However, unless the delta were submerged or otherwise isolated from the atmosphere, oxidation would continue and metals and acidity would continue to enter the harbour. The visual pollution resulting from the presence of the delta would not be addressed by this approach either.

Unless the water quality coming off the lease site were first improved, diverting the river mouth would also divert toxic plumes into a different area of the harbour, with unknown consequences.

'High-tech' solutions, such as electrical fusion which would anneal the tailings into a more stable glass, are practical for small volume, highly dangerous wastes (such as nuclear wastes), but are economically prohibitive on a 'delta-sized' problem.

## 6.5 Remediation options for Macquarie Harbour

### 6.5.1 Do nothing

The 'do nothing' option for Macquarie Harbour will lead to an improvement in water quality if pollutant emissions from the lease site are substantially reduced. Water quality in the harbour rapidly reflects inputs from the King River (Koehnken 1996) so improving lease site emissions will improve the harbour. Similarly, since approximately 85% of the dissolved copper entering the harbour remains dissolved and ultimately exits the harbour, a reduction in lease site emissions will reduce copper inputs to coastal waters, and prevent further accumulation of copper in the harbour sediments.

If lease site emissions are not reduced, then no significant improvement in the water quality of Macquarie Harbour can be expected.

### 6.5.2 Dredge the most contaminated sediments

The sediments in the northern harbour have been identified as actively releasing metals to the water column. If this material were removed, presumably metal inputs to the water column would be reduced. However the great volume of sediments in the northern harbour (>100 $Mm^3$, Koehnken 1996) make this a highly expensive option, and one that would result in very little change in water quality unless all emissions from the lease site were eliminated. In addition to cost, the issue of a 'safe' disposal site and pollutant plumes associated with dredging operations would need to be resolved.

### 6.5.3 Capping contaminated sediments

Capping the most contaminated sediments in the harbour with a 'clean' layer of material such as clay, would reduce metal release to the water column without requiring the movement of the sediments. However, the costs associated with identifying, transporting and placing a suitable capping material have rendered this option not feasible (Guidici et al 1996).

# 7 Recommended remediation options

## 7.1 Objective of remediation strategy

The long-term objective of the remediation strategy is to ultimately achieve the environmental quality objectives set for the rivers and harbour (see section 5.7). Because the MLRRDP has overwhelmingly identified the lease site as the major source of contaminants, the remediation of the lease site to reduce the amount of acid drainage leaving it has been identified as the top priority of the remediation strategy. As summarised in this report, in order to achieve the downstream EQOs in the King River and Macquarie Harbour, approximately 99% of acid drainage emanating from the lease site must be eliminated. This is demonstrated in figure 7.1 which depicts the required reduction in copper concentrations in the lower King River before recovery of a modified ecosystem could be expected. Unfortunately, even this level of remediation is not predicted to facilitate significant ecological recovery in the Queen River, though it is a step in the right direction.

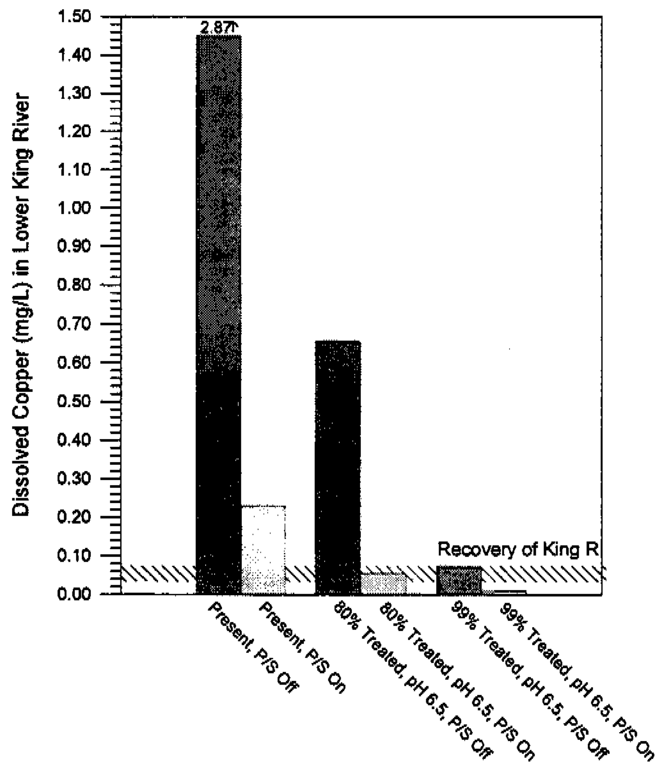


**Figure 7.1** Present and projected dissolved copper concentrations as a function of the percentage of acid drainage treated (neutralised), the final pH of the neutralisation, and power station (P/S) operation, compared with copper concentrations considered by the MLRRDP as required for the recovery of a 'modified ecosystem' in the lower King River

Even the elimination of 99% of the acid drainage from the lease site, however, might not result in 'full recovery' of the King River because the tailings resident in the banks and bed of the King River will continue to be a source of pollutants. It is difficult to predict what impact the tailings input will have on the river once lease site remediation occurs, because the present riverine input is so low compared with the lease site input (generally <1%) that it is difficult to accurately quantify. Additionally, it is not possible to quantify the expected change in overall water quality of the King River because of the reworking and erosion of bank and bed material. However, because acid conditions facilitate the release of metals, an improvement in the King River water quality and raising of the pH would be expected to decrease the input from the tailings.

*Recommendation*

***The major emphasis of any remediation strategy should be the Mount Lyell lease site***

*Recommendation*

***The goal of remediation must be to address virtually 100% of the acid drainage exiting the lease site. Interim measures which are a 'step in the right direction' and are achievable in the short term should be progressed, but must not be viewed as substitutes for the required long-term remediation effort essential for downstream recovery.***

## 7.2 Division of responsibility

Tasmania and Australia would benefit from the remediation of the Mount Lyell lease site. An improvement in water quality would translate into an improvement in social amenity for the region, and considerable economic benefits would be derived from increased tourism in the area and the expansion of aquaculture activity in Macquarie Harbour. Successful remediation would also promote sustainable development and fulfil Australia's international obligation to protect and enhance the natural values of the World Heritage Area through the cessation of pollution entering this sensitive region.

The development and implementation of any successful remediation strategy will have to be consistent with the legal framework which has evolved around the Mount Lyell lease site. Of particular significance is the *Copper Mines of Tasmania Pty. Ltd. Agreement Act 1994,* which defines the commitments of the State Government and CMT with respect to development options, environmental responsibilities, indemnities and royalties (CMT 1995). The CMT Environmental Management Plan (1995) highlighted the following points agreed to in the Act:

- The Act recognises that Mount Lyell is a unique site and that a new operator should not be required to remediate 100 years of pre-existing contamination and pollution.
- CMT is indemnified through the Act for environmental damages caused by any previous occupation or use of the leased land.
- CMT's operation is required to comply with Best Practice Environmental Management (BPEM), but to ensure that CMT is not made indirectly liable for past environmental harm, any environmental regulation must take the impact previous occupation has had on the leased land into account. This is referred to as the 'formulated position' in the Act.

Under the CMT Act, the liability associated with the discharge of acid drainage from the Mount Lyell lease site is assumed by the Tasmanian State Government. Tasmania's Sustainable Development Advisory Council (SDAC), in its deliberations regarding the redevelopment of the mine, has stated that all acid drainage derived from the dewatering of the underground workings should be treated.

The *Mining And Mineral Resources Act 1996* is the second most relevant piece of legislation with respect to remediation of the lease site, in that it establishes CMT's exclusive access to the mineral resources contained on the leased land, *including* dissolved metals in the acid drainage stream, the major focus of remediation. The combination of the CMT Act and the Mining Act results in the situation where the mining company has exclusive access to the dissolved metals in the acid drainage as a mineral resource, yet the State Government is liable for any damage these same dissolved metals may cause once released. The development and implementation of a remediation strategy will have to be negotiated and agreed to by the party responsible for the environmental liability (State Government) and the party with 'exclusive' right to the mineral resource (CMT).

Based on technical and legal considerations, the MLRRDP has concluded that the implementation and management of acid drainage remediation works on the lease site, including any recovery of metals, would be most appropriately coordinated and conducted by CMT, based on a formal agreement with the State and perhaps Commonwealth Governments. The successful development and implementation of a remediation strategy for the lease site will most efficiently be achieved through a high degree of integration with the mining operations which would maximise the use of existing infrastructure, mine site management expertise and hence resources.

Though an integrated approach provides the most transparent mechanism for remediation, there may be circumstances under which the present lease holder is unable or not willing to pursue remediation measures within an acceptable time frame. If this situation arises, the State Government should negotiate an agreement with the leaseholder which would allow a third party access to the lease and the dissolved metals in the acid drainage. Because CMT has been a very cooperative and proactive partner in the MLRRDP process, it is highly unlikely this situation would arise. However, the MLRRDP has been approached by several groups who have expressed interest in the establishment of a copper recovery system, or trialing new technologies on the lease site. The State Government should be in a position to pursue these 'outside' alternatives if CMT is not willing or able to participate.

