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Pillara Mine closure and rehabilitation

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Abstract

Detailed planning and diligent management were critical to the successful mine closure and rehabilitation of Lennard Shelf's Pillara operations. Rehabilitation works commenced during the second half of 2009 and were completed, on schedule and under budget, in October 2010. Remarkably the rehabilitation of Pillara was entirely funded by the in-house sale of the mine's assets.

The benign, non-acid forming (NAF) nature of the tailings, in combination with geochemical data, led to the design of a three layer cover. An initial layer of limestone waste rock was covered with subsoil and vegetated topsoil to achieve a final cover depth between 475 and 575 mm. Erosion barriers of waste rock were also constructed along the contours of the tailing storage facility (TSF) to direct water to appropriate drainage channels. The TSF cover design was adapted to suit the remaining areas of the Pillara mine site, as required.

Aerial photos taken at the end of the 2010/2011 wet season demonstrate significant vegetation growth over the TSF, box-cut and process plant areas. Monitoring of the site continues and initial results are positive. Lennard Shelf is working closely with the Department of Mines and Petroleum (DMP) towards proving the rehabilitation outcome and achieving a bond reduction.

1 Introduction

The rehabilitation of Pillara operations is an example of how detailed planning and careful project management can lead to a successful mine closure. In July 2008 the operator, Lennard Shelf Pty Ltd, submitted a suspension plan to the Department of Mines and Petroleum (DMP) (Lennard Shelf Pty Ltd, 2008c) detailing the closure and placement of operations into care and maintenance. A rehabilitation plan detailing the processes of land reclamation was finalised in December 2008 after an extensive sampling programme and geochemical and engineering studies. The rehabilitation works at Pillara mine site were completed according to schedule and under budget in October 2010. A rehabilitation monitoring plan was finalised in December 2010 and subsequently approved by the DMP (MBS Environmental, 2010).

1.1 Project setting

Pillara is located in the West Kimberley region of Western Australia approximately 25 km southeast of Fitzroy Crossing. The Pillara operations comprised of underground mining of lead/zinc ore and a 2.4 million tonne per annum (mtpa) beneficiation plant. The lead/zinc concentrate was transported 300 km east to the port of Derby, where it was shipped to international markets. The tailings were transferred to a centrally thickened discharge tailing storage facility (TSF) located 2 km from the beneficiation plant.

The mineralisation of the Pillara ore is a Mississippi Valley Type (MVT) deposit situated within middle and upper Devonian aged limestones and dolomites, which form part of the Lennard Shelf carbonate complex. The waste rock is non-acid forming (NAF) with high acid neutralising capacity (ANC) resulting in a tailings material predominately NAF and environmentally benign (Lennard Shelf Pty Ltd, 2008b).

The Pillara mine site is situated between two landscapes classified as limestone hills and gently sloping plains. Typical vegetation includes small trees, shrubs and spinifex grasses. Soil types include hard-setting gravelly soil, loamy soils and clays. These habitats support a range of mammals, birds, reptile and amphibians.

The region experiences a monsoonal summer and a dry winter. The monsoonal summer (wet season) extends from November to April and brings most of the annual rainfall to the region via thunderstorms and tropical cyclones that occur between December and March. The mean annual rainfall is 710 mm over 36 rain days

per year and maximum temperatures range from 40.6°C (November) to 29.6°C (July) (Lennard Shelf Pty Ltd, 2008a).

2 Development of the rehabilitation plan

A rehabilitation plan for the Pillara mine site and TSF was initiated in early 2008 then finalised and submitted to the DMP in December 2008 (MBS Environmental, 2008). The plan was based on the results of an extensive geochemical sampling programme and TSF rehabilitation trial.

The objectives of the rehabilitation plan were to:

- Identify landforms, surfaces and structures that needed to be rehabilitated.
- Identify procedures for the removal or burial in situ of all remaining infrastructure.
- Outline procedures for the restoration of all surfaces affected by the Pillara mining operation.
- Outline procedures for the appropriate removal of soils impacted by lead, zinc and hydrocarbons.
- Outline procedures for the establishment of a self-sustaining vegetative cover on all restored surfaces, similar in composition to the surrounding landscape.
- Outline a timeline for achieving the various rehabilitation tasks.
- Establish criteria to assess rehabilitation progress and completion.

