

Co-Disposal of Coal Mine Tailings and Coarse Reject: A Promising New Technique

D.J.WILLIAMS¹

ABSTRACT

The washing of Australian black coal produces coarse grained waste or coarse reject, and fine grained waste or tailings. Coarse reject is easily handled and is conventionally dumped in piles where it ravel at its angle of repose. Tailings, on the other hand, are difficult to handle and have conventionally been kept separate from the coarse reject and disposed of separately. Conventionally, thickened tailings are pumped as an aqueous slurry to a storage, where they remain in the form of a "wet" deposit. The rehabilitation problems associated with wet tailings have prompted a search for alternative disposal techniques. The technique of co-disposal by the combined pumping of the tailings and coarse reject is emerging as the favoured approach.

1. INTRODUCTION

Australia has major black coal mining operations in Queensland's Bowen Basin and in the Hunter Valley of New South Wales, with considerable potential for further development of these coal fields. The run-of-mine coal must be washed to meet export market specifications. Processing produces coarse grained waste (up to 100 mm in size, termed coarse reject), and fine grained waste (2 mm and finer, termed tailings). The coarse reject is easily handled and is conventionally loose dumped in piles, where it ravel at an angle of repose of about 37° to the horizontal. However, loose dumping of the coarse reject may lead to acid mine drainage problems and degradation of the material, and the dump slopes may have to be flattened to ensure stability and minimise erosion in the long term.

The tailings are difficult to handle and conventionally have been kept separate from the coarse reject and disposed of separately as an aqueous slurry. The resulting "wet" tailings deposits are difficult to rehabilitate and result in very limited potential for future land use. The recognition of the future environmental and economic liability of current coal mine waste disposal practices has brought about a hardening of the approach taken by the Regulatory Authorities. Over the last decade a number of alternative disposal techniques have been tried. However, they have not involved a fundamentally new approach, and have met with variable success. A promising new technique involves the co-disposal of coarse reject and tailings slurry by combined pumping to a storage. This cost-effective technique results in a mixture which has reasonable engineering properties and behaviour, and offers potential to facilitate rehabilitation and future land use to a high level, and limit any acid mine drainage.

2. CURRENT APPROACH OF REGULATORY AUTHORITIES

The Regulatory Authorities in both Queensland and New South Wales require new coal mine projects to address the disposal and rehabilitation of washery wastes in their environmental management plan. The plan must subsequently be demonstrated by the mine, to the satisfaction of the Authority, to meet agreed environmental performance criteria. These relate to erosion and water contamination, both on the surface and below ground. Essentially, the mine should aim for negligible erosion of the surface of the rehabilitated landform, and negligible mine-induced contamination of surface or ground water. The extent to which the mine achieves its environmental performance criteria is rewarded by a partial refund of the security deposit which must be lodged with the Authority. The full security deposit is a realistic estimate of the full cost of rehabilitation, and for Queensland is typically in the range A\$15 000 to A\$25 000 per hectare. Existing coal mines will progressively, to the extent possible, be brought into line with the policy for new coal mines. A similar policy applies to all other mining developments.

The Authorities give little guidance as to how the performance criteria could be met, but expect the mine to consider all available approaches to washery waste disposal and rehabilitation, having due regard to the characteristics and behaviour of the materials involved, and to any peculiarities of the mine site and its location. The Authorities are reluctant to see the further proliferation of conventional wet tailings storages, which present rehabilitation difficulties, and there is increasing concern about the potential for acid mine drainage from coarse reject dumps.

In view of the tight criteria which must be met, by new coal mines in particular, washery waste disposal and rehabilitation must now be engineered to create an environmentally acceptable final landform at reasonable cost. To achieve this, the shape and surface treatment of the final landform must be decided in advance. To minimise cost, the shape formed by the deposited waste should ideally match, as closely as possible, that of the final landform, provided that the environmental performance criteria can be met.