*Recommendation*

***Implementation and management of remediation works needs to be based on a negotiated agreement between Governments and the lease occupant recognising the present legal framework within which mining occurs. The agreement must provide a legal, logistical and financial framework within which remediation can proceed.***

## 7.3 Overview of options

The results of the MLRRDP studies indicate that there are two principal remediation options which will achieve the environmental quality objectives. These are the ongoing neutralisation of acid drainage with the subsequent collection of precipitation products and release of clean water to the river; or the permanent removal of acid drainage from the catchment via collection, and discharge, to the ocean using a pipeline. The first option will be referred to as the 'neutralisation option', and the latter as the 'pipeline option'. Each of these options could be preceded by solvent extraction/electro winning (SX/EW), a process which removes copper from the acid drainage streams and produces a saleable product which could generate revenue to offset costs. Recovering the copper is consistent with best practice, as it recovers a resource and converts a waste into an asset. It must be stressed that although an SX/EW plant removes copper, the other contaminants, including aluminium and extreme acidity, remain in the raffinate which continues to have a pH at the most as low as the initial acid drainage. In other words, the SX/EW is not a process which alone would promote the achievement of downstream water quality objectives, although it does greatly reduce copper concentrations in the acid drainage, which has environmental benefits. Its main role is to provide a cash stream, and must be combined with either neutralisation or a pipeline to enhance the water quality in the rivers and harbour.

The neutralisation option, pipeline option and SX/EW technology are described below, including a description of the system, resultant water quality, reliability, environmental impacts, social acceptability issues and associated costs. A comparative discussion of possible configurations of the three follows the individual descriptions, as does a qualitative cost benefit discussion.

### 7.3.1 Consideration of flows and water management

The success of either remediation option in promoting the identified environmental quality objectives is contingent on the system being capable of preventing the release of acid drainage into the riverine environment. For this to be achieved the water flow on the lease site must be fully understood so the infrastructure associated with remediation, pipelines, retention pond(s), plants, etc, is appropriately designed to minimise releases into the environment.

Historically, the flows on the Mount Lyell lease site have not been well quantified. Initial investigations by the MLRRDP identified a median flow of about 225 L/s as an appropriate design flow for remediation works. It was assumed that a remediation option capable of dealing with the median flow coupled with a retention pond with capacity to hold the 95th percentile flow for 24 hours would be suitable. This approach assumed that during very high flows, greater than 400 L/s, the acid drainage would be much more dilute and downstream dilution would further reduce environmental impacts of any 'releases' beyond the designed holding capacity.

Subsequent detailed chemical and flow investigations completed by Imtech (1997) indicate that acid drainage does *not* become substantially more dilute during high flows, and treating the mean flows would only treat about 75% of the copper load and 68% of the acidity associated with lease site acid drainage. This would not be sufficient to achieve the downstream EQOs. Imtech (1997) suggested any remediation option must be capable of treating a flow of up to 450 L/s if the retention pond is to be limited to 35 000 $m^3$.

Additional flow analyses by the HEC (1997), utilising a 4 flow source routing model of the lease site which incorporated a 35 000 $m^3$ retention basin, supported the requirement for a larger plant, and specifically, a plant capable of adjustable flow rates. Adjustable flow rates are required because of the inconsistency of lease site flows. If during periods of low flow, a plant had to be shut down until there was a suitable feed volume in the holding pond to warrant a period of plant operation for 24 hours, the storage capacity of the holding pond would be effectively reduced, and spills would be more likely. Because of this, as demonstrated in table 7.1, a fixed-flow treatment plant of 450 L/s has no advantage over a fixed treatment plant of 350 L/s, with the former spilling 1.9% of the total flow, and the latter only 1.8% based on the available period of flow records (HEC 1997).

**Table 7.1** Results of HEC model runs using actual flow data 02/02/96–27/08/96

| | Adjustable treatment plant flow rates (L/s) | | | | | |
|---|---|---|---|---|---|---|
| | 225 | 250 | 300 | 350 | 400 | 450 |
| Max rate of spill (L/s) | 520 | 780 | 500 | 240 | 235 | 0 |
| Total spill volume ($m^3$) | 670900 | 475900 | 223400 | 96300 | 43500 | 100 |
| Per cent of total flow spilled | 14.2 | 9.6 | 4.0 | 1.5 | 0.6 | 0.001 |

| | Fixed Treatment Plant Flow Rates (L/s) | | | | | |
|---|---|---|---|---|---|---|
| | 225 | 250 | 300 | 350 | 400 | 450 |
| Max rate of spill (L/s) | 510 | 510 | 550 | 420 | 315 | 400 |
| Total spill volume ($m^{3)}$ | 702200 | 517100 | 250900 | 113400 | 72700 | 158000 |
| Per cent of total flow spilled | 14.8 | 10.3 | 4.5 | 1.8 | 1.0 | 1.9 |

Because of the paucity of reliable data, the HEC was limited in the available dataset for flow analyses. However, the model was able to be run over a three-year period based on reduced quality extrapolated data relating flow to rainfall for the area. Results are given in table 7.2.

The results suggest that 1 day of spillage every three years could be expected from a neutralisation system incorporating an adjustable 450 L/s plant and a 35 000 $m^3$ retention pond.

**Table 7.2** Results of HEC model runs on extended period 16/05/93–27/08/96

| | Adjustable plant | | Fixed plant | |
|---|---|---|---|---|
| | 225 L/s | 450 L/s | 225 L/s | 450 L/s |
| Maximum rate of spill (L/s) | 710 | 50 | 670 | 180 |
| Total spill volume ($m^3$) | 2759400 | 4000 | 2877600 | 406400 |
| Percent of total flow spilled | 10.6 | 0.009 | 0.86 | 11.0 |
| Maximum continuous spill times (days) | 23 | 1 | 17 | 5 |

*Water management infrastructure*

In addition to appropriate sized plants and holding pond(s), lease site water management must include the minimisation of the acid drainage produced through the diversion of all clean water sources. This will not only minimise the volume which requires treatment or storage, but will maximise copper concentrations in the contaminated water streams which is important for the successful implementation of SX/EW technology.

As discussed above, it must be expected that under some conditions, some spillage of acid drainage will occur. For this reason, it is desirable to develop a water management system which is capable of diverting specific flows out of the treatment system under extreme situations. Ideally the identified flows would be the least contaminated of the acid drainage sources. This would allow for the collection of the most contaminated sources in the retention pond during a large event or in the case of technical failure of the remediation technology, and would insure that the polluted water released down stream would require minimum dilution from other water sources to obtain an acceptable water quality. It is unknown how much the required infrastructure to achieve this might cost, but an allowance of at least \$1 million should be considered. The cost of a retention pond situated on a nearby site has been estimated to cost \$860 000 by HECEC (1996). This site is capable of accommodating a 35 000 $m^3$ pond, is in close proximity to the mine workings, and is not a site which would be expected to interfere with future mining operations.

***Recommendation***

> ***Lease site water management is a key element of successful remediation, and reducing the production of acid drainage through the diversion of clean water should be a top priority. Remediation must include the containment and treatment of acid drainage contaminated storm waters as well as 'normal' flows. It must be recognised that as the mining operation evolves, the quantity and quality of acid drainage produced on the lease site will change, and today's remediation effort must be flexible enough to respond to tomorrow's development in a cost-effective manner.***

*Environmental impact of acid drainage releases*

Presumably in the event of a very major flood, all downstream tributaries would also be discharging very large quantities of water, and dilution would be rapid. During such conditions, the impact a release would have on downstream water quality would be dependent on the concentration of pollutants in the acid drainage, the volume of available 'clean' water for dilution, the duration of the event, and meteorological factors controlling the dispersion of King River water in Macquarie Harbour. A possible management tool for these extreme flood events would be for the John Butters Power Station to be run as much as possible during the event to provide maximum downstream dilution.

## 7.4 Neutralisation of acid drainage

### 7.4.1 Description of system

As discussed in Section 6.3.1, the neutralisation of acid drainage is a proven technique which is widely used in the mining industry, and has been adopted as the 'Best Available technology economically achievable' in the USA and Canada (Miedecke 1996). The steps of conventional neutralisation and precipitation technology are summarised in section 6.3.

A flow chart showing the implementation of this technology on the Mount Lyell lease site is presented in figure 7.2.

