

# Case History Analysis of Mine Water Pollution in New South Wales, Australia

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## ABSTRACT

In this paper, problems associated with mine waste water discharge quality in two mines are examined in the environmentally sensitive regions in New South Wales, Australia. In the first mine, the problem of controlling and treating surface run-off from a large coal mine site is discussed. The study involved sampling and analysis of mine wastewater during various weather conditions over a period of six months. The samples were analysed for a range of physical and chemical water quality parameters. The study indicated that during minor storms, the mine wastewater treatment system worked effectively, but during a moderate to major storm, the treatment system was not adequate and that improvements in the layout were required. The second mine was concerned with rehabilitation planning and environmental management of a new gold and silver deposit in a green field site in an environmentally sensitive area. The mining complex consisted of an open pit mine, a treatment plant incorporating Carbon-in-Pulp (CIP) Cyanide process and liquid waste disposal facilities. The paper presents an environmental management strategy including a water quality monitoring program adopted in this mine based on the policy guidelines set by the Department of Minerals Resources for the environmental management of mines. This approach has demonstrated to the authorities the total commitment of mine operator to the protection of the surface environment as well as participating in the economic welfare of the community.

## INTRODUCTION

Historically, mining is viewed as an essential industrial activity incompatible with the protection of the surface environment. However, environmental issues have assumed unprecedented prominence in Australia over the past several years and occupied a central position in the political, social and economic arena. Research in Australia and overseas has established that river water quality can be seriously affected by the mine water discharge and therefore, mine waste water quality monitoring and treatment is becoming an increasingly important issue to local communities [1]. Pressures from both urbanisation and mine water discharges have necessitated the need for compliance with the standards in water quality set by the state's Environmental Protection Authority (EPA). In order to achieve the desired water quality levels set by the EPA, mine waste water treatment systems are required. Failure to meet the required standard of discharge may result in imposition of heavy fines by the EPA or in extreme cases losing of mining licence. This paper is concerned with a study to assess the performance of a new mine waste water treatment system during or immediately after major storms in order to assess the efficiency of the treatment plant. The paper also describes an environment management strategy adopted in a green site mine in an agricultural area.

## QUALITY OF MINE WASTE WATER DISCHARGE

In general, the mine effluent quality varies significantly from mine to mine. The discharge licence conditions also varies from mine to mine depending on the source and receiving waters. However, the following water quality criterion has been used as a guide by the EPA for most mine waste water discharges in this region.

NFR (Non-Filtrable Residue)	≤	30 mg/L
Chemical Oxygen Demand (COD)	≤	50 mg/L (not sensitive areas)
Chemical Oxygen Demand (COD)	≤	30 mg/L (sensitive areas)
pH	=	6.5 - 8.5

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**SURFACE RUN-OFF CONTROL AND TREATMENT- A CASE HISTORY**

**Site Description**

The Colliery concerned is situated about 30 km north west of Wollongong. The surface facilities at the mine occupy two separate areas as shown in Figure 1. The southern site for the administration buildings, pit head, bath house and workshop and the northern site for coal handling and preparation buildings, pit head, bath house and workshop and the northern site for coal handling and preparation plant (washery) and gas drainage facilities. The average coal production is some 2.0 million tonnes run of mine coal per annum. The large area between the northern and southern sites is utilised by several large stockpiles of coal and a coal refuse disposal area. Because of their size and exposure to weather, the stockpiles are prone to water and wind erosion. At the waste tip area, the soil overburden is removed and replaced with the coal refuse from the washery. The waste is then compacted, progressively rehabilitated and revegetated down the valley.