Surface erosion is difficult to avoid on even very flat slopes if the exposed materials are highly erodable. Less erodable materials would allow surface vegetation to be established, which would mitigate against subsequent erosion. To minimise the erosion of susceptible materials, or of steep slopes, protection of the surface by sound rock beaching would be

¹ Department of Civil Engineering,
The University of Queensland, QUEENSLAND 4072

required. However, a source of sound rock would need to be readily available. If surface erosion can be controlled by a suitable capping of the waste, it is likely that the contamination of surface water can also be controlled. The control of ground water contamination depends on avoiding the seepage of contaminated water from the waste into the underlying ground.

The minimisation of oxidation of the mine waste materials is essential to the maintenance of acceptable water quality. Materials with a potential to form acids should be separated, selectively disposed of, and either isolated from atmospheric oxygen or treated. In the past, little attention was devoted to separating waste materials with a potential for generating acid mine drainage. In particular, material in coarse reject dumps which readily oxidises, can do so to the base of the dump, and in some cases can ignite, giving off noxious gases. By virtue of their fine grain size and high moisture content, tailings deposits comprising material which readily oxidises, will experience oxidation to only limited depth (the upper 15 cm, or so).

3. ECONOMIC IMPLICATIONS

It has been recognised that the future liability of past coal mine waste disposal practices in Australia, involving difficult to rehabilitate wet tailings deposits and potentially environmentally unacceptable coarse waste dumping, could force the premature closure of otherwise economically viable coal mines. Even without this future liability, conventional man-made tailings dams are expensive to construct, wet

tailings deposits occupy large areas of land, and such deposits can be expensive to rehabilitate. Coal mine waste disposal and storage options must be developed which meet enhanced environmental standards aimed at ensuring sustainable mining development, while minimising the initial, ongoing maintenance, and future rehabilitation costs involved.

4. CURRENT DISPOSAL PRACTICES

Conventionally, the tailings are thickened and then pumped as an aqueous slurry at a solids concentration of about 30% by weight to a storage, where they form a "wet" deposit. The tailings undergo beaching, sedimentation, self-weight consolidation, and crusting if desiccation of the surface occurs. A delta with an average slope of only about 1 in 100 is formed, with some hydraulic sorting of particles taking place down the delta. With increasing distance down the delta from the highest point, (about 5 m beyond the discharge point) particles of finer grain size are deposited. Figure 1 shows this effect for the delta formed in the Main Tailings Dam at Aberdare Colliery in the Ipswich Coalfields. Also shown in Figure 1 is the input particle size distribution.

A secondary trend is for the specific gravity of deposited particles to decrease with increasing distance down the delta from the highest point (Figure 2). The deposit remains wet because of the fine grain size of the tailings and hence its low permeability, with a thin crust forming where desiccation can occur.