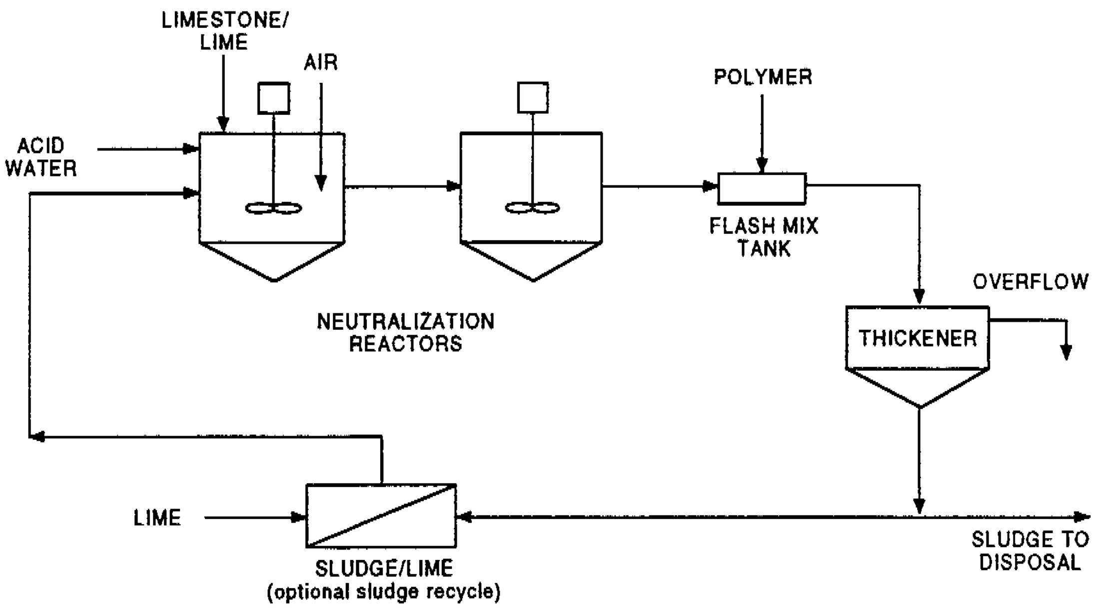


**Figure 7.2** Idealised schematic diagram of a neutralisation system (from Miedecke 1996)

A major advantage of implementing neutralisation technology on the Mount Lyell lease site is the availability of alkaline tailings produced during the flotation process currently used by CMT. It has been estimated (Imtech 1997) that approximately 45% of the alkali required to neutralise all acid drainage on the lease site could be met by the remnant alkalinity of the tailings once CMT reached full production levels of 3.5 million tonnes per annum. The use of tailings as an alkali source is best practice because it uses a waste product as a resource, which also results in considerable savings. While this is a significant advantage while the mine site is occupied and process tailings are being produced, there are serious limitations if mining ceases, or mineral processing techniques are altered and the composition and/or volume of tailings is altered.

Imtech (1997) has investigated three options for the neutralisation of acid drainage: neutralisation with tailings alone, neutralisation with tailings and limestone, and neutralisation with tailings, limestone and lime. The differences between the three approaches are the volume of acid drainage which can be neutralised, the resulting pH after neutralisation, and the cost.

If the downstream environmental quality objectives are to be achieved, the MLRRDP findings indicate that the neutralisation option requires the collection and neutralisation to pH 6.5 of all acid drainage waters. As investigated by Imtech (1997), this would require the addition of tailings, limestone and lime to the acid drainage. Other options outlined by Imtech (1997) would not achieve the desired downstream EQOs, but would result in some improvement in Macquarie Harbour, as outlined in table 7.3. The overwhelming issue associated with not neutralising all of the acid drainage, or not neutralising to a final pH of 6.5, is that the predicted resultant copper concentrations in the Queen and King River, would significantly exceed the LOEC (lowest observable effects concentration) values as established through chemical modelling (Klessa et al 1997) and toxicity testing (Humphrey et al 1997). The only advantage of neutralising less acid drainage or neutralising to a lower pH is a reduction in associated costs. However, because this would result in a reduced environmental benefit, there would be little downstream economic and marginal environmental benefit, as the improvements would probably not be sufficient to enhance aquaculture, tourism, or fulfil Australia's international responsibilities in terms of the World Heritage Area. This is not to ignore the possibility of a gradual implementation of neutralisation beginning with treating less than 100% acid drainage, but the ultimate goal must be for complete treatment.

**Table 7.3** Neutralisation scenarios as investigated by Imtech (1997) and corresponding projected environmental benefit

| Neutralisation scenario | Resultant pH of neutralised water | % acid drainage neutralised | Projected environmental benefit |
|---|---|---|---|
| tailings only | 6.5 | approx 45% | EQOs not met in King or Queen Rivers, some improvement in harbour |
| tailings & limestone | 6.5 | approx 65% | EQOs not met in King or Queen Rivers, some improvement in harbour |
| tailings & limestone | 5.97* | up to 100% | EQOs not met in King or Queen Rivers, some improvement in harbour |
| tailings, limestone & lime | 6.5 | 100% | EQOs met in King River, EQOs met for Macquarie Harbour, likely improvement in Queen River |

* This figure roughly coincides with what the resultant pH would be if all acid drainage sources were treated with tailings and limestone only as a cost saving mechanism

*Neutralisation of all acid drainage*

If all acid drainage is to be neutralised, the process would occur in 3 steps, utilising the remnant alkalinity of mill tailings, limestone and lime in large reactor vessels on site. As proposed, the entire neutralisation process would occur on the Mount Lyell lease site, and a flocculant or coagulation agent would need to be added in the latter stages of the process to promote maximum settlement of the precipitated metalliferous sludge. Recirculation of the precipitated sludge back through the system could possibly be required to promote suitable growth and settlement of particles. The retention of all solids is a crucial aspect of this remediation option, as any solids which are released to the river would be metal rich. The neutralised water would be directly discharged into the Queen River, with the sludge, and water required for transport, pumped to the tailings pond for permanent disposal.

### 7.4.2 Resultant downstream river water quality

Neutralisation of all acid drainage would result in the removal of greater than 98% of the total copper, aluminium, zinc and iron loads (Miedecke 1996). Bench tests cited in CMT's EMP indicate waters with an initial copper concentration of 200 ppm would have a resultant copper concentration of 0.02 ppm, a 99.99% efficiency, if neutralised to pH 6.5. Manganese and sulphate would be far less affected, with manganese concentrations being only slightly reduced and sulphate concentrations reduced to about 2000 ppm from about 3800 ppm. Such elevated concentrations of manganese and sulphate would not be acceptable to DELM if proposed by a new mining operation. However, given the present degree of environmental devastation in the Queen catchment, the composition of the released water would represent a major water quality improvement in the river. Additionally, the ecological impact of both of these compounds is subject to debate, and presently Australia does not have a water quality guideline for manganese. Guidelines for sulphate are typically focused at preventing salt build up in soils, and not due to toxicological considerations.

An interesting consideration with respect to manganese is the role this metal may to play in the greatly reduced copper toxicity observed in Macquarie Harbour. Stauber et al (1996) hypothesised that the bioavailability of copper was significantly reduced due to the presence of metal hydroxides, such as manganese, iron and aluminium in the water column. Because neutralisation would greatly reduce the flux of iron and aluminium entering the harbour, it may actually be *beneficial* to continue the discharge of manganese into the harbour. Additional investigations, some of which are currently under way, need to be completed before the relative importance of manganese, iron and aluminium in reducing toxicological affects can be known.

Based on the modelling results of Klessa et al (1997), and the toxicological testing conducted by Humphrey et al (1997), achieving a very high efficiency in the neutralisation plant will be crucial to the recovery of the downstream environment. These investigators have shown that under certain flow conditions, down stream water quality is significantly compromised even when 95% of the acid drainage is removed from the system. Hence, virtually *all* acid drainage needs to be neutralised with at least a 99% efficiency to obtain the maximum downstream benefit.

In spite of the manganese and sulphate concentrations present in the 'clean' water, the question of maximising the quantity of water treated and the efficiency of the system, and the potential problem if precipitates are released, the resultant water quality will promote the achievement of downstream environmental quality objectives. A 'modified' ecosystem would evolve in the King River, and very importantly, the water quality of the river would no longer pose a 'chemical barrier' for the migration of fish from Macquarie Harbour into tributaries of the King.

The recovery of the Queen River is less certain because of the much lower dilution rates. Even 1% of the present acid drainage could be enough to inhibit aquatic organisms establishing in the Queen. It must be noted that Davies et al (1996) have identified the bed of the Queen as being largely inhospitable for the establishment of infauna, so water quality is probably not the only constraint on the recovery of the Queen River.

### 7.4.3 Reliability of neutralisation system

The reliability of a combined holding pond and neutralisation facility will be dependent on the size of the holding pond and management of the neutralisation plant. Scheduled 'down time' will need to be carefully planned to coincide with low rainfall periods to insure the capacity of the holding pond is not exceeded. A mechanical failure of the neutralisation system which required significant down time would force acid drainage to be discharged into the riverine environment as is the present scenario. A release of even a small percentage of the acid drainage for a duration of 12 hours could result in significant downstream environmental harm based on toxicological investigations (Humphrey et al 1997). It is unknown what the recovery time from such an event might be.

A continuously operating neutralisation system operated by Placer Dome Canada at the Equity Silver Mine in British Columbia, Canada, has achieved annual average removal efficiencies of 99.99% for copper, 99.93% for zinc and >99.99% for iron over a five year period (M Aziz, pers com). A significant difference between the Equity system and that proposed for Mount Lyell is the inclusion of a treated water holding pond in the Equity system, which has sufficient capacity to handle in excess of 2 years treated water (M Aziz, pers com). In contrast, the Mount Lyell system would discharge water into the Queen directly from the neutralisation system.

Based on the Equity experience, scheduled downtime is generally associated with removing gypsum build up from the reaction tanks, pipes and agitators. Unscheduled downtime has resulted from lime silo blockage, frozen pipelines, power outages, and acid drainage feed pump failure. The Environmental Coordinator at Equity suggests that 'a good knowledgeable crew goes a long way to reducing and preventing downtime' (M Aziz, pers com).

### 7.4.4 Environmental impacts of the neutralisation option

The neutralisation of acid drainage results in 'clean' water which is suitable for release to the ambient environment and a metalliferous sludge which must be disposed of in an appropriate manner. The obvious and safest disposal site for the generated sludge is the tailings dam used by CMT near the Mount Lyell lease site. The co-disposal of neutralised acid drainage and tailings is already occurring as part of CMT's environmental management of the lease site, as CMT voluntarily neutralises 8% of the lease site acid drainage using remnant alkalinity in the mill tailings.