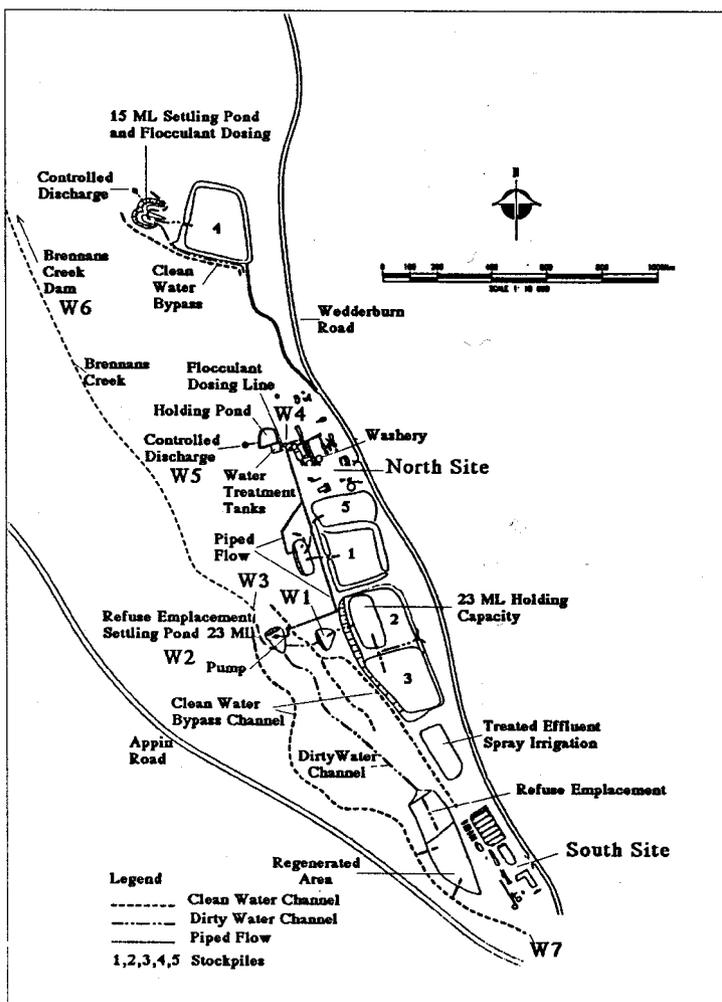
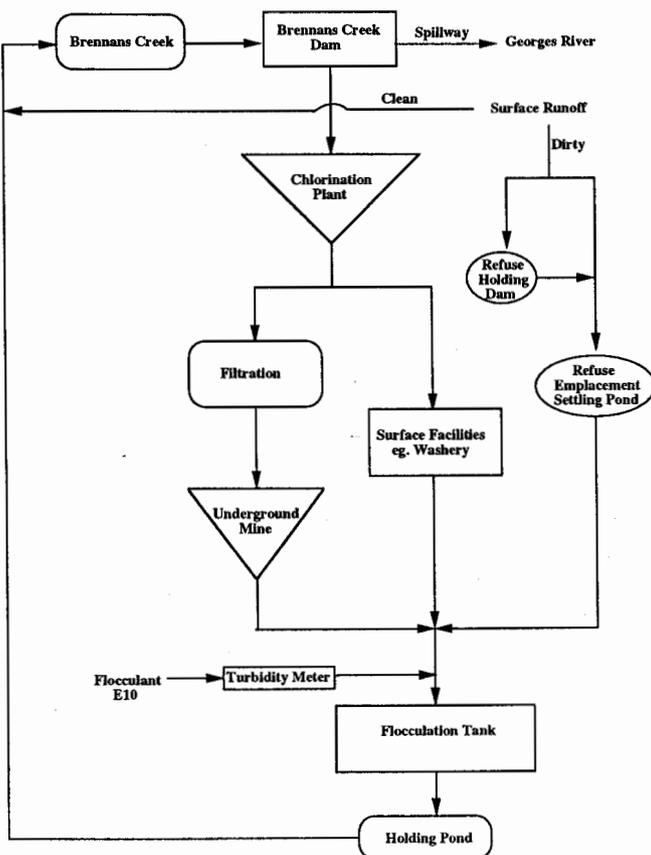


Figure 1 Mine waste water treatment facilities

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Waste Water Treatment System**