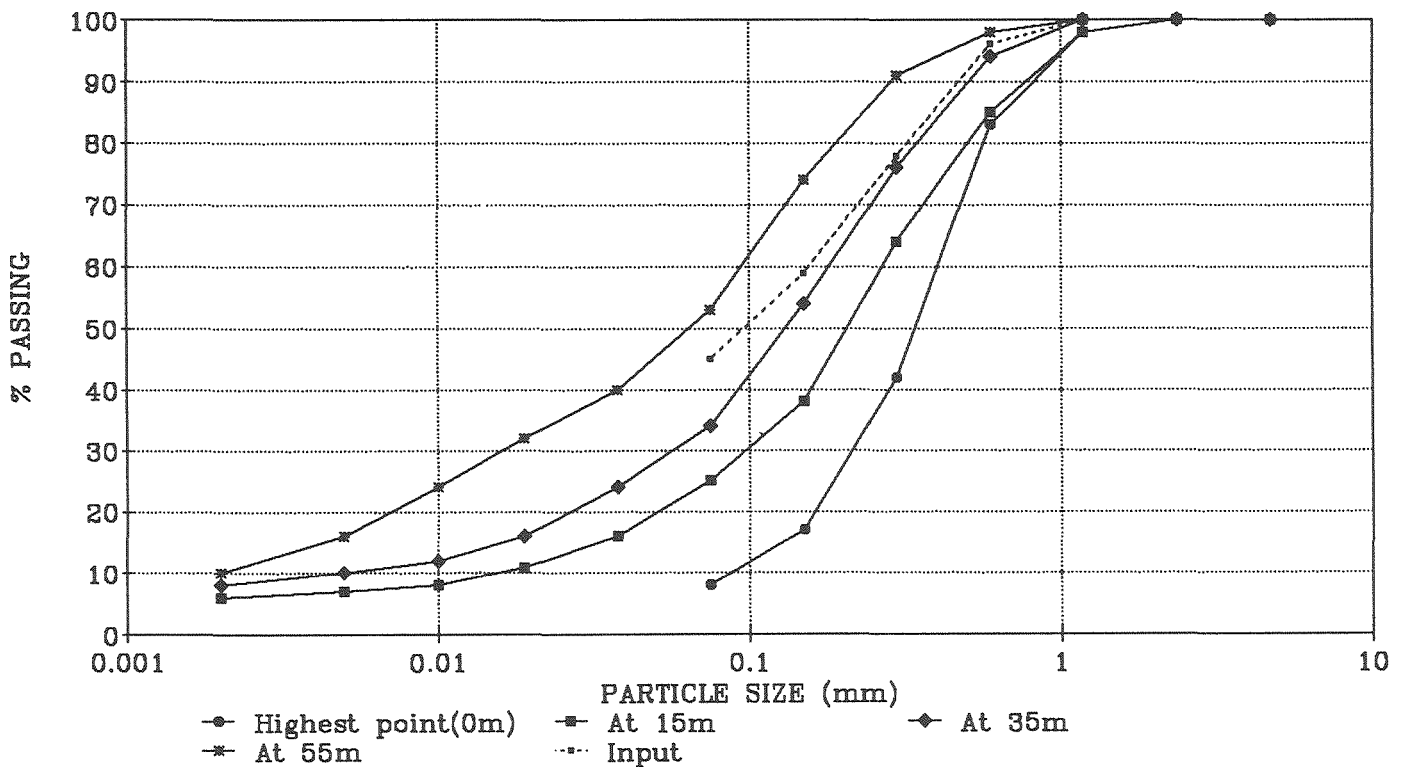


Figure 1: Hydraulic sorting of particles with distance from highest point of Aberdare Colliery Main Tailings Dam delta, Ipswich Coalfields.

