water from mine tailings dams and other industrial facilities such as sewage treatment plants and effluent from intensive animal industries.

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