As part of the rehabilitation plan a detailed materials balance was completed across the entire mine site to ensure sufficient rock and soil was available to cover the areas highlighted for rehabilitation. Borrow pits were constructed to provide subsoil and supplement existing topsoil stockpiles. A detailed sampling programme was undertaken to select borrow pit locations with the most suitable subsoil. The seed material in the old topsoil stockpiles was found to be viable despite being stockpiled in 1997. Waste rock (mullock) was sourced from the Pillara waste dump, ROM and hardstand areas.

In order to fund the rehabilitation works, the mine's assets including the processing plant were marketed for sale on an individual basis. The sale of assets was undertaken in-house and Lennard Shelf engaged in aggressive marketing techniques to achieve the highest possible returns. Items that could not be sold or transferred were ultimately buried in the boxcut, landfill site or selected borrow pits.

Throughout the mine closure and rehabilitation planning process open communication in the form of one-on-one meetings were maintained with the land stakeholders. These stakeholders included the Shire of Derby West Kimberley, the traditional Gooniyandi people and pastoral land owner Gogo Station.

2.1 Geochemical sampling

A detailed geochemical study of the Pillara TSF was commissioned in late 2008 (MBS Environmental, 2009). The study included the potential for capillary rise of salts and contaminants, prediction of water quality and the potential for seepage from the TSF. The following conclusions were made:

- All of the tailings can be classified as NAF and therefore benign.
- Leachate data indicates the tailings are slowly becoming less saline, with slightly alkaline pH values and will support plant growth.
- The water mound beneath the tailings surface is at depths below the predicted capillary rise value (Martin, 2004). The capillary rise of salts is extremely unlikely to occur as the level of the water mound lowers over time.

A rehabilitation trial on the TSF was commenced in August 2008 to assist in selection of a suitable TSF cover. Materials selected for the trial TSF cover were waste rock, subsoil and vegetated topsoil. Waste rock (limestone) had been used to construct the ROM, crushed ore pad, hardstand areas, and bunds, while the surplus was stockpiled on the waste dump. Lennard Shelf intended to use this limestone rock as a subgrade layer to the TSF cover and to form contour ridges and spillways. These wastes were sampled and found to be NAF with low concentrations of salts, sulphate or heavy metals (MBS Environmental, 2009).

Lennard Shelf utilised their knowledge and experience from a previous successful rehabilitation at nearby Cadjebut and revisited the site to examine the progress of the TSF cover. With this knowledge and experience, combined with the geochemical and physical properties of the Pillara tailings, the following assumptions were made in developing the trial cover design:

- Growth medium – The minimum thickness of the combined subsoil / topsoil cover required was 250 mm to provide a sufficient growth medium for spinifex, other grasses and shallow rooted species.
- Capillary rise – The maximum capillary rise for the tailings was estimated (Martin, 2004) to be about 1.7 m which was less than the depth to saturation (greater than 2 m below the tailings surface).
- Diurnal concentration – Diurnal hot day time / cool night time temperature / humidity changes would concentrate soluble components in the top 50 to 150 mm of soil or tailings during the dry seasons, but any concentrations other than relatively insoluble products such as gypsum would be largely flushed during a normal wet season.

A trial area was located adjacent to the discharge ramp and covering an area of approximately 3 ha. Three zones were prepared with alternative cover designs consisting of the different rock/soil ratios shown in Figure 1.

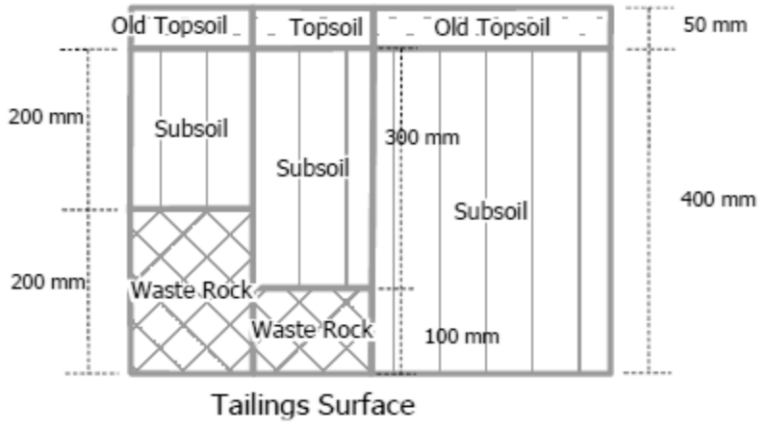

Figure 1 Trial TSF cover designs over three zones (MBS Environmental, 2009)

The results of the TSF rehabilitation trial indicated that all of the three trial covers met the rehabilitation requirements. The inclusion of the 200 mm waste rock cover as a subgrade layer was considered the most robust defence against erosion compared with a subsoil only cover plus this minimised the quantity of subsoil required, whilst utilising waste rock from other areas of the mine site (ROM, hardstand areas and waste dump).