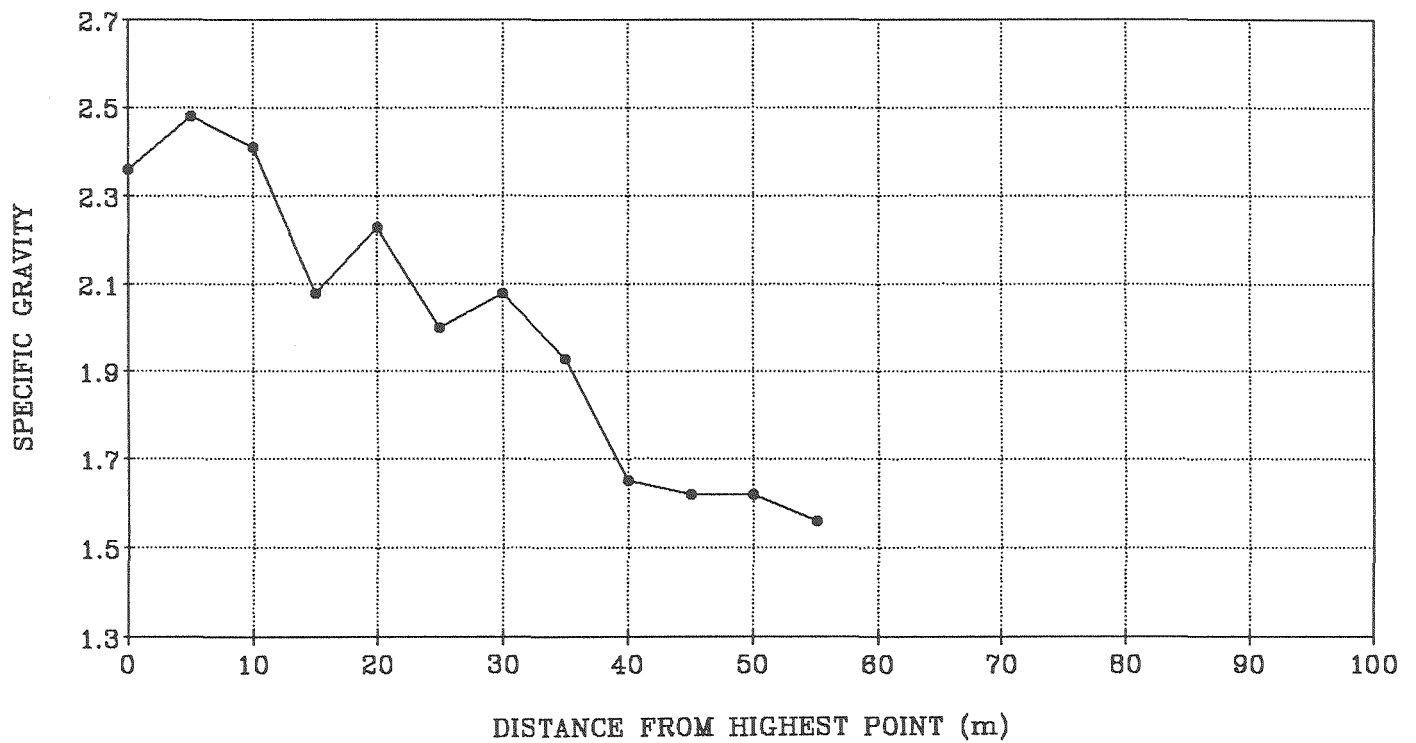


Figure 2: Variation of specific gravity with distance from highest point of Aberdare Colliery Main Tailings Dam delta.

The more sophisticated washeries are capable of separating coal down to about 60 μ m, while the old inefficient washeries may release as tailings the minus 2 mm size. Typically, coal mine tailings comprise 20 to 40% clay size (finer than 2 μ m) and 5 to 30% sand size (coarser than 60 μ m), with the remainder of silt size (2 to 60 μ m). The typical tailings particle size distribution may be described as sandy clayey silt, with about 70% silt and clay size. Tailings typically have a liquid limit in the range 30 to 45% and plasticity index in the range 10 to 25%, indicating a Unified Soil Classification of ML or CL. However, some tailings are non-plastic. The average specific gravity of coal mine tailings is typically in the range 1.7 to 1.8, compared with about 2.7 for mineral matter, indicating that up to 60% coal is present. The undrained shear strength of the tailings is typically about 10 kPa in the soft tailings at depth, with the surface crust of about three times that strength. The tailings have a drained angle of internal friction of about 30° in direct shear and about 28° in triaxial compression. The in situ permeability of the soft tailings at depth is typically of the order of 10^{-7} m.s⁻¹, one or two orders of magnitude higher than indicated by laboratory test results. Due to layering of the deposit, the horizontal permeability is about five times that in the vertical direction.

The problem of dewatering the wet tailings deposit is both relieved to some extent and exacerbated when the surface of the sediment becomes exposed and desiccates. While desiccation results in the formation of a relatively stiff surface crust, the crusting effect persists to only shallow depth, it is largely reversible on re-wetting, and it results in a surface layer of very low permeability despite the presence of desiccation cracks. The very low permeability of the crust (as much as three orders of magnitude lower than that of the underlying soft tailings), inhibits the further dewatering of the underlying tailings.

In response to wet tailings disposal becoming less acceptable, the Australian coal mining industry, notably in New South Wales, initially turned to the mechanical dewatering of the thickened tailings. Centrifuges were first used for this purpose. These achieved a substantial increase in the solids concentration of the tailings. However, the consistency produced was not amenable to transportation by conveyor or truck, nor to pumping. Belt press filters have been used with greater success. They can produce a filter cake capable of transportation by conveyor or truck, and the feed may readily be combined with the coarse reject in dumps. Mechanical dewatering carries a number of technical problems, among them allowing for the variable input feed, assessing the potential for and the consequences of the filter cake re-wetting in the dump, flattening the dump slope to an angle acceptable in the long term, and the choice of an appropriate surface treatment. However, also working against mechanical dewatering is that it is extremely expensive, particularly in flocculants. The cost of the flocculant required can amount to \$1 to 2 per tonne of coal produced, depending on the proportion of tailings.