The collection, treatment and recycling of used water emanating from the mining operations are carried out in an integrated manner. All water including that from the sewage treatment plant is returned to the mine for general use via a storage dam. The dam has 500 hectare catchment area and 320 million litres capacity. Water from the dam is pumped via a chlorination plant to the surface facilities and underground mine. During moderate to heavy storms, the mining operations at the site produce a large volume of surface run-off which must be controlled and treated. Surface runoff can be divided into clean water and dirty water. Clean water from the southern site is drained into two clean water bypass channels whereas dirty water from the stockpiles (2 and 3) and refuse emplacement area is drained into the dirty water channel. The dirty water enters a 13 million litres refuse water dam and/or a 23 million litres refuse emplacement settling pond. When the dirty water in the refuse emplacement settling pond reaches a certain level, an automatic pump starts and pumps the dirty water to the mine waste water treatment tanks adjacent to the washery. Dirty water along with the mine and process water is mixed with 2.5% E10 flocculant solution at a rate dependent on turbidity of the combined mine waste water. Following the flocculation process the mine waste water overflows into a holding pond where it enters the creek and creek dam. Another settling pond is located below several stockpiles and this waste water is also flocculated prior to entering the creek. Figure 2 shows the mine waste water treatment flow sheet.



**Figure 2 Mine waste water treatment system flow sheet**

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There are only two authorised EPA waste water discharge points on the site. One is located at the creek dam spillway while the other is at the treated effluent spray irrigation area. Approximately 1500 m down stream from the dam, creek flows into the Georges River which is classified by the EPA as class "C" - Controlled Waters. The discharge licence condition at the dam spillway states that water shall not be discharged during dry season. It also states that during wet weather, monitoring of the discharge must be undertaken but with no set limits on any water quality parameters.

Several large stockpiles and a dirt disposal operation occupy most of the southern site. Because of this and the high annual rainfall in the region, surface run-off creates several difficulties in controlling and treating the effluent. Recently new improvements have been carried out in this area including the construction of clean and dirty water channels, a refuse holding dam and a refuse emplacement settling pond. These improvements followed on from the earlier findings that the mine water effluent had the highest Non Filterable Residue (NFR) concentration of nine mines studied in the Illawarra region [2].

**Sampling Locations and results of water analyses**

In order to assess the performance of the mine waste water treatment and disposal system during storms, seven sampling locations were established. These included upstream and downstream sampling locations in addition to five sampling locations within the mine waste water treatment system as outlined in Table 1.

**Table 1 Mine sample locations and description**

Sample Location	Site Description
W1	Refuse holding dam
W2	Refuse emplacement settling pond
W3	Clean water by-pass channel adjacent to refuse emplacement settling pond
W4	Dirty water from the refuse emplacement settling pond
W5	Holding pond spillway
W6	Discharge point
W7	Upstream from mining operations

The mine's waste water treatment was sampled twice over a six month period. These sampling days occurred immediately after two intense storms. The results of some of the physical and chemical analysis of water are given in Table 2. At sampling locations W1, W2, and W4 mine waste water was heavily polluted with coal fines which gave it a black colour. On both sampling days water in the clean water drain and at the creek dam spillway was observed to be clean. Finally, a significant improvement in the mine waste water colour was noticed on both sampling days after the flocculation process.

**Discussion**

The purpose of the mine water quality control installation at this mine was to reduce the very high Non-Filterable Residue (NFR) content in the water. The system was designed to deal with the storm water discharge immediately following a 10 mm rainfall over a period of 24 hours. It was therefore no surprise that the water quality was not within the prescribed limits on the initial day of sampling primarily due to a moderate to heavy rain storm (92 mm of rainfall in 48 hours). It is also observed that the size of 23 million litres settling pond was inadequate for heavy storms. A large quantity of dirty water would have discharged into clean water drain and therefore, into the creek dam during this storm. This may be seen by the high NFR results obtained at W6 on 15/9 (a day after dirty surface run off had discharged into the creek) in comparison to low NFR at W6 on 5/10. Flocculating the

