PROPOSED UPGRADED ILMENITE PROJECT

AT CAPEL WESTERN AUSTRALIA

BY

WESTRALIAN SANDS LTD

REPORT & RECOMMENDATIONS

BY THE

ENVIRONMENTAL PROTECTION AUTHORITY

DEPARTMENT OF CONSERVATION & ENVIRONMENT

PERTH, WESTERN AUSTRALIA.

BULLETIN 225

JUNE 1985

ISBN 0 7309 0658 2

PREFACE

Following its assessment of the Public Environmental Report (PER) for the proposed upgraded ilmenite project at Capel by Westralian Sands Limited (WSL), the EPA concluded, in its report of June 1985 (Bulletin 225), that the project was likely to have unacceptable environmental impacts on the ground and surface waters around Capel. In response to further information supplied by WSL, the Department of Public Works and the Government Chemical Laboratories, the EPA prepared an addendum which concluded that the major objections to the project had been overcome. This is dependent upon the Company strictly following the commitments given in the PER and its subsequent submissions. The EPA's report and addendum are presented herein.

1. INTRODUCTION

Westralian Sands Limited (WSL) is proposing to construct and operate a plant to produce upgraded ilmenite from ilmenite taken from the Company's mine at Capel.

The EPA has assessed the proposal following the preparation and Public Environmental Report (PER) by WSL. The PER was released for public comment for a period of four weeks. Further discussions have taken place between the Company, the Public Works Department and the Department of Conservation and Environment on the disposal of solid and liquid effluents. The results of these discussions are incorporated in this report.

2. SUMMARY AND GENERAL COMMENTS

The EPA does not consider the proposal to be environmentally acceptable in its present form.

The project is unacceptable in the following areas:

1) The control of leachates from the solid waste disposal sites: The Company is currently proposing to dump iron oxide and a neutralised effluent solid into the North Capel mine site and one-year capacity surface pits. It is probable that water leaching through these materials will carry various salts into high quality groundwater. The EPA is not convinced that the methods currently proposed by the Company will stop this leaching and prevent contamination of the groundwater.

2) As part of the process the Company proposes various holding dams to contain process liquors. If these dams leak, effluent containing acid, metals and salts could enter the groundwater. The EPA is not convinced that the methods currently proposed by the Company will detect any leaks and recover the lost liquors which may contaminate the groundwater.

3) The Company proposes to discharge treated effluent to the Elgin Drain which ultimately will enter the Geographe Bay. The EPA is not convinced that the proposed effluent treatment systems devised by the Company will achieve the Company's stated objectives of discharging water into the Elgin Drain with levels of contaminants reduced so as to be in accordance with criteria for aquatic ecosystems laid down in the Australian Water Resources Council's "Compilation of Australian Water Quality Criteria".

It is necessary that on completion of operations there is no negative environmental legacy which the State will inherit.

This project proposes to use a considerable amount of groundwater to supply the plant. The 2.6 x 10^6 m^3 yearly plant water consumption is equivalent in volume to a little less that half Bunbury town's yearly water supply. The EPA considers that the potentially serious environmental impacts relate to this large water usage. If the Company modified its processing technology to decrease its water usage and recover water from its waste products the possible environmental impacts of this project could be greatly reduced.

This Report contains recommendations which show the direction in which the planning for this proposal should proceed if ultimately it is to become environmentally acceptable.

3. PROJECT DESCRIPTION

The major raw materials for the process are ilmenite from WSL's mine at Capel, coal from Collie, a sulphur source, ammonium chloride, lime and sulphuric acid from Perth and other sources.

The raw materials and product will be transported by road.

Ilmenite is roasted in a kiln with coal and a sulphur source. The roasted ilmenite is then contacted with a weak ammonium chloride solution to oxidize the iron in the roasted ilmenite. The iron oxide is then removed by washing. Acid leaching is then used to remove residual iron from the mineral grains to leave ugraded ilmenite. The major effluents are:

Air - sulphur dioxide, particulates

Solid - iron oxide, inert solids predominantly char and dust, neutralised effluent solid.

Liquid - plant spillage, potential leakage from process liquor holding dams, leachate from solid waste dumps, neutralised effluent liquor discharge.

The ilmenite will be supplied from the Company's mines at Capel.

The EPA notes the Company's statement that this plant will consume 180,000 t yr^{-1} of ilmenite feed, all of which can be supplied at WSL's current mining rates. The EPA understands this to mean that ilmenite which would previously have been exported will now be processed locally and that this plant will not create a demand for the enlargement of existing granted tenement areas.

Water for the process will be abstracted from deep aquifers below the site.

4. ENVIRONMENTAL IMPACTS AND MANAGEMENT

4.1 Site

The site was selected because it was close to sources of the raw materials, was near to the North Capel mine pit, which provided a location to dispose of solid waste, and was close to the Company's existing infrastructure.

The processing works and the proposed waste disposal sites are located on the Company's land.