Another approach has been to dispose of tailings slurry within the valleys formed between successive overburden (spoil) piles within the pit, and to subsequently cover the desiccated tailings with spoil. In covering the desiccated tailings, sufficient fill must be placed to enable safe access for construction plant. However, the addition of too much fill can cause "bow wave" failures if the bearing capacity of the crust is exceeded. If mixing of the tailings and spoil is desired, spoil must be placed before crusting of the tailings surface. Technical difficulties associated with storing tailings slurry within spoil pile valleys include the seepage of tailings water into the spoil and its impact on the overall water balance, on spoil pile stability, on inflows into the pit, and on the ground water.

5. CO-DISPOSAL

A promising new coal mine washery waste disposal technique has emerged which involves the co-disposal of coarse reject and tailings slurry by combined pumping. This technique is employed at Jeebropilly Mine in the Ipswich Coalfields. The mixture has greatly enhanced engineering properties over those of tailings only, and there is potential to form a self-supporting elevated landform on disposal of the mixture. The formation of an elevated landform would obviate the need for a substantial containment structure. A catch drain and small dam would serve to collect the water emanating from the mixture. The inclusion of tailings with the coarse reject may also lead to a reduction of any oxidation of the coarser particles. The combined coarse reject and tailings slurry is far more permeable (by 3 or 4 orders of magnitude) than tailings only, and therefore settles out rapidly to form a mixture of reasonable engineering properties. It achieves an average surface slope of about 1 in 15 (compared with about 1 in 100 for tailings only), which may be suitable as a final landform, obviating the need for expensive rehandling of the waste material.

The delta which forms on co-disposal is immediately trafficable. Particle sorting on the surface of the delta formed at Jeebropilly Mine exhibits a significant trend of increasing particle size with increasing distance down the delta from the discharge point (Figure 3, obtained by dry sieving since considerable fines attach themselves to the coarse particles depositing on the delta). Also shown in Figure 3 is the input particle size distribution (pipe sample). The particle size distribution on the delta is everywhere finer than that input due to breakdown of the material on exposure. The explanation for

the apparent anomaly of increasing particle size down the delta is the variation in the specific gravity of the particles deposited down the delta (Figure 4). Close to the discharge point (10 m), there is little variation of specific gravity with varying particle size, and the specific gravity is relatively high, at about 2.2. Towards the pond (90 m), the specific gravity of the deposited particles is much reduced and decreases significantly with increasing particle size.

The particle size distributions of samples recovered from 500 mm beneath the surface of the delta are reasonably uniform with distance down the delta from the discharge point (Figure 5, obtained by dry sieving). This is attributed to the infilling of the voids between the coarse particles deposited towards the pond with segregated fines. Other fines are carried as wash load to the pond.

At Jeebropilly Mine, the solids concentration at which the combined wastes are pumped averages 30% by weight. While a high proportion of the fines attach themselves to the coarse particles deposited on the delta, a substantial proportion of the tailings together with fines produced by material breakdown on the delta, find their way to the pond, where they sediment out. The segregation of fines could be substantially reduced by pumping the mixture at a higher solids concentration and at lower velocity. Segregation would also be reduced by increasing the length of flow over the delta. Meandering bunds could be constructed to achieve this by pushing up deposited material on the delta. The location of the pipe discharge point could also be varied to considerable advantage.