While the tailings dam is actively being used, the pH will be controlled such that it is suitable for the disposal of the precipitated sludge. The long-term close out plans for this tailings dam includes a passive water cover which will prevent the oxidation of sulphidic material, and will prevent the dissolution of metal hydroxides, formed from the neutralisation reaction, *as long as the pH of the dam remains greater than 6.5*. Because the pH of the ambient waters in the Princess Creek catchment is less than this value, it is inevitable that the pH of the dam will eventually fall to ambient levels (once the inherent alkalinity is consumed), and remobilisation of metal hydroxides could occur. The time required for the pH of the dam to equilibrate with ambient conditions will be a function of the hydrology of the dam and the buffering capacity of the tailings. Because it is economically advantageous to consume as much of the alkalinity in the tailings as possible during the neutralisation process , there is a concern that the long-term neutralisation capacity of the tailings dam could be quite low at the time of close out. These concerns are augmented by the generally low and variable acid neutralisation capacity of the tailings, and the poorly understood chemical processes which result in a significant increase in alkali demand in the acid drainage upon ageing.

Conversely, it is also possible that conditions in the dam will be conducive for the formation of metal sulphides, which would remain stable as long as anoxic conditions were maintained. While it is suggested that the long-term chemistry and hydrology of the tailings dam be investigated with the aim of predicting the possibility of future metalliferous discharges from the dam, the MLRRDP recognises that the use of a tailings dam as a long-term repository for the sludge is considered best practice and endorses this concept based on current knowledge.

Another environmental issue associated with the neutralisation scenario is the establishment of a limestone quarry in the Halls Creek catchment. Trucking, blasting and quarrying the limestone would all need to be completed using best practice techniques.

### 7.4.5 Social acceptability of the neutralisation scenario

The successful design and implementation of a neutralisation system on the Mount Lyell lease site could eliminate virtually all of the pollution presently leaving the lease site and greatly enhance downstream water quality. Because this scenario promises to fix the problem of acid drainage, there is unlikely to be public opposition to the proposal. It is highly probable that a modified ecosystem would establish in the King River, and pollutant concentrations in northern Macquarie Harbour would be reduced by about two orders of magnitude (Tong in prep). Assuming that a responsible and long-term repository for the metalliferous sludge can be guaranteed, then there is little likelihood that there would be any negative social impact. Quarrying of limestone will result in additional labour requirements, and additional work opportunities would be created for the producer of the lime. The implementation of a neutralisation system would not encroach on the bare hills of Queenstown, and there would be no land scars apart from quarrying.

Another positive social benefit of this scenario is that because of its comparably low initial capital investment cost, it is a flexible option which will be able to respond to new technology or methods developed in the future, either related to the neutralisation process or the SX/EW process.

### 7.4.6 Costs of neutralisation option

Miedecke estimated the capital costs associated with a neutralisation plant capable of treating 225 L/s to be approximately $2.8 million, plus or minus 30%, and annual operating reagent costs of about $1 million. This did not include costs associated with the development of a holding pond or other infrastructure required for lease site water management, which would probably be on the order of $1 million for a pond (HECEC 1996), and $2–3 million for the other works. More recent cost estimates by Imtech (1997) include $5 million for a neutralisation plant capable of treating up to 450 L/s, and $4 million associated with the required infrastructure (retention pond, pipes, pumps, diversion works). The annual operating costs associated with running the larger plant, including reagents, maintenance, and labour are estimated to be about $2.2 million (Imtech 1997). Full costings for the three scenarios investigated by Imtech are contained in Appendix B, table 1, and summarised in table 7.4.

The costs presented in table 7.4 are an indication of the full cost associated with each of the options, though they do not accurately reflect direct costs to Government.

If the tailings only option were adopted initially, CMT would bear all of the costs as this option is consistent with the company's environmental management plan and 'best practice'. The amount Government would need to contribute to either of the other two options would also be decreased due to funds already allocated to the remediation of Mount Lyell by the Commonwealth Government in the 'Tasmania Package' (approx. $4 million), and by funds available in the Mount Lyell Closure Fund (approx. $0.75 million) held by the State

Government. However, because most of the annual cost associated with the tailings-limestone option and the tailings-limestone-lime option are operating costs, a very long-term financial commitment is required for the success of either option.

**Table 7.4** Costs associated with three neutralisation options (all figures in $AUS)

| | tailings only 70% of underground treated (45% total) | limestone & tailings 100% (65% total) | tailings, limestone & lime, 450 L/s, 99% all sources treated |
|---|---|---|---|
| Capital costs | $1 500 000 | $4 000 000 | $9 500 000 |
| Annual operating costs | $323 000 | $989 000 | $2 223 000 |
| Life of plant | | 15 years | |
| Interest rate | | 5% | |
| Annual cost | $468 000 | $1 374 000 | $3 090 000 |
| Net present value, all costs | $4 853 000 | $14 265 000 | $32 069 000 |
| Interest rate | | 10% | |
| Annual cost | $520 000 | $1 515 000 | $3 406 000 |
| Net present value, all costs | $3 957 000 | $11 522 000 | $25 905 000 |
| Interest rate | | 15% | |
| Annual cost | $580 000 | $1 673 000 | $3 762 000 |
| Net present value, all costs | $3 389 000 | $9 783 000 | $21 996 000 |

*Possible cost saving on neutralisation option*

Because of the time scale of the MLRRDP and the time-intensive nature of gaining reliable information about flows, alkali demand and neutralisation capacity of the tailings by CMT, the MLRRDP has been unable to fully investigate variations on the neutralisation option. However, there has come to notice one significant new technology which potentially has the capability of greatly altering the high costs of neutralisation. Osmotic membranes have the capability of concentrating the dissolved components in a water stream, and producing a relatively 'clean', albeit acidic filtrate. In one mining operation where this technology is utilised, the pollutant stream is concentrated by a factor of 4 to 5, and the reagent use has been reduced to one-sixth.

In the case of Mount Lyell, there would be two significant advantages to producing a more concentrated pollutant stream. The first would be that a more concentrated, lower volume acid drainage stream would require a smaller quantity of neutralisation reagents. Because the great majority of the annual costs associated with neutralising all acid drainage is reagents, the implementation of osmotic membrane technology could radically reduce the requirement for costly lime.

The second advantage of implementing membrane technology would be the concentration of copper in more dilute acid drainage streams such that concentrations were suitable for SX/EW copper removal. This could provide a greater revenue stream, which would make neutralisation a more viable option, and is more fully discussed in Section 7.6.

Because of the newness of the membrane technology information, and the necessity of involving the lease operator in the evaluation of the process, the MLRRDP has not obtained accurate costings nor determined the feasibility of the technology on the lease site, but strongly recommends that it be pursued once an agreement between Government and the lease operator is obtained.

### 7.4.7 Step-wise implementation of neutralisation option

One of the main advantages of pursuing the neutralisation option, is that it lends itself to a step-wise gradual implementation which is both economically and operationally advantageous. While the 'tailings only' option does not meet the downstream environmental quality objectives, it is a low cost step in the right direction. The next step, however, will depend on negotiations between the Government and CMT, as to how SX/EW and possibly membrane technology could be implemented, what portion of the revenue stream can be applied to neutralisation, and who will bear the additional required costs. However, if this option is adopted, the primary goal must be to ultimately neutralise *all* acid drainage sources on the lease site.

## 7.5 Ocean disposal of acid drainage (pipeline option)

At first, the ocean disposal of acid drainage sounds like an anachronistic approach to the Mount Lyell problem. However, when fully considered in the context of the present environmental impact of acid drainage on the riverine, estuarine and marine environment, and with the incorporation of an SX/EW plant, it is a plausible approach to remediation worthy of consideration.

A pipeline remediation option would require the collection of all acid drainage sources in a large holding dam, the removal of as much copper as feasible using SX/EW technology, and piping to the ocean. The water which would enter the ocean would be chemically equivalent to the present acid drainage except about 75% of the copper would be removed. Downstream water quality would be enhanced through the removal of all possible acid drainage sources from the catchment.

The same flow issues apply to the management of a pipeline as for the neutralisation scenario, and the overall success of this approach is directly dependent on the prevention of acid drainage spills into the Queen and King Rivers.

As discussed in section 6.3.4, three pipeline routes have been investigated from an engineering point of view, one that follows the route of the old Abt Railway; one which generally follows the Queenstown-Strahan road and HEC transmission towers; and a third which crosses Misery Flats to the north (termed the topographic route). Three pipeline materials, polyethylene, fibreglass and stainless steel, were investigated, and it was found that the two most economic options were the topographic or Abt Railway routes using polyethylene piping material.

### 7.5.1 Resultant downstream river water quality

The downstream water quality in the Queen and King catchments would be dramatically improved because the acid drainage source would be removed from the catchment. Because the pipeline would have a 100% efficiency, its overall effectiveness would be dependent on the successful collection of *all* acid drainage sources. Assuming at least 99% of the acid drainage could be collected and diverted, the downstream environmental quality objectives would be met.

Flows in the Queen and King would be reduced by the volume piped to the ocean. Under median conditions this would represent a 15% reduction in Queen River flows and a 0.3% to 3% reduction in the lower King River, depending on the operation of the power station.