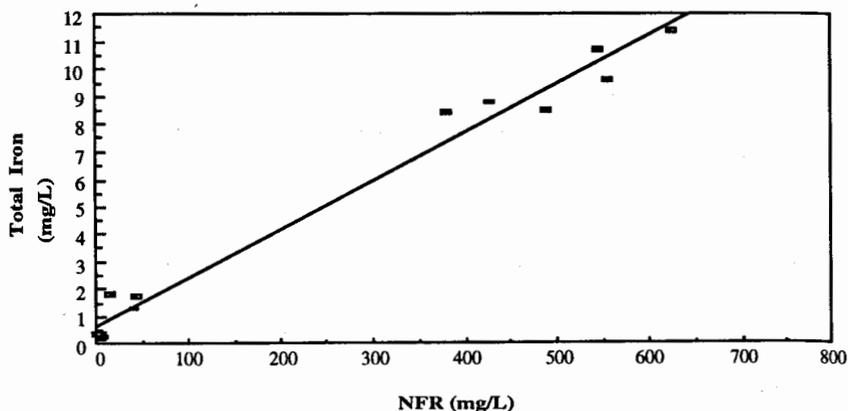
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 dirty surface run-off with E10 was found to be an effective method of reducing NFR in the mine waste water discharge. The efficiency of flocculation during the period of study was between 89 to 97 %.

Table 2 indicates that the Conductivity and Total Dissolved Solids in the mine waste water increased from W2 to W5 on both sampling days. This was primarily due to the mine water from the pit together with washery effluent was mixed at W4. It may be assumed that both these effluents had high TDS content. It is also interesting to note that the TDS at the creek dam spillway was relatively high on both sampling days when considering the amount of rainfall prior to sampling. Other Collieries in the region also discharge mine water to the same creek which increases the salinity level in the Upper Georges River.

**Table 2 Mine waste water quality after storm events**

Sampling location	Colour		NFR (mg/L)		TDS (mg/L)		Conductivity (µS/cm)		Total Iron, mg/L	
	15/9	5/10	15/9	5/10	15/9	5/10	15/9	5/10	15/9	5/10
W1	black	black	426	624	195	212	323	426	8.82	11.4
W2	black	black	546	556	268	277	456	733	10.70	9.64
W3	clear	-	-	1	-	33	-	138	-	0.37
W4	black	black	380	488	842	893	1240	1450	8.45	8.52
W5	brown	brown	42	14	856	868	1525	1672	1.72	1.83
W6	clear	brown	40	8	796	781	1088	1455	1.29	0.26
W7	clear	clear	6	5	310	308	724	688	0.22	0.37

It can be seen in Table 2 that there is a high total iron content in mine water which could be correlated to high iron content of the coal. The sampling locations W1, W2, and W3 are heavily polluted with coal fines and the NFR at these locations can be correlated to total iron content as shown in Figure 3.



**Figure 3 The relationship of NFR with total iron content of mine waste water**

5<sup>th</sup> International Mine Water Congress, Nottingham (U.K.), September 1994

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No heavy metals were detected within the surface run-off treatment system above any significant level on either group of samples. Finally, most parameters increased between the upstream and downstream sample locations.

#### **Summary of results**

The new surface run off treatment system does not perform up to expectations during and 24 hours after a moderate to heavy storm. Due to the inadequacy of the refuse emplacement holding pond, dirty surface water can pollute the Creek and the Creek Dam in case of moderate to heavy storm events. But the treatment system was very effective in reducing high NFR from entering the Creek during the minor storms.

Mine waste water quality varied significantly throughout the mine waste water treatment system. At the Dam Spillway, the TDS of the discharge was relatively high, therefore the discharge may increase salinity levels in the upper Georges River. It was also found that the total iron of the waste water was in substantial quantities and a correlation exists between total iron content and NFR of the mine waste water. No other heavy metals were detected in the mine waste water to a any significant level and most physical and chemical parameters increased between the upstream and downstream sample locations. One of the recommendation from the above study was that in order to handle large quantities of storm water, a valve should be placed at the exit of stockpile 2 holding dam so that dirty water can be controlled down to the refuse emplacement settling pond.