There is a need to establish what proportion of tailings can be

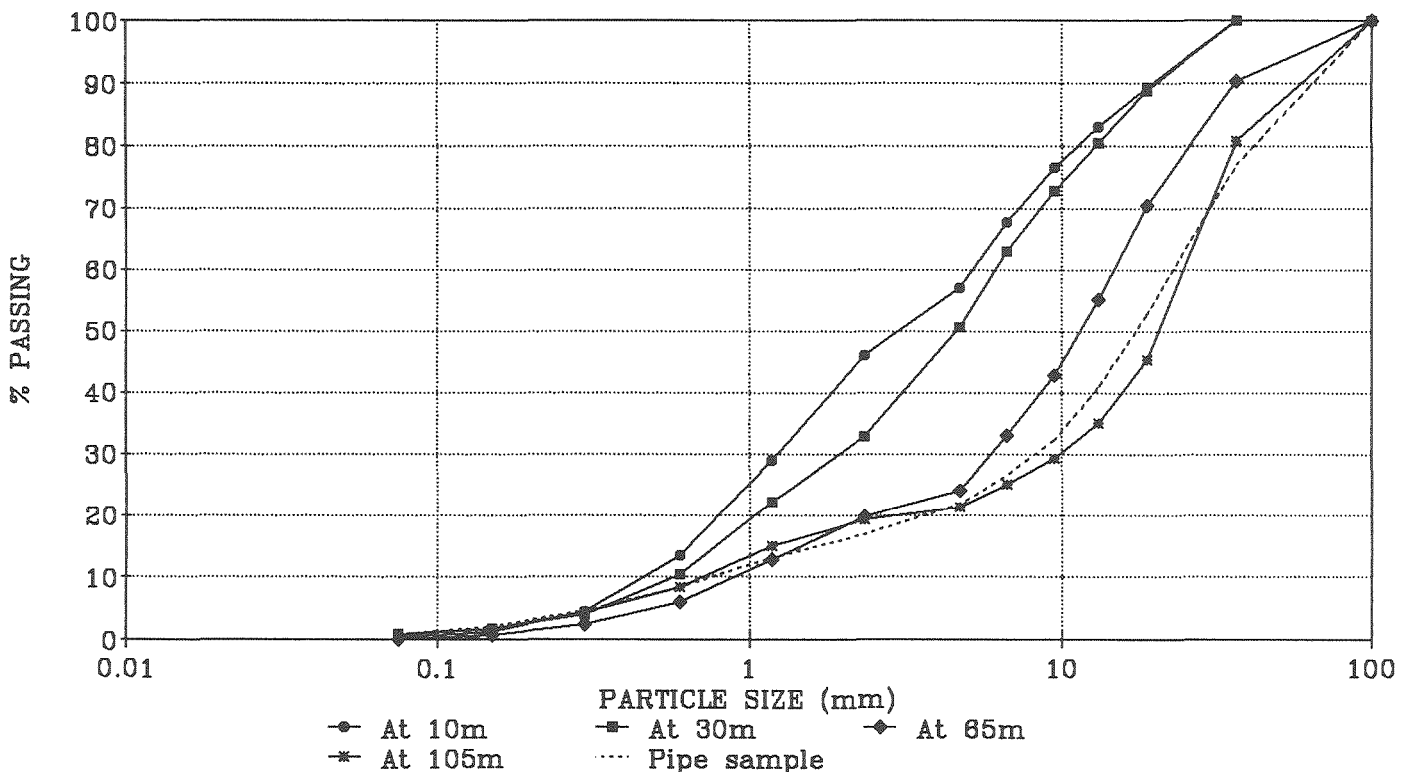


Figure 3: Hydraulic sorting of particles with distance from discharge point on surface of co-disposal delta at Jeebropilly Mine, Ipswich Coalfields.