Flows in the Queen and King would be reduced by the volume piped to the ocean. Under median conditions this would represent a 15% reduction in Queen River flows and a 0.3% to 3% reduction in the lower King River, depending on the operation of the power station.

### 7.5.2 Environmental impacts of pipeline scenario

Although the resultant river water quality downstream of the Mount Lyell lease site would be better from the 'pipeline scenario' than the treatment option, there are many other environmental impacts associated with the option that need to be recognised.

*Marine issues*

It is very important to stress that the MLRRDP *has not directly considered marine impacts associated with the ocean disposal of acid drainage.* The investigations conducted by the MLRRDP have been strictly limited to the cost and feasibility of designing and constructing a pipeline to the ocean, without assessing what kind of outfall would be appropriate, or what impact there might be on the environment. Additional investigations akin to an environmental impact statement (EIS) would need to be completed before these issues could be fully assessed.

Notwithstanding the lack of detailed marine impact information, it is worthwhile to briefly highlight some aspects of the present state of knowledge regarding the dispersal of acid drainage in Macquarie Harbour and the Southern Ocean. Presently, 100% of the acid drainage leaving the lease site enters northern Macquarie Harbour. Based on the work of Teasdale et al (1996) and Koehnken (1996), approximately 85% of the copper entering the harbour remains in the water column and ultimately exits the harbour to the ocean, at concentrations of approximately 35–45 ppb. This equates to approximately 620 tonnes/year of copper entering the marine environment via Hell's Gates (based on 730 tonnes/day exiting lease site). Under the pipeline SX/EW scenario, between 70 and 180 tonnes/year of copper would directly enter the marine environment, as the remainder would be removed via the SX/EW plant. Other pollutants would be unaffected by SX/EW processing. Although the flux of copper is considerably less, at maximum only about 25% of the present situation, the concentration of copper entering the ocean would be far greater at the point of discharge (approximately 10–15 ppm). If a diffuser were able to achieve a 1:100 dilution within a few hundred metres, maximum dissolved copper concentrations of 100 ppb to 150 ppb would be expected. In reality, as the acid drainage was neutralised by the seawater, metal hydroxides would quickly precipitate and dissolved copper concentrations would be considerably lower. The fate of the metalliferous precipitates would depend on the ocean currents and design of the diffuser. Given the high energy environment off of Ocean Beach and the coarse-grained nature of the bottom sediments, it is seems unlikely that large accumulations of metal precipitates would accumulate near shore. However, an environmental impact study would need to be identify the ultimate fate of the material.

In comparison, the present copper concentrations entering northern Macquarie Harbour typically range from 300 ppb to about 3000 ppb, though concentrations as high as 9000 ppb have been recorded. Neutralisation of acid drainage in the harbour is controlled predominantly by wind driven mixing, so the rate of dispersal is presently controlled by meteorological factors. King River plumes containing high concentrations of metals can persist for hours or even days under some conditions, and have impacted on the operation and growth of the harbour-based aquaculture industry.

The impact a small volume of water containing high copper concentrations would have on the marine environment would need to be assessed relative to the present impact a much larger volume of water containing lower copper concentrations, but much higher total loads, is having on the same environment. As there is no historic baseline pre-mining marine information, this may be a very difficult task.

If an ocean outfall were to be established, a permit for its construction and operation would be required from DELM based on a development proposal and environmental management plan which comprehensively considered the associated marine impacts.

*Land issues*

The establishment of a pipeline would result in a visual impact on the landscape, the severity of which would depend on the route chosen and extent of burial. A pipeline following the route of the Abt railway would not be widely visible except along the lower reaches of the King River, unless the railway were re-established. If the pipeline followed the road and HEC transmission towers, there would be some visual impact, but it would coincide with existing land disturbances from the road and towers. A pipeline which crossed Misery Flats and entered the ocean near the Henty dunes would traverse considerable tracts of currently unimpacted land.

In the case of a pipeline failure, there could be an impact on the area immediately surrounding the pipeline. If the failure occurred near a watercourse, acid drainage would enter the waterway and undoubtedly have an impact, the severity of which would depend on the size of the waterway, the volume and composition of the acid drainage, and the duration of the spill.

Legal and financial aspects associated with the acquisition of land required for the pipeline have not been considered by the MLRRDP, nor included in the financial analysis.

*Macquarie Harbour*

The implementation of a pipeline would prevent acid drainage from the lease site entering Macquarie Harbour. There would continue to be relatively small inputs from the King River due to the continued oxidation of tailings present along the banks of the river, and from the large quantity of tailings resident in the harbour which have been shown to be a source of metal to the overlying water column (Teasdale et al 1996). One issue which would require further investigation prior to the implementation of a pipeline, would be the effect such a measure would have on the copper toxicity in the harbour. Under the current regime, Stauber et al (1996) have found that the toxicological impact of copper in the harbour is very much less than suggested by applying estimation techniques from the literature. A possible reason for this is because of the presence of iron, aluminium and manganese colloids in the water of the harbour which bind the copper, resulting in reduced bioavailability. Much of the manganese, aluminium and iron which enter the harbour is associated with the acid-drainage rich King River discharge. A pipeline which removes the acid drainage, may also result in a lowering of the concentration and impact of 'beneficial colloids', and might, theoretically, *increase* the toxicity of copper coming from the Macquarie Harbour sediments.

### 7.5.3 Social acceptability of the pipeline scenario

Internationally, the ocean dumping of waste materials is socially and politically unacceptable, and Australia is a signatory to the Convention on the Prevention of Marine Pollution by dumping of wastes and other matters. However, the establishment of ocean outfalls for the disposal of sewage and industrial effluent is not covered by this agreement and although declining, remains an accepted practice in Australia and the rest of the world.

Locally in Tasmania there was strong community opposition to the ocean disposal of pulp mill effluent associated with the proposal for a new pulp mill at Wesley Vale, although there are other industrial and municipal ocean outfalls present in the State. The MLRRDP did not conduct formal surveys about the acceptability of ocean disposal of acid drainage, but public meetings held in Strahan and Queenstown suggested that this concept might be reluctantly accepted if it resulted in the best net environmental outcome and is the only possible way of removing pollution from the King and Queen Rivers. Obviously, concerns were expressed about possible impacts on the marine environment.

The construction phase of a pipeline would create significant employment opportunities on the west coast. Once completed the operation and maintenance of the structure would not result in significant employment.

### 7.5.4 Cost associated with the pipeline scenario

The HECEC (1996, 1997) has provided a range of estimates for the construction and maintenance of a pipeline based on different capacities, routes, and pipeline materials, which are presented in more detail in section 6.3.4. As discussed in Section 6.3.4, the most economic material for a suitable pipeline has been found to be polyethylene (MDPE). A summary of costs associated with two possible routes of a 450 L/s pipeline is presented in table 7.5; full costings are contained in Appendix B, table 2.

**Table 7.5** Costs associated with the pipeline option (all figures in $AUS)

| | Abt Railway route | Topographic route |
|---|---|---|
| Total capital costs | $28 869 000 | $24 947 000 |
| Operating costs | | |
| year 1–10 | $1 534 000 | $1 377 000 |
| year 11–20 | $1 803 000 | $1 607 000 |
| year 21–30 | $2 071 000 | $1 836 000 |
| Life of pipeline | 30 years | |
| Interest rate | 5% | |
| Annual cost | $3 565 000 | $3 130 000 |
| Net present value, all costs | $54 808 000 | $48 114 000 |
| Interest rate | 10% | |
| Annual cost | $4 703 000 | $4 114 000 |
| Net present value, all costs | $44 338 000 | $38 786 000 |
| Interest rate | 15% | |
| Annual cost | $6 002 000 | $5 237 000 |
| Net present value, all costs | $39 408 000 | $34 386 000 |

These costings include approximately $2 million for a retention basin and pumps, $1 million for a diffuser, $1 million for environmental studies, as well as a 15% contingency. The costs, however, do not include those associated with land acquisition, nor do they reflect the $4–5 million presently available for remediation.

Estimating land acquisition costs is difficult, and would vary with the route, but because the proposed routes traverse predominantly Crown Land, the financial costs may small compared with the overall price tag.

A disadvantage of adopting the pipeline approach to remediation, is that there is not the possibility of step-wise implementation. A very large capital investment must be made before *any* downstream improvement is realised. The 'permanency' and expense of such an option also precludes the ability to update or modify the remediation technique once the pipeline were constructed. However, once implemented, it will remove all acid drainage from the Queen River, King River and Macquarie Harbour nearly all of the time (low possibility of spills due to overflows or pump failure).

### 7.5.5 Variations on pipeline SX/EW option

Though not considered in depth by the MLRRDP, it would also be possible to discharge partially neutralised acid drainage with the pipeline to the ocean. The most cost-effective option would be to neutralise as much raffinate as feasible to a pH of 6.0 utilising tailings (and possibly limestone) from CMT's operation. The precipitated sludge would report to the tailings pond, with the associated neutralised water discharged via the pipeline. At full production it has been estimated that up to 45% of the acid drainage could be neutralised by tailings alone in this manner. This would result in a substantial removal of metals from the raffinate discharged to the ocean, but the resultant water quality would not be suitable for release into the riverine system.