### **ENVIRONMENTAL MANAGEMENT OF A NEW GOLD AND SILVER MINE IN A GREENFIELD SITE**

#### **Environmental Approach to Mine Planning**

By its very nature, mining operations disturb the surrounding natural land, air and aquatic environments. Therefore, it is necessary to conduct mining operations with the environmental safe guards and rehabilitate the mine after completion of the mining operations in order to meet the expectations of the community, government and the industry. Mining and explorations, in New South Wales, Australia, are authorised under any of the following three principal legal authorisation procedures:

- (i) A Mining or Coal Lease issued by the Department of Minerals Resources and operated in compliance with the lease conditions.
- (ii) By virtue of the private ownership of the mineral and in accordance with the conditions of the development consent. This is implemented by the State Environmental Protection Authority or
- (iii) Under a title granted under the Crown Lands Act by the Department of Conservation and Land Management.

Thus, in recent years there is a shift in the public expectation that the regulatory authorities should pay emphasis to anticipating and preventing environmental impact due to mining rather than using earlier reactive approach [3]. The Department of Mineral Resources is responsible for promoting mining development, management and utilisation of minerals resources in New South Wales. It places emphasis on environmental factors in planning, operational and rehabilitation phases of mining. This objective is achieved by using a combination environmental management plans, appropriate conditions on titles, and financial guarantees against performance, developed in consultation and co-operation with industry [4].

#### **Lease Condition and Financial Guarantee**

Most mining in New South Wales is authorised by a title issued under the mining Act 1992. The principal sections of the Act enabling the imposition of conditions are section 70 - under which a mining operation can not be suspended without written consent of the Minister, section 273 which protects natural resources, section 238 - which includes conditions for protecting the environment

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and section 239- which deals with the rehabilitation of area damaged by mining. The last condition is particularly important as it permits the Department of Mineral Resources, through the Minister, to vary the environmental or rehabilitation conditions in a mining title. This power of amendment illustrates the importance placed on satisfactory environment performance to vary the lease condition.

Until passing of the 1992 Act, the only available sanction for the breaches of the lease conditions was the cancellation of the tenement. While this threat is still pertinent, implementation of such threat in reality is highly improbable. However, the Mines Act 1992, section 5, has created an offence to carry out mining in contradiction to the conditions of the mining lease issued by the Department of Minerals Resources which are specified in the Mining Rehabilitation and Environmental Management Plan (MREMP).

### **Mining Rehabilitation and Environmental Management**

The Mining Rehabilitation and Environmental Management Plan is an essential official vehicle for providing environmental considerations into mine planning [4]. It prevents adverse effects of mining, reduces environmental cost and provides agreed procedure for rehabilitation of the mine after mining operations have ceased. In order to encourage responsible mine environmental management, the title holders are required to submit as a condition of their title to the Department of Minerals Resources a detailed MREMP for approval. This plan is reviewed annually throughout the life span of the mine. All concerned authorities are represented at a single on-site meeting to discuss the plan with the mine operator's representatives. The plan is then approved as submitted or on a modified form. The compliance of the approved plan is then mandatory, although there is a provision for amendment during the year if circumstances change. The annual reporting procedure is the key element to MREMP. Thus, the Environmental Rehabilitation and Environmental Management Plan provides flexibility to both mine operators and government in response to changing circumstances and increasing knowledge of the local environment. In order to assist the mine operator in the preparation of MREMP, an extensive set of guidelines are prepared by the Department of Minerals Resources by incorporating both short term mining operational objectives and long term rehabilitation goals of the mine. The scope of the MREMP documentation can be varied with the scale of operations. The Department of Mineral Resources is responsible for overseeing the plan, for co-ordinating the input of various government authorities and ensuring that the mine operations and rehabilitation programs are being carried out in accordance to the lease conditions and the MREMP. The advantages of Mine Rehabilitation and Environmental Management Plan are as follows:

- The plan incorporates all government actions and compliances in a single documentation, thus, avoiding conflicting government requirements and developing a single reporting system.
- The agreed MREMP permits rapid evaluation of controls and eliminates unnecessary duplication of efforts by various government authorities and the mine operator.
- For the Department of Mineral Resources, the MREMP ensures that environmental planning is an integral part of mine planning and not introduced as a piecemeal or as of minor importance.
- An annual review and a single combined site inspection meeting eliminates lot of interference and duplication by government departments
- Integrated mine planning and environmental management approach has resulted in cost reductions by many mining operations. Thus, MREMP concept is a valuable instrument for assisting both government and industry in the management of environmental impacts of mining from large gold mines to small intermittently operating quarrying operations.