A risk assessment of the TSF rehabilitation was also completed in 2010 with the purpose to identify contaminants of concern, potential environmental receptors and exposure pathways (MBS Environmental, 2010). The risk assessment combined with extensive sampling and geochemical testwork were crucial to the development of the final rehabilitation plan.

2.2 Timeline

The proposed programme for the rehabilitation of the Pillara mine site and associated TSF was consolidated into four stages:

- Stage 1: Preliminaries and clean-up.
- Stage 2: Infrastructure removal.
- Stage 3: Rehabilitation earthworks.
- Stage 4: Monitoring.

Table 1 Programme for the rehabilitation of the Pillara mine site

Stage	Works	Date Commenced	Date Completed
Stage 1	Preliminaries and clean-up	October 2008	January 2010
Stage 2	Infrastructure removal	January 2010	July 2010
Stage 3	Rehabilitation earthworks	April 2010	October 2010
Stage 4	Monitoring	October 2011	Ongoing

Preliminary rehabilitation tasks were scheduled to commence in 2009 and included the consolidation of scrap, bioremediation of hydrocarbon impacted soils, general tidying up and arranging for the sale and salvage of mine site assets. Rehabilitation earthworks (Stage 3) were scheduled to coincide with the dry season to minimise delays and impacts resulting from monsoonal storm events. The rehabilitation of the Pillara mine site mining operations was interdependent on the rehabilitation of the TSF. Significant volumes of material were to be transferred from the mine site mining operations to the surface of the TSF, however, a sufficient drying period was required before earthworks could commence on its surface. Subject to the sale and transfer of mine site assets the rehabilitation of the mine site, as well as the TSF, was scheduled to be completed during 2010.

Stages 1 and 2 were largely completed in-house prior to the end of the 2009/2010 wet season. The thorough preparation of the site allowed the earthwork contractor to commence rehabilitation works on schedule.

The rehabilitation earthworks of the TSF were completed over the 2010 dry season as a series of phased tasks (Lennard Shelf Pty Ltd, 2009):

- Phase 1: Lowering/ reshaping of the access ramp and construction of the TSF cover from the upper slopes progressively down towards the lower slopes.
- Phase 2: Removal of the sediment stockpile with infilling and re-landscaping of the low lying eastern TSF perimeter in conjunction with construction of the perimeter tailings surface cover and southern and eastern perimeter drainage.
- Phase 3: Infilling of the low lying first detention pond (No.1) with tailings from drain excavation and sediment removed from the second detention pond (No.2) in conjunction with construction of the northern perimeter drainage and spillways.
- Phase 4: Rehabilitation of borrow pits and exposed topsoil surfaces and other minor works.

3 Rehabilitation processes

The majority of assets were sold and removed from site during 2009 with the processing plant dismantled and removed during the first half of 2010. The rehabilitation earthworks commenced in April 2010 and were completed on schedule in October 2010, despite some rain delays.

3.1 TSF

For the long term success of the TSF rehabilitation it is critical that the landform remains stable and is able to cope with the monsoonal rainfall events common to the area. To achieve this, the design criterion was based on a one-in-one hundred year rain event (1:100 ARI). A key aspect of the TSF design was the construction of drainage control breaks and erosion barriers. This was achieved by placing barriers of limestone waste rock along the TSF surface contours to direct water to appropriate drainage channels (Figure 2). The rock barriers were approximately five metres wide and nominally spaced every 100 m, they also served as temporary access tracks during the rehabilitation and monitoring process (Lennard Shelf Pty Ltd, 2009).