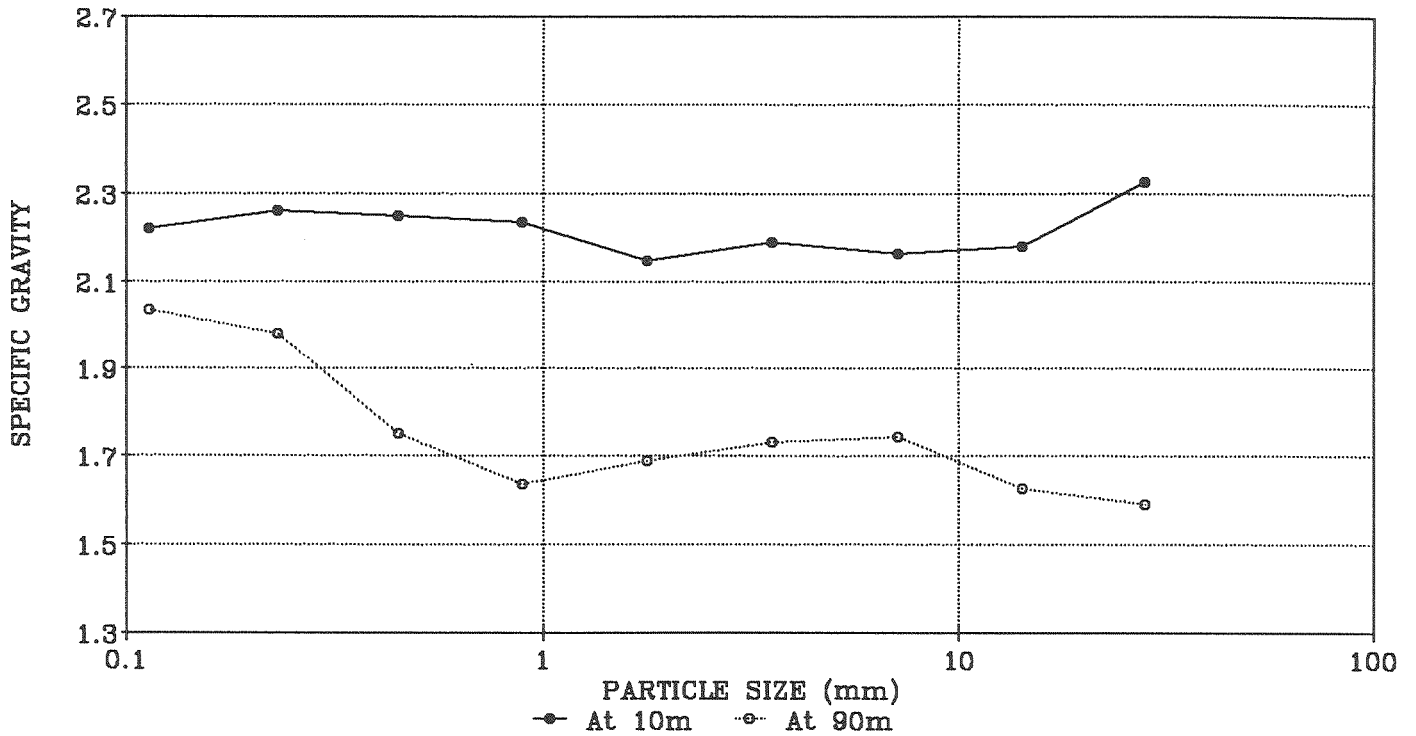


Figure 4: Variation of specific gravity with particle size and distance from discharge point for surface samples from co-disposal delta at Jeebropilly Mine.