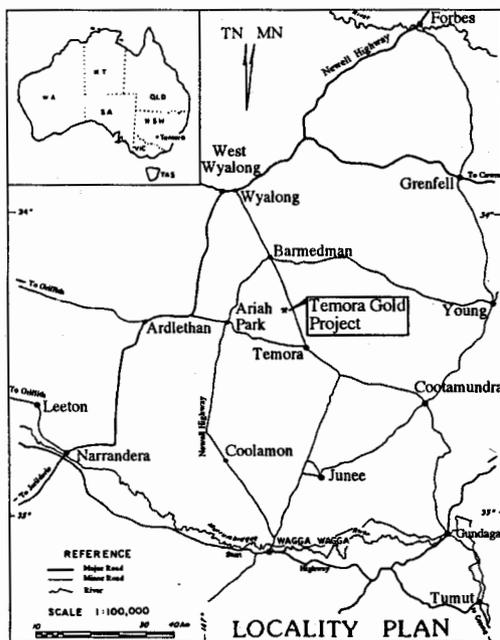
### **Operating a New Gold and Silver Mine in Green Field Environment**

The mine concerned is a new gold and silver open cut operation, located on an ore deposit which has not been previously mined. The mine is located approximately 15 km north of Temora and is the largest gold producer in NSW, Australia (Figure 4). The deposit comprises 4.5 million tonnes with

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2.5 g/t gold, 5.4 g/t silver together with 1.6 million tonnes low grade ore with less than 1.5 g/t gold. This mine has been successfully established in an agricultural area and is a major industrial and financial venture supporting the township of Temora. From the very onset, the mining proposal at Temora was planned and executed on the principle of environmentally sustainable development to provide economic stimulus to local businesses. The major features of this project are that the mining is carried out by open cut methods and on site treatment of ore by carbon-in-pulp method which necessitated strict environmental control to minimise surface impacts and potential cyanide pollution problems.



**Figure 4 Locality plan of the Temora mine site [5]**

**Site Description**

The mine is situated about 15 km north of Temora within a 680 hectare farming properties of 'Lilydale' and 'Cedar' (Figure 4). The company also owns an exploration lease of 7560 hectare in the vicinity. The mine comprises an open pit mining operation, and the surface facilities including an administrative building, a mill, workshop and a sub-station. The average mineral production is some 0.7 million tonnes run of mine ore per annum. The open pit itself occupies 21 hectare and surrounded by the company's land for carrying out all ancillary operations within the lease-hold. The surface area on the north-west side of the open pit is used to store soil and the western side of the open pit is utilised for stockpiling low grade and marginal ores. The southern part of the pit is used for the disposal of waste and marginally overburden material. The south west part of the lease area was used for the disposal of tailings and liquid waste. Figure 5 schematically represents the Temora project development from the exploration stage to production stage.

**Mining and Recovery Operations**

All mining operations were carried out by a mining contractor who was responsible for production, transportation and disposal operations. The ore and overburden were mined by drilling and blasting operations, and removed by hydraulic excavator and 50 tonnes dump trucks. The ore was delivered to the crusher or preferably to the ore and low grade stockpiles to facilitate blending. Waste material