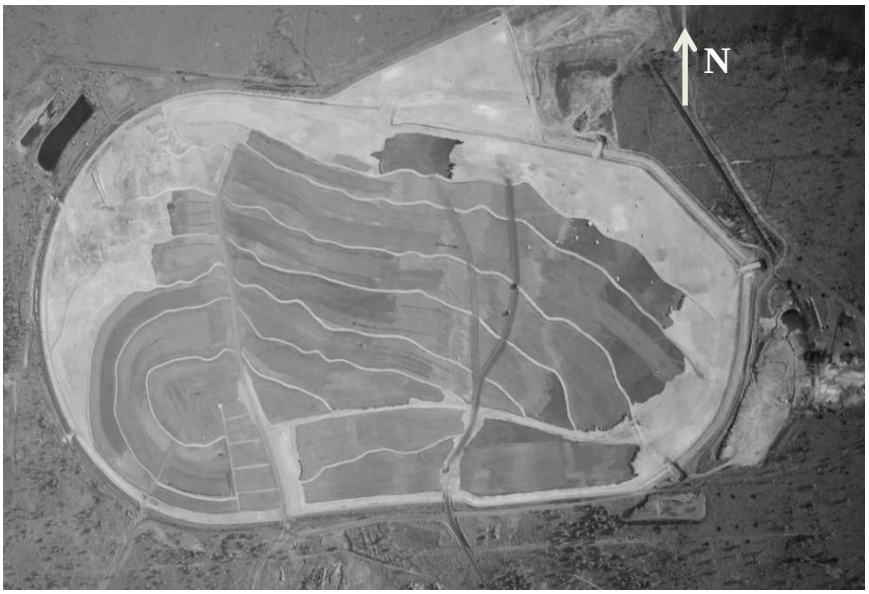

Figure 2 Aerial photo of Pillara TSF showing rock barrier contours

Three layer designs were selected for the TSF cover as determined by the TSF trials and geochemical studies. The initial layer of limestone waste rock was covered with subsoil and graded prior to spreading of the vegetated topsoil. The final topsoil was lightly scarified along the contour to mix topsoil and subsoil and prevent erosion of the surface during heavy rainfall and rectify compaction from earthworking equipment.

The TSF surface was sub-divided into cover zones based on tailings surface landform and beaching angles. The cover thickness and soil/waste rock mix composition varied according to these cover zones to optimise tailings surface cover stability and erosion control (Table 2).

Table 2 Final TSF cover design specification (MBS Environmental, 2009)

Zone	Area (Ha)	Beach Angles	Waste Rock/Soil Cover Composition (mm)			Cover Thickness (mm)
			Waste Rock	Subsoil	Topsoil	
Upper slope	18.0	1.5–2%	200	200	75	475
Mid slope	32.9	1.0–1.5%	300	200	75	575
Lower slope	44.4	0.75–1.0%	200	200	75	475
Perimeter	26.1	0.50–0.75%	100	300	75	475
Southern	11.4	0.5–1.0%	100	300	75	475

During the rehabilitation process, an area of the TSF, approximately 45,000 m^2, was identified as abnormally wet. These tailings were traced back to a time during operation when the processing plant was producing poorly thickened tailings. The high slimes content in the tailings meant that the area was unlikely to dry within the rehabilitation timeline allowance. A fourth cover type was selected with an increased rock depth of 400 mm to accommodate the ongoing settlement process.

3.2 Mining area

The TSF cover design was adapted to suit the remaining areas of the Pillara mine site. The mining area comprised of the decline, box-cut, heavy machinery workshops, refuelling facilities and the administration offices. Hydrocarbon contaminated soil was removed from all areas and treated on-site by bioremediation. The remediated soil was used as fill for the box-cut.

The decline was allowed to flood and the box-cut void filled using general waste from around the site such as concrete rubble, piping, remediated soil and other waste. This bulk waste was covered with 800 mm of waste rock prior to 300 mm of subsoil and a final layer of 200 mm of topsoil (MBS Environmental, 2008). The depth of these layers eliminated the need to line the box-cut void. The resulting landform was then shaped and ripped to form a gentle sloping mound. The elevation of the rehabilitated box-cut is intended to prevent water run-off from pooling on, or near the box-cut.

3.3 Processing plant area

The processing plant area included the crusher, crushed ore stockpile, beneficiation plant and concentrate storage shed. Prior to rehabilitation a detailed sampling programme was commissioned to identify areas of soil contaminated with hydrocarbons and heavy metals. All hydrocarbon contaminated soil was treated by bioremediation while soil contaminated with heavy metals was removed to the TSF. During the dismantling and cleaning process surface contaminants were monitored and were removed and disposed of into the TSF, prior to the placement of any subsoils.