## 7.6 Solvent extraction/electro winning process (SX/EW)

The inclusion of an SX/EW plant is highly recommended by the MLRRDP for either remediation strategy, in that it potentially provides a revenue stream which could offset some of the remediation costs. An SX/EW plant would recover 75% to 90% of the dissolved copper in the acid drainage, and produce a saleable copper product at a relatively low cost. As noted above, an SX/EW plant does not remove any other contaminants from the acid drainage, and the waste water (termed raffinate) must be treated prior to release into the riverine environment.

Imtech (1997) has investigated the feasibility of SX/EW technology and concluded that at present, only the acid drainage stream pumped from level 18 within the mine is suitable due to fluctuating flows and copper concentrations of the other acid drainage sources. Imtech (1997) and other work have also shown that a considerable percentage of the copper flux exits the lease site during large storm events, which would not be recovered if only the underground sources are directed through the SX/EW plant.

Because much of the acid drainage flow is considered too dilute for copper recovery, it is envisaged that select acid drainage streams would be fed through a small settling pond and SX/EW plant, and then report to the larger holding pond prior to neutralisation or piping to the ocean. Unfortunately, this scenario does not allow the recovery of the large quantities of copper transported during large rain events. Koehnken (1996) has documented copper fluxes in excess of 9 tonnes per day during rain events following prolonged dry periods.

The application of osmotic membrane technology has the potential to allow SX/EW technology to be implemented below a collection point for *all* acid drainage on the lease site, including large storm events, thus significantly increasing the quantity of copper recovered. The membrane technology could concentrate the copper concentrations to such a point that virtually all copper on the lease site could by passed through an SX/EW plant without increasing the volume capacity of the plant. As the MLRRDP has not fully investigated or costed this option, it is strongly recommended that it be pursued with CMT.

### 7.6.1 Environmental impacts of SX/EW

The environmental impacts associated with remediation strategies incorporating SX/EW technology vary somewhat from those associated with systems which exclude copper recovery. One difference is that the SX/EW process requires the addition of an organic reagent, and it has been estimated that there would be 10–15 ppm kerosene added to the raffinate during the process. (Imtech 1997). Because kerosene at concentrations of 0.1 ppm have been associated with the tainting of fish flesh (ANZECC 1992), the dilution required to reach 'safe' levels will not be achieved until the (treated) raffinate is introduced into Macquarie Harbour, under normal flow conditions. Techniques for removing the kerosene or mitigating its impacts will need to be investigated and incorporated into the final remediation option. A second difference is that the SX/EW process actually *decreases* the pH of the raffinate by about 0.2 pH units. This has a negligible affect on the alkali demand of the raffinate because it has been determined that virtually all of alkali demand in the acid drainage is contributed by dissolved metals, with pH accounting for less than 0.01% of the total (Imtech 1997). Based on Imtech's results, a decrease in pH of 0.2 units would be expected to represent an increase in alkali demand of 0.003%.

### 7.6.2 Costs associated with SX/EW

The capital costs associated with an adequate SX/EW plant range from \$2.8 million to \$4.7 million depending on the volume and grade of the acid drainage (Miedecke 1996, Imtech 1997). These costs are summarised in table 7.6 and provided in full in Appendix B, table 3. Imtech (1997) suggests that the lower capital cost would provide a plant able to treat 100 litres of acid drainage per second, while the higher estimate is associated with a plant capable of treating 232 L/s. CMT has identified the fluctuating water temperature of the acid drainage as a potential issue in the application of SX/EW, and additional capital cost could be required to maintain a steady reaction temperature.

**Table 7.6** Costs associated with the implementation of SX/EW technology as estimated by Imtech (1997) *excluding* the cost of treating raffinate. NPV and annual cost calculations completed by C Attwater (all figures in $AUS).

| | 100 L/s | 200 L/s | 232 L/s |
|---|---|---|---|
| Total capital | $2 760 000 | $4 359 000 | $4 715 000 |
| Total operating | $593 000 | $703 000 | $725 000 |
| Revenue (copper sales @ $US1.05/lb) | $1 271 000 | $1 814 000 | $1 915 000 |
| Net income | $678 000 | $1 111 000 | $1 191 000 |
| Life of plant | | 15 years | |
| Interest rate | | 5% | |
| Annual revenue | $412 000 | $691 000 | $736 000 |
| NPV (positive asset value) | $4 280 000 | $7 174 000 | $7 642 000 |
| Interest rate | | 10% | |
| Annual revenue | $315 000 | $538 000 | $571 000 |
| NPV (positive asset value) | $2 399 000 | $4 092 000 | $4 340 000 |
| Interest rate | | 15% | |
| Annual revenue | $206 000 | $366 000 | $384 000 |
| NPV (positive asset value) | $1 206 000 | $2 138 000 | $2 246 000 |

Based on this financial analysis, it is evident that the operation of an SX/EW plant is a commercially viable operation *if* the treatment of raffinate is not included. Because the actual revenue derived from an SX/EW plant will be affected by the concentration of copper in the acid drainage, the efficiency of recovery of the SX/EW plant, the selling price of copper and the exchange rate of the Australian dollar, the 'net' and 'annual' revenue figures in table 7.6 could vary somewhat. However, it is evident from this financial analysis that an SX/EW operation could be expected to raise hundreds of thousands of dollars per year which might be available for defraying remediation costs, but not the millions which are required for either the pipeline or 'full' neutralisation option. (cf tables 7.4, 7.5). Of course, any financial arrangement will need to be based on an agreement between the State and CMT recognising CMT's right to the mineral resource.

## 7.7 Possible configurations of remediation strategies

The MLRRDP has identified two options for remediation of the Mount Lyell lease site which would satisfy the downstream environmental quality objective. These are: neutralisation of acid drainage with the inclusion of SX/EW technology; and ocean disposal of acid drainage via a pipeline combined with SX/EW technology. Schematic diagrams of how these systems might be implemented are presented in figure 7.3.

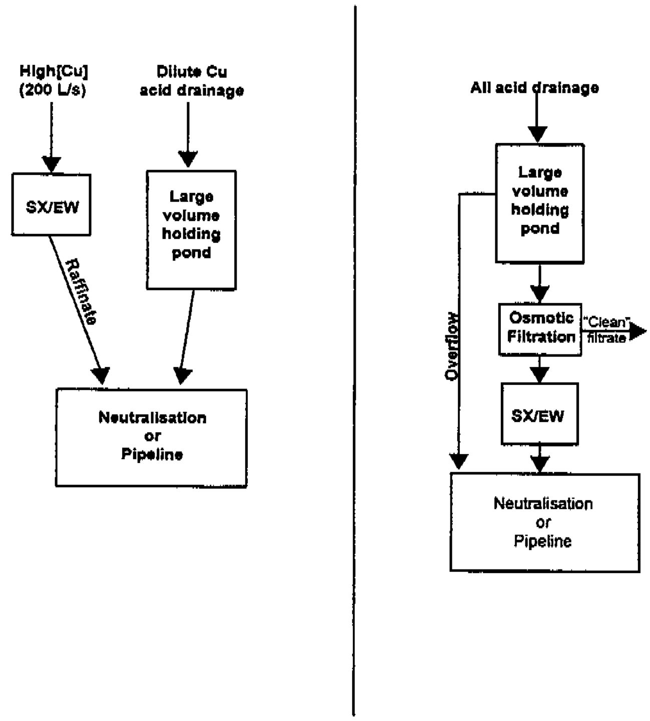


Figure 7.3 Schematic diagrams of possible configurations of remediation strategies on the Mount Lyell lease site. In the second diagram the fate of the 'clean' permeate will be determined by its water quality. Some neutralisation of this water might also be required.

The second schematic includes osmotic membrane technology which has recently been briefly investigated by the MLRRDP, and which potentially, could increase the amount of recoverable copper, and possibly decrease the quantity of neutralising reagents required. The decrease in neutralising reagents will be dependent on the water quality of the 'permeate', ie the clean water stream produced during the membrane process. Because the feasibility costs associated with this technique are unknown at this time, the following comparative discussion is based on the first schematic only.

## 7.8 Discussion of costs of neutralisation and pipeline scenarios

Table 7.7 summarises the capital costs, operating costs and projected environmental benefit for the two options, as well as a costing for neutralisation without SX/EW for comparison.

**Table 7.7** A comparison of costs associated with remediation options (AUS$)

| Remediation option | Capital cost for establishment ($million) | Net annual cost ($million) (based on 10% interest, including repayment of capital) | Projected environmental benefit |
|---|---|---|---|
| Neutralisation | 9.5 | 3.4 | EQOs achieved in King River and Macquarie Harbour |
| Neutralisation & SX/EW | 14.2 | 2.9 | EQOs achieved in King R. and Macquarie Harbour |
| Pipeline & SX/EW | 25–29 | 3.6–4.3 | EQOs achieved in King River and Macquarie Harbour |

The figures in table 7.8 are the full costs associated with the remediation options and do not reflect any savings due to the present availability of approximately $4 million for remediation works. However, because of the high proportion of the annual cost that is attributable to operating costs ($2.2 million for neutralisation and $1.3–2.1 million for pipeline), an initial reduction in capital expenditure by $4 to 5 million will not dramatically lower costs over the life of the project.

Several important conclusions are evident from this table. Primarily, there is no cost neutral or inexpensive way of achieving the downstream EQOs and the revenue generated from copper recovery will not be sufficient to cover all costs associated with remediation. Within this context, the most economically viable option is neutralisation with SX/EW.