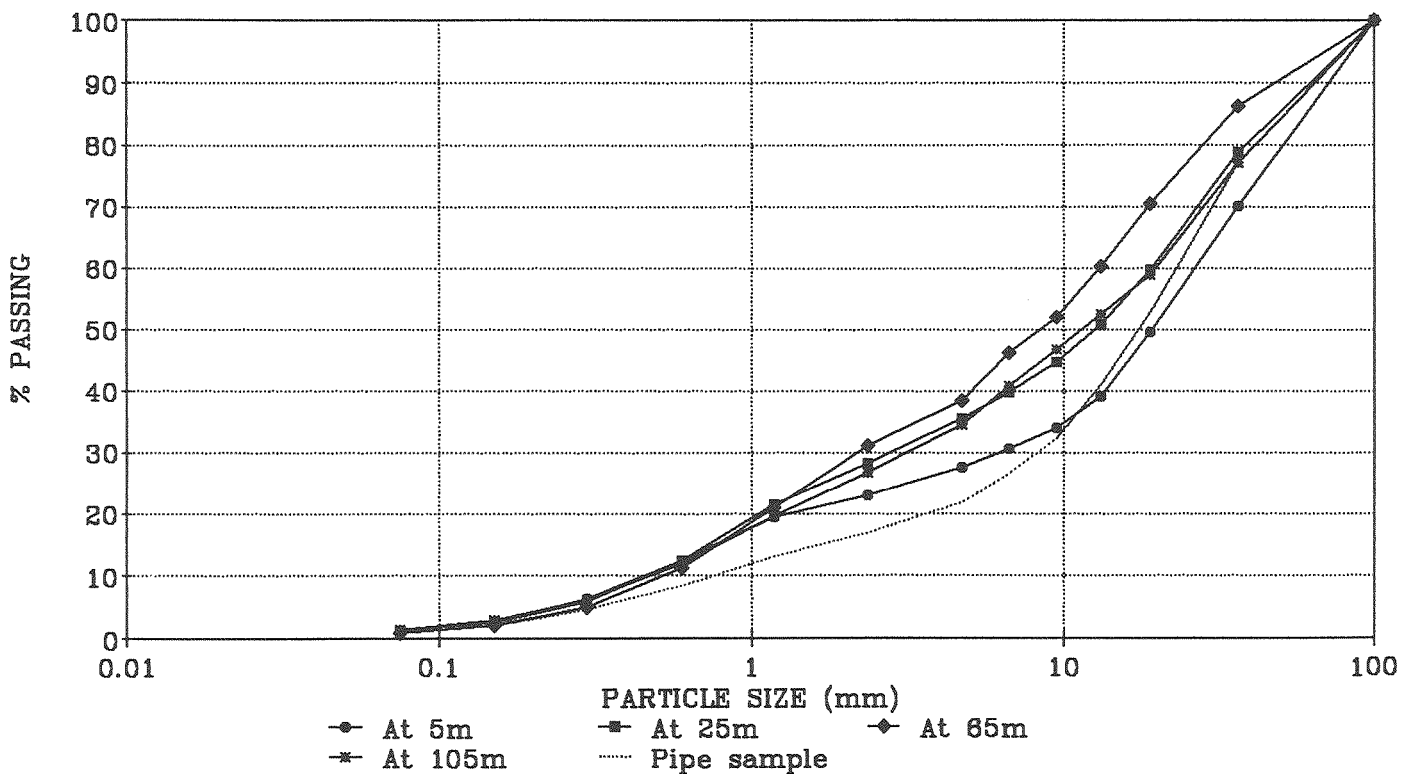


Figure 5: Hydraulic sorting of particles with distance from discharge point 500mm beneath surface of co-disposal delta at Jeebropilly Mine

accommodated within the pore space between the coarse reject, since a high proportion of tailings is a feature of some mines. An acceptable shape for the final landform must be defined, and the choice of an appropriate surface treatment made. The technique of co-disposal remains to be proven for other washery waste materials at other mine sites. As conditions vary between coal mines, and even at the one coal mine over time, the need for other alternatives should not be discounted at this stage.

6. CONCLUSIONS

Coal mine washery waste disposal and storage options must be developed which meet enhanced environmental standards aimed at ensuring sustainable mining development, while minimising the initial, ongoing maintenance, and future rehabilitation costs involved. The co-disposal option, involving the combined pumping of coarse reject and tailings slurry, ideally to an elevated landform, offers the best potential technically, economically, and environmentally. It remains to carry out the research necessary to optimise this technique and ensure its successful application at a range of coal mines having different washery waste materials and conditions. Application of the technique to mining operations other than coal may also be possible.

In order that the mining industry not forfeit the potential to exploit mineral resources, it must demonstrate that sustainable mining development is possible, compatible with community environmental expectations and the very real need to protect the environment. The key issue is the need for the engineered disposal of mining wastes to ensure that the environment is protected. Mining in the past has focused on the short term imperative of a "contain and forget" approach to that non-productive side of mining activity involving the handling of the wastes produced. Successful engineered mine waste disposal and rehabilitation removes a potential future liability, which is threatening the viability of many existing mines.

7. ACKNOWLEDGMENTS

The research on which this paper is based was carried out under National Energy Research, Development and Demonstration Council Project #1264, which was completed in March 1992. The co-operation of the managements of Aberdare Colliery and New Hope Corporation Ltd, owner of Jeebropilly Mine, in allowing access to their mines for sampling and testing of washery waste materials is appreciated. The assistance of Dr Peter Morris, V. Kuganathan and Peter McMillan of The University of Queensland, in the collection of data included in this paper, is gratefully appreciated.