The plant infrastructure was dismantled and removed by the buyer in early 2010 and the site cleaned and prepared for rehabilitation earthworks. The remaining small concrete plinths and concrete floor areas were removed and buried with contaminated soil in the TSF. The larger plinths and concrete floors that housed parts of the plant such as the Ball and SAG Mills were, due to their size, approved by the DMP to be left in place. These were cleaned, then left in situ, the floors had holes strategically drilled into them to allow for drainage and then were covered with subsoil material, shaped and ripped to achieve a stable free draining landform as per the rehabilitation plan (MBS Environmental, 2008).

The concentrate storage shed was dismantled and the remaining concrete structural walls were cleaned and deemed suitable by an engineer to use as covers for the seven ventilation and escape shafts around the mine The floor was then cleaned, drilled for drainage then subsoil placed and the area was shaped then ripped.

4 Rehabilitation outcomes

Completion criteria were established in the Pillara rehabilitation plan to enable progressive assessment, and ultimately demonstrate successful rehabilitation. The overall rehabilitation objective of the Pillara Rehabilitation Plan was to establish a safe, stable environment with a self-sustaining and resilient vegetative cover similar in species richness and density to the surrounding landscape to meet an agreed post mining land use (Lennard Shelf Pty Ltd, 2010).

In addition to ongoing monitoring an independent audit of the site was completed under the Contaminated Sites legislation of the Environmental Protection Authority (EPA). At the time of writing this audit was in progress.

Throughout the mine closure and rehabilitation Lennard Shelf took a proactive approach to communications with relevant stakeholders and government departments. Relationships have been maintained and feedback positive.

4.1 Monitoring

Rehabilitation progress at Pillara continues to be assessed, following completion of rehabilitation activities. A rehabilitation monitoring plan (Lennard Shelf Pty Ltd, 2010) has been approved by the DMP, but a final timeframe for the conclusion of monitoring is still to be determined by the DMP. Two key indicators will be measured post rehabilitation; vegetation establishment and survival, and erosion. The success of vegetation establishment and survival will be determined by comparison with similar vegetation communities in the surrounding grassland. Erosion monitoring of the area will be via visual monitoring and rill surveys. Should erosion occur at an unacceptable rate (greater than 50 mm movement per month), appropriate remedial measures will be implemented, with particular emphasis on removing the cause of erosion.

Ground water monitoring has historically been conducted to comply with existing environmental and water licences. Numerous test bores are located within the vicinity of the TSF and will continued to be monitored quarterly in conjunction with surface water quality in the borrow pits and sediment traps installed. The rehabilitation water quality requirements are outlined in Table 3. Initial observations also indicate that

ground water levels within the mine have returned to normal and discharge has occurred as planned from the northern vent rise into a previously used mine de-watering route and wetlands.

Table 3 Ground water monitoring analytes (Lennard Shelf Pty Ltd, 2010)

Analyte	Trigger Level	Reference
ph	6.5–8.5	Licence criteria
TDS	5,000 mg/L	Licence criteria
TSS	80 mg/L	
Fluoride	2 mg/L	ANZL guidelines for fresh and marine water quality for livestock drinking
Arsenic	0.007 mg/L	Licence criteria
Cadmium	0.002 mg/L	Licence criteria
Copper	2 mg/L	Licence criteria
Lead	0.1 mg/L	ANZL guidelines for fresh and marine water quality for livestock drinking
Zinc	3 mg/L	Licence criteria
Thallium	0.8 µg/L	Canadian water quality guidelines for protection of aquatic life

In addition to ground level monitoring Lennard Shelf has undertaken regular aerial inspections of the site to collect photographic evidence to support their claims of rehabilitation progress. Aerial photos taken at the end of the 2010/2011 wet season demonstrate significant vegetation growth over the TSF, box-cut and process plant areas. These visual results have been confirmed by ongoing vegetation surveys.

5 Conclusion

The rehabilitation outcomes of Pillara mine site in Western Australia have resulted from an extensive sampling programme and detailed planning. Through hands-on management Lennard Shelf was able to fund the Pillara rehabilitation from the sale of mine assets. The rehabilitation works were completed according to schedule and under budget in October 2010. Monitoring of the site continues and initial vegetation results are positive. Throughout the closure and rehabilitation process Lennard Shelf took a proactive approach to communication with relevant government regulators and is working closely with the DMP towards proving the rehabilitation outcome and achieving a bond reduction.

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