However, in spite of the apparent high costs associated with implementing one of these options, the economic and social gains which would be realised in the King River and Macquarie Harbour would greatly exceed these values.

As more fully discussed in section 3, the expansion of the existing aquaculture industry in Macquarie Harbour alone is projected to be in excess of $8 million per year if water quality in the northern harbour was permanently improved, which would include a land-based processing plant in Strahan. Tourism, which already contributes more than $18 million to the west coast economy would receive a significant boost if water based recreational activities, such as fishing and rafting, became a reality in the lower King River and could easily contribute an addition $5 million a year to the local economy. Importantly, the cessation of pollution entering a World Heritage Area would contribute to the 'clean – green' Tasmanian image and fulfil Australia's international obligation and responsibility to guard the natural values of the WHA as agreed to under the Convention Concerning the Protection of the World Cultural and Natural Heritage. Remediation would also enhance the reputation of the State's mining industry.

Because of the benefits which would be realised by remediating the Mount Lyell lease site, and the recommendation from SDAC that all mine water be treated prior to release, it is vital that the Government and CMT begin to work towards a suitable arrangement whereby remediation is achieved while recognising CMT's legal rights. Obviously there is a wide range of permutations concerning how remediation of the damage caused by acid drainage could be achieved, and the first step is determining the rights and responsibilities of both the Government and CMT.

## 7.9 Discussion of relative merits of neutralisation and pipeline scenarios

In determining the preferred remediation strategy for the Mount Lyell lease site, the Program Implementation Committee (PIC) of the MLRRDP has evaluated each of the options against the original criteria identified at the inception of the program as well as expanding the evaluation criteria to include factors which emerged as the program progressed. In most cases, these evaluations were based on material obtain through the Projects, but the evaluation of social and political acceptability issues were based on the views of the PIC. The final list of evaluation criteria therefore include:

- the *effectiveness* of the option in the achievement of the identified environmental quality objectives for the Queen and King Rivers and Macquarie Harbour;
- actual and potential *environmental impacts* resulting from the implementation of the remediation option outside the river or harbours (ie remediating the lease site should not result in significant environmental harm elsewhere);
- the *cost* of implementing the strategy from the point of view of Government;
- the *social and political acceptability* of the remediation option;
- the *flexibility* of the remediation option to incorporate new technology or facilitate step-wise implementation;
- the effect on the downstream environment in the event of *mine closure* or future mine development.

The first two criteria are considered to be the most important by the PIC. The goal of the program is to maximise the downstream improvement (effectiveness) without creating or increasing environmental impacts in a different area (criterion 2). The cost, social and political acceptability criteria are considered to be next in importance because the outcome must be socially acceptable, and financially achievable. Finally, the flexibility of a remediation option and the downstream impacts associated with mine closure were considered, though because these criteria are very difficult to quantify given the broad range of potential situations which could arise, they were considered to be a minor issue compared with the first four.

### 7.9.1 Effectiveness

All three of the scenarios presented: neutralisation; neutralisation with SX/EW; and pipeline with SX/EW; have been identified as being suitable in achieving the downstream water quality objectives. The 'weak link' of all three scenarios is the possibility of acid drainage spills from the lease site into the Queen River, and based on flow analyses, regardless of the efficiency of the remediation options, a spill can be expected to occur for at least 1 day every few years coinciding with an extreme rainfall event.

Because under a neutralisation scenario the resultant downstream water quality is dependent on the efficiency of the system and all water is ultimately discharged into the Queen River, malfunction of neutralisation equipment, or the incomplete retention of precipitated sludge would lead to contaminated water exiting the lease. In comparison, under a pipeline scenario, all collected water would be removed from the catchment, thus it is potentially more efficient than neutralisation. Pump malfunction would be the primary cause leading to 'preventable' acid drainage releases, and although this risk is probably less than that associated with a neutralisation scenario, the resulting release would be untreated acid drainage, whereas a neutralisation-associated release might be partially treated water. Under either scenario, it would be possible to have some safe guards in place, such as lime sacks which could be placed in Haulage Creek, or emergency lime dosing equipment which could neutralise the acid drainage even though the precipitated sludge would not be removed from the river. Either of these strategies could reduce, though probably not eliminate, downstream impacts.

Scenarios which include the partial neutralisation of acid drainage (any scenario where less than 100% of the collectable acid drainage is treated, or where the final pH of the neutralisation reaction is less than 6.5), which includes the 'do nothing' option, will not achieve the EQOs, and therefore are not highly favoured by the MLRRDP except as steps on the path to the ultimate goal.

### 7.9.2 Other environmental impacts

A major difference between the neutralisation scenarios and the pipeline scenario is that the former directly address the acid drainage problem and provides a 'best practice' solution, whereas the latter basically relocates a modified, and somewhat more benign version of the acid drainage to another part of the (already impacted?) environment. Additional pipeline-related environmental impacts are the potential for acid drainage spills to occur far removed from the Mount Lyell lease site due to pipeline failure, and the visual and physical land scars resulting from construction.

A potential environmental impact associated with neutralisation is the re-release of metals from the tailings dam if a pH greater than 6.5 is not maintained, which, given that the ambient pH of waters in the region is less than this value, is a distinct long-term possibility. However, this situation can potentially be managed through the long-term close out options for the tailings dam. Other environmental impacts associated with neutralisation scenarios include those associated with quarrying and the transport of neutralisation reagents, which are considered to be minor.

Based on this criterion, the MLRRDP strongly endorses the neutralisation scenario which incorporates SX/EW because it eliminates copper as a contaminant, and 'solves' the remaining acid drainage problem. Although SX/EW would eliminate the same quantity of copper in a pipeline scenario, the long-term discharge of waste into the ocean cannot be condoned.

### 7.9.3 Costs

Given that the costs provided in this report are estimates and could vary by as much as 30%, the differences in cost between the scenarios are effectively insignificant, and all will require considerable Government funding for full implementation. A major difference between the options, however, is that the pipeline will require a very large capital cost before *any* improvement in the downstream environment will be achieved (cost of environmental impact studies plus cost of constructing pipeline), whereas the gradual implementation of a neutralisation scenario will have immediate benefits for Macquarie Harbour, without requiring an immediate financial commitment for full implementation. An added economic advantage of step-wise implementation of neutralisation, is that downstream response can be monitored, and remediation plans progressively refined so there is always an efficient use of resources, whereas a pipeline requires 'all the eggs in one basket' before remediation works begin.

The implementation of SX/EW is strongly endorsed on a cost basis, due to the resultant revenue stream. Although it has been conclusively demonstrated that SX/EW will not result in a cost neutral situation, it will defray some of the ongoing costs.

The preceding issues have led the MLRRDP to favour a step-wise implementation of a neutralisation scenario incorporating SX/EW based on cost considerations. The most economic approach would be to immediately utilise the neutralising capacity of the tailings to treat as much acid drainage as possible, while SX/EW is established and future funding secured.

### 7.9.4 Social and political acceptability

The social acceptability of the neutralisation concept is probably greater than the pipeline, because it addresses the problem and does not transfer waste to a new receiving environment. However, before an educated assessment of the public reaction to a pipeline could be gained, the environmental impact studies associated with a marine outfall would need to be completed and the public made aware of the results. The fish farming representative on the MLRRDP Consultative Committee strongly favoured the pipeline option because it affords the best protection from pollution entering the northern harbour.

While the neutralisation SX/EW scenario is thought to be the most socially and politically acceptable by the MLRRDP, the 'do nothing' option is deemed to be the most unacceptable outcome. Because of the longevity and severity of the environmental issues associated with the discharge of acid drainage, and the large amount of effort and money invested in the MLRRDP and other studies, there is a large expectation from the community that something will be done. There is no putting Mount Lyell back in the 'too hard basket'.

### 7.9.5 Flexibility

Flexibility is a difficult criterion to assess without knowing what future advances in technology or developments on the lease site might occur. Notwithstanding this, the MLRRDP considers a step-wise implementation of neutralisation to be the most flexible option. That is, new technologies, altered flow rates, and new reagents could all be introduced without wasting previous capital expenditures. Any variations will still require a holding pond, thickener, SX/EW, alkali source, etc, so it would be a matter of readjusting the system rather than redesigning it. Ideally new technologies could be incorporated as equipment required replacement.

In the case of an SX/EW pipeline option, there would be considerable difficulty associated with incorporating modifications, although the SX/EW does provide some flexibility at the front end. Because a pipeline and pumps would need to be sized to reflect current conditions, any radical change in flow could not be easily accommodated, and there might be excess (or insufficient) capacity. An example of this would be if in the future a technique were identified to prevent water from entering the underground workings, and the volume of acid drainage requiring treatment were greatly reduced.

### 7.9.6 Effect of mine closure/development

Similar to the flexibility issue, evaluating the impact of mine closure or development is difficult because the resulting situations are unknown. A significant unknown is what will be the impact on acid drainage discharge when the underground workings are flooded, either due to closure or redevelopment of surface workings. While it is certain that the pollutant load and hence alkali demand of the water exiting the lease site would decrease once the underground workings were flooded, it is unknown whether this would lead to the demise of SX/EW as an applicable option due to lower copper concentrations.

In broad terms, however, mine closure would have a more significant impact on the neutralisation scenario because mill tailings, which are an important alkali source, would no longer be available. This could result in a substantial increase in operating costs if the alkali demand of the acid drainage were to decrease by less than 50%. Conversely, the operating costs associated with a pipeline would probably remain fairly constant.