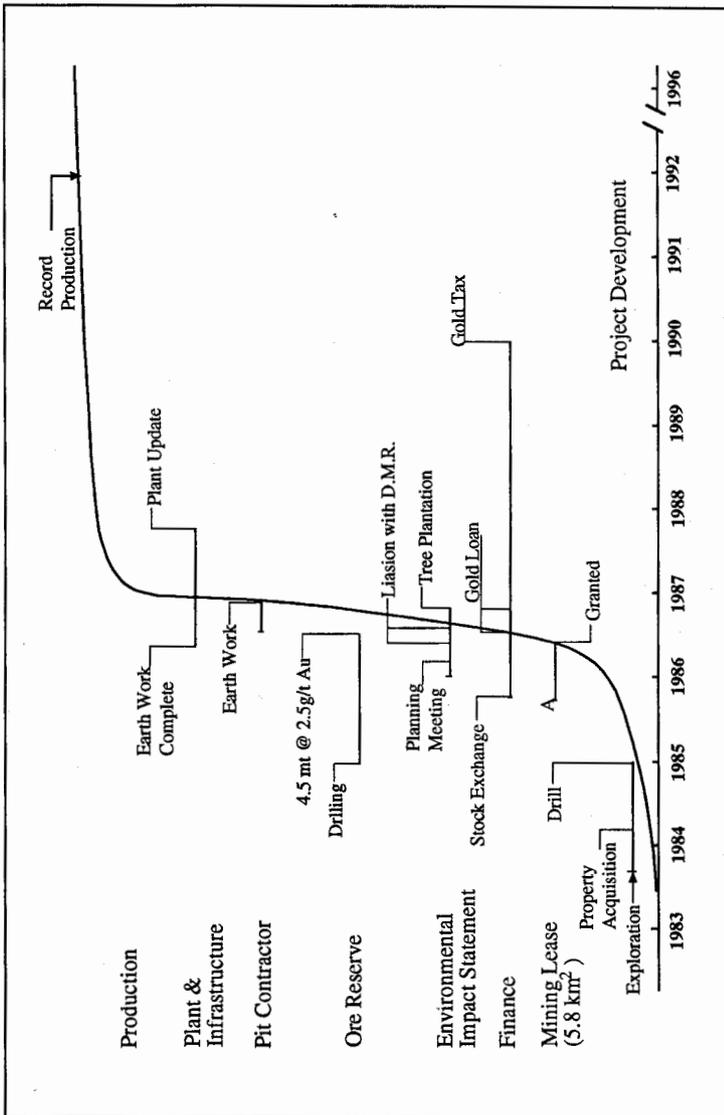


Figure 5 Temora mine project development plan

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was taken to the waste dumps or for constructing containment walls of the tailings dams. The ore on the stock pile was blended according to hardness and grade and transported to the crusher to meet the milling requirements. The mill was commissioned in February 1986 with a capacity of 500,000 tonnes per annum which was upgraded to 800,000 tonnes per annum in 1988. The ore from the stockpile is fed to the mill by front end loader and truck. The ore received from the stockpile or the mine is crushed in a single stage double toggle jaw crusher from top feed size of 1m down to a product size of 200 mm. The crushed ore is stored in a coarse ore bin of 2,900 tonnes capacity before being conveyed to one of the two grinding mills to reduce to the particle size of 150 microns. The finely crushed ore is then leached in a cyanide solution which chemically removes gold and silver from the ore.

The gold and silver are recovered as cyanide complexes from the leach solution with carbon granules utilising carbon in pulp process. The metals are recovered from the solution by electrolysis and smelting the cathodes in gas fired barring furnace. The final product is a gold bullion containing between 25-30% fine gold, 40-45% silver and remaining 25- 35% copper. The solution after the recovery of precious metals is disposed off in tailings cells. The cells are designed to decant and settle the tailings expediently, decompose cyanide in the solution and maximise the recirculation of the process water to the treatment plant (Figure 6). When each cell is full of the dry tailings, it is progressively rehabilitated by compacting the surface, covering it with subsoil and top soil and revegetating it with selected trees and shrubs.

### **Environmental Management of the Site**

From the very onset of the project, it was decided that after restoration and rehabilitation of the mining operations, the site will return to grazing. Particular emphasis was placed on the visual screening of the site operations, progressive, and maintenance free site rehabilitation of waste dumps, low grade ore stockpiles and tailings cells (Figure 6).

Special attention was given to stabilise all earth works, drainage lines and disturbed land from erosion by means of combination of tree plantation, grassing and rock armouring. Clean and dirty water runoff was to be kept separate to minimise contamination of the revegetated areas. On all areas owned by the company surrounding the mining and waste disposal sites, soil conservation and farm management practices were carried out in accordance to the accepted guidelines of the Soil Conservation Service.

One of the main conditions of granting mining lease at Temora was completion of an Environmental Impact Statement for the site and its acceptance by the statutory authorities. The main outcome of the Environmental Impact Statement (EIS) was to carry out the base line environmental monitoring of the site and preparation of Mining Rehabilitation and Environmental Management Plan for the mine. The main feature of the environmental management plan was to ensure complete restriction of waste water discharge from the mining lease and to carry out environmental monitoring of air quality, waste water quality and noise levels around the mining operations.

### **Water Quality and Dust Monitoring**

Water quality samples were taken two years prior to the commencement of the mining operations both within and outside the mining lease. Ground water quality was monitored on a quarterly basis in the piezometric boreholes around the periphery of the tailings dams to detect possible seepage. Four key water sampling sites outside the mining lease and five sampling sites within the mining lease are regularly monitored for a range of chemical parameters (Figure 6). Results to date indicate that there is no contamination of water downstream of the mining lease and that the normal pollution control measures are adequate. Consequently, at an annual review, some of the conditions for water quality monitoring have been relaxed at certain locations [6].

In addition water quality monitoring, monthly monitoring of air quality at seven residential sites was also undertaken during this period. Dust monitoring 20 months after the commencement of mining operations have shown no substantial increase in the ambient dust levels. As a result of the review of the MREMP, the dust sampling operations are now discontinued [6].

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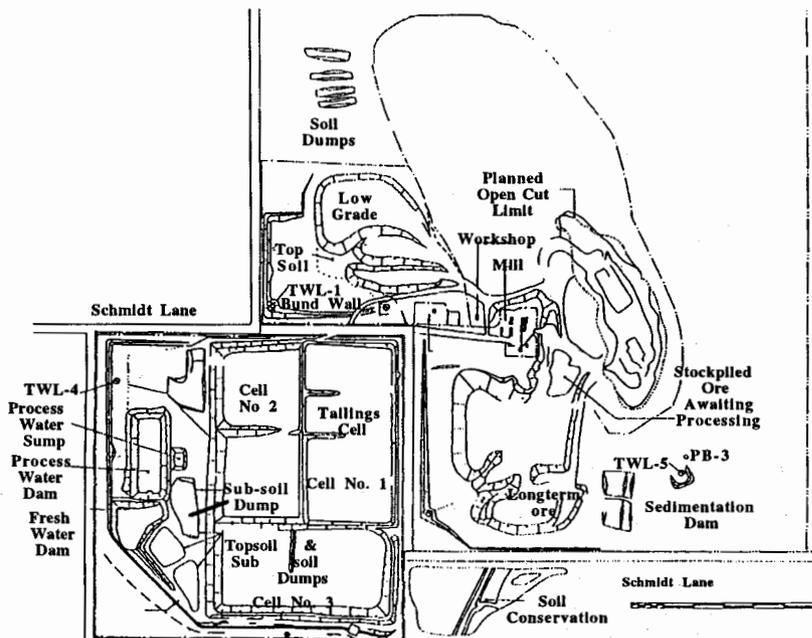


Figure 6 Site layout of the surface facilities [5]

**Noise and Blast Monitoring, and Erosion Control**

Regular monitoring of noise and blast vibration levels during mining at various locations surrounding the mine has ensured that operational safe guards are followed to keep these impacts within the accepted limits. ( 45 dBA 7.00 am to 10.00 pm, and 35 dBA 10.00 pm to 7.00 am). Acceptable overblast pressure level is < 115 dBA (linear) at private residences.

A soil erosion management and conservation program is an essential part of the overall rehabilitation strategy of the mine site. Topsoil removal and stockpiling is continued as mining and waste rock disposal continues. The soil mounds are seeded and grassed to ensure stability and to preserve nutrient levels until it is used for revegetation. Land degradation is further reduced by the construction of contour banks and erosion protection works. This protective work has permitted greater catchment and flow of water to downstream farms.

**Conclusions**

The Mining Rehabilitation and Environmental Management Plan provides a dynamic mechanism to evaluate environmental performance of a mine against stated objectives and provides a mechanism for review of the regulatory controls on an annual basis. As a result of this procedure, it was possible to discontinue dust monitoring at Temora Mine on the basis of past records of dust levels. At the same time, assessment of water quality data resulted in a permission to release some dirty water off site. Frequency of monitoring at certain localities has also been relaxed, sampling now being required after significant rainfall.

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