### 7.9.7 Summary

Based on the identified criteria and best knowledge available at present, the MLRRDP recommends that neutralisation of *all* acid drainage sources be pursued with the incorporation of SX/EW (or equivalent technology) to extract copper and offset some of the expenses. While this recommendation recognises the merits of a step-wise implementation of the option, the ultimate goal must be to collect and treat virtually all acid drainage sources, as partial implementation will not achieve the environmental quality objectives.

The adoption of this option will promote the EQOs and is consistent with 'best practice environmental management' as it addresses the problem directly rather than relocating it. The flexibility of the preferred option is highly compatible with waste minimisation strategies aimed at reducing the volume of acid drainage generated through diversion works, and it uses a 'waste' (tailings) as a resource by reducing the amount of lime/limestone necessary for neutralising the acid drainage. In the longer term, reducing the generation of acid drainage through the reprocessing of waste rock dumps and preventing the ingress of all water into the underground workings should be incorporated into future mining plans.

***Recommendation***

> ***The preferred remediation strategy is the neutralisation of 100% of the acid drainage to pH 6.5, implemented in a progressive manner.***

***Recommendation***

> ***A copper recovery technology should be implemented with the neutralisation system as this offers the potential to offset some neutralisation costs depending on negotiations with the present mine operators. The technology used should be determined once feasibility and engineering issues are resolved, and 'emergent' technologies are evaluated. This component of the remediation strategy will have to be developed recognising the possibility of reduced copper loads associated with successful diversion works.***

## 7.10 Horses for courses for minor sources

While the MLRRDP has identified and recommended a central collection and treatment strategy for acid drainage on the Mount Lyell lease site, there are a number of smaller, passive techniques which have been successfully trialed on site, and which are recommended as suitable for small acid drainage sources, particularly those not easily diverted to a central collection point, or those not reporting to the Queen River.

The covering of the Magazine Creek waste rock dump and the installation of a SAPS (successive alkalinity producing system) have both been very effective at reducing acid drainage emissions, though long-term monitoring will be required to confirm the effectiveness of the systems.

The design and placement of these 'horses for courses' should be determined as the large-scale, lease site water management plan is developed.

## 7.11 Remediation of the King River

Results of the MLRRDP indicate that the banks of the King River are a very small pollutant source in comparison with the Mount Lyell lease site. Additionally, since the cessation of tailings discharge into the river system, there has been substantial erosion of the resident tailings deposits, and re-emergence of 'natural' river banks. Any attempt to quicken the natural rate of tailings removal in the river has the potential to create plumes in the harbour and/or result in a large release of associated metals. It is therefore prudent to not interfere with the movement of tailings through the river system at this time.

The tailings and slag resident in the river bed have also been identified as a relatively very small source of contaminants, and because of the potential for plumes or large-scale metal releases, it is recommended that dredging not be attempted at this time. Generally, the largest threat posed by the tailings in the river would be through the oxidation of sulphidic material. Hence, the bottom of the river is actually a fairly safe place for the tailings.

Visually, the King River is a stark reminder of poor past mining practices, and revegetation would enhance the amenity of the area. Although revegetation trials have been successful and have created great community interest, the rapidity of tailings erosion in the river and relative success of natural revegetation suggest that a large expenditure on revegetation at this point in time is not warranted. However, encouraging community participation in the custodianship of the banks of the King is an important and worthwhile aspect of long-term remediation. Community groups, such as Landcare, should be strongly supported to complete works in carefully selected areas not subject to erosion or flooding. At the same time, monitoring of the vegetation trials should continue, such that when revegetation efforts are focused on the river banks, the best techniques are utilised and resources are not wasted.

Stopping the release of acid drainage should be the primary focus of remediation efforts for the next few years. Because biological investigations have shown that the water quality in the King River is a 'chemical barrier' to fish migration into the tributaries of the river, an early, intermediate target of remediation should be to improve water quality such that recruitment of fish will again occur.

During the initial remediation period, the river should be observed, revegetation trials evaluated, and revegetation by community groups encouraged. Once the major source of pollution has been ameliorated, then, depending on the state of the river, remediation efforts could turn towards this region.

***Recommendation***

> ***An early target of remediation should be to improve water quality in the lower King River such that recruitment of fish will again take place in the tributaries of the King River, even if the King River itself remains uninhabitable.***

***Recommendation***

> ***Revegetation of the King River banks is recommended to enhance the visual amenity of the area and reduce dust emissions. Community groups should be encouraged to participate in the 'greening of the King', such that local ownership is promoted. Funds should be sought through applicable Government programs. In terms of water quality, the best remediation option for the King River is to clean up the water exiting the lease site.***

## 7.12 Remediation of King River delta

Of the possible options explored for the remediation of the delta, the only feasible, economic and environmentally sound strategy is revegetation. The present delta contributes only a small percentage of the present pollutant load to Macquarie Harbour, but the movement of large volumes of tailings could result in undesirable, and unnecessary environmental impacts, which should be avoided. The MLRRDP recommends a similar approach to revegetation of the King River delta as to the banks of the King River: that the present trials should be monitored, and where practicable, revegetation by community based groups (eg. Landcare) should be encouraged. The present wetland/dryland trial being conducted on the delta needs to be evaluated, especially with respect to shifting substrates and the practicality of carrying out earthworks on the soft delta sediments.

Revegetation will promote the stabilisation of the delta, minimise the dispersal of dust, reduce the oxidation of tailings, and promote the activity of sulphate-reducing bacteria to precipitate metals in an insoluble form.

Because the river channel and delta front are unstable and subjected to frequent inundation, it is not realistic to promote revegetation of these areas until water quality has substantially improved. However, the inland areas of the delta offer good areas for the promotion of revegetation, and, depending on the results of the present wetland-dryland revegetation trial, these regions should be targeted for remediation.

The MLRRDP recognises the ongoing navigational difficulties associated with the mouth of the King River, but because of the rapid erosional re-adjustment of tailings which is occurring in the river, dredging of the mouth would not provide a long-term solution, and could create toxic plumes in northern Macquarie Harbour.

***Recommendation***

> ***Revegetation of the King River delta is recommended to enhance the visual amenity of the area and reduce dust emissions. Community groups should be encouraged to participate in the 'greening of the King', such that local ownership is promoted. Funds should be sought through applicable Government programs. In terms of water quality, the best remediation option for the King River is to clean up the water exiting the lease site.***

## 7.13 Remediation of Macquarie Harbour

Given the volumes of tailings resident in Macquarie Harbour, the exorbitant costs associated with moving them, and the relative 'safety' of where they reside, the MLRRDP recommends that no remediation effort be directed to Macquarie Harbour sediments other than reducing the input of pollutants from the Mount Lyell lease site. A cessation of pollution would enhance the amenity of the harbour for the people of Strahan, the aquaculture and tourism industries, and the World Heritage Area.

Once pollution stops entering the harbour, the contaminated sediments will continue to reside in the harbour 'forever'. Although the northern harbour has been determined to be a long term source of metals to the water column, the sediments in the southern harbour are a 'sink' for metals, and presumably, once pollution ceases entering the harbour, these sediments would eventually be buried by cleaner material.

Because of the complexities of the currents, pollutant behaviour and copper toxicity in Macquarie Harbour, it is essential that monitoring of the harbour be ongoing and comprehensive. The necessity of ongoing monitoring has been recognised by the Consultative Committee of the MLRRDP, which have passed a resolution calling on the Secretary of DELM to guarantee monitoring will occur for at least the next 5 years.

***Recommendation***

> ***The long-term water quality monitoring program in Macquarie Harbour should continue. Similar to the King River, remediating the lease site and diminishing/eliminating the discharge of acid drainage into the harbour is the best remediation strategy for the harbour.***

# 8 Where to from here?

The first step towards remediation of the Mount Lyell lease site has already occurred. The utilisation of tailings by CMT for the neutralisation of acid drainage is a step in the right direction which must now be expanded upon by Government. The MLRRDP has identified what improvements in lease site emissions need to be made to promote downstream recovery. Remediation efforts must now focus on incorporating this scientific knowledge into an engineered reality.

The next step must be for the State Government and CMT to negotiate an agreement which will promote remediation, recognise CMT's right to mineral access, and permit the involvement of third parties if required. The agreement must provide a legal, logistical and financial framework within which the following works can cooperatively occur:

- detailed engineering investigation into water management on the lease site which identifies the works required to divert all clean flows, and a plan for a retention pond and associated infrastructure;
- trialing of existing and 'new' technologies, such as SX/EW and osmotic filtration, to better determine potential copper recovery and neutralisation efficiencies.

The recent commitment of approximately $4 million by the Commonwealth Government towards Mount Lyell remediation will provide a basis for initiating these activities, though additional funding will be required to achieve an improvement in the downstream environment. Funding sources need to be identified at the Commonwealth, State and local level, and should not be limited to Government sources.

In addition to furthering the large scale neutralisation SX/EW option, the trials established by the MLRRDP for the remediation of smaller sources of acid drainage, and the revegetation of the river banks and delta, need to be monitored and assessed at regular intervals. As remediation of the site progresses, the downstream environment needs to be periodically assessed such that improvement is documented, and remediation plans are refined to optimise downstream results.