4.2 Raw Materials

As indicated above the raw materials from the project will come from various sources. The upgraded ilmenite will be exported from Bunbury and the majority of the solid wastes will be disposed of on site.

The EPA notes near neighbours' opposition to the proposed site based upon the public's experience of noise and dust nuisance from WSL's existing mining operations in the north Capel mine pit.

The company has plans to institute measures to control dust emissions from transport and stockpiles. However, comment has been made on the potential for dust nuisance from the disposal of solid wastes the EPA recommends accordingly.

RECOMMENDATION

If the three major environmental impacts of this proposal are rectified, and if the project is to proceed, the EPA also recommends that dust emissions from stock piles, transportation of raw materials, waste disposal and product be controlled at all stages of the operation. The Company should submit its plans for dust control for approval to the Department of Conservation and Environment.

Water will be drawn from the aquifers 150-200m below the plant site. The geology of the area is such that it is possible that there could be connections between this aquifer and the surface aquifers from which other users, eg farmers draw water. The Company proposes to extract 2.6 x 10^6 m^3 yr^{-1}; this is a significant amount of water equivalent to a little less than half the yearly water demand of Bunbury town. Because of the possibility of the deep and shallow aquifers being connected it is possible therefore that a such an abstraction of groundwater could affect the surrounding water users and possibly exclude other beneficial future uses of this resource. The abstraction of groundwater will need to be licensed under the Rights in Water and Irrigation Act and the Company will have to satisfy the Public Works Department's licensing requirements.

The PER does not give detailed information on the storage of hazardous chemicals eg sulphuric acid or the emergency procedures to be implemented following the spillage of such chemicals. However the Company has indicated that sulphur will be stored on site undercover in a sealed area of the plant. This will prevent any acidic leachates being formed in the sulphur store.

RECOMMENDATION

If the three major environmental impacts of the proposal are rectified, and if the project is to proceed, the EPA also recommends that details of the storage of hazardous chemicals and

contingencies to recover spillage should meet the requirements of the Explosives and Dangerous Goods Division of the Department of Mines.

4.3 Air Emissions

The major air emissions are discussed below:

4.3.1. . The Final Products Drying.

The characteristics of this gas are by % volume

CO_2	2.3
H_2O	19.7
N_2	61.6
O_2	16.4
SO_2	0.01
particulates	0.3g m^{-3}

This will be emitted through a stack 14.3m high in accordance with the Clean Air Act;

4.3.2 . The Dedusting System.

Following scrubbing the emitted air will have a particulate load of 0.3g m^{-3} and a moisture content of 2.5%;

4.3.3 . The Kiln Exhaust Gas.

This is the major source of air emissions. The gas will be passed through a series of cleaning steps. When it is finally emitted it will have the following composition by % volume.

CO_2	9.7
H_2O	49.5
O_2	1.9
SO_2	0.2
CO	nil
H_2	nil
particulates	0.3 g m^{-3}

It is assumed that the remainder of the gas is made up of nitrogen.

This is emitted at a maximum discharge rate of 90 940 m^3 hr^{-1} through a stack with a height of 52m above ground level.

The significant pollutants are:

sulphur dioxide	6.3g m^{-3}
particulates	0.3g m^{-3}

The particulate emission level of 0.3 g m^{-3} is above the level normally permitted under the Clean Air Act. Based on the isolated location of the plant the Company applied to the Air Pollution Control Council for an exemption. The Council approved this exemption and granted a maximum emission level of 0.3 g m^{-3}.

4.4 Liquid Wastes

This plant will utilise 2.6×10^6 m^3 yr^{-1} of an available source of good quality groundwater. There is a danger that this plant could disadvantage later demands for water and, if leakages of the various process effluents are allowed to occur, could diminish the water quality.

The following are potential sources of pollution involving liquid waste:

- from pipe breakage, plant spills and process liquor holding dam leakage;

- leachate from the neutralised effluent solids solar evaporation ponds;

- the effluent stream from the clean water storage dam to the Elgin drain;

- leachates from the iron oxide and neutralised effluent solids disposal sites.

4.4.1 . Pipe Breakage, Spills and Dam Leakage.

As indicated in the PER, the monitoring of pipe breakage and the containment and clean up of plant spillage are a matter of good design, good house-keeping and close observation of operations.

The Company proposes to use 1mm polyethylene liners under all its process liquor holding dams. Furthermore if monitoring bores positioned around the dams indicate a breach in the liner has occurred the dam will be taken out of service and the liner repaired.

The EPA recognises that the Company will have to maintain a high standard of operational competence to avoid spillage and pipe breakage. The design of the various process liquor holding dams will have to be approved by the Water Resources Branch of the Public Works Department.

4.4.2 . Neutralised Effluent Solids Evaporation Pond.

The leachate from the neutralised effluent solids evaporatic ponds will contain numerous contaminants, the major ones being:

Total Dissolved Salts TDS	2900
SO_4	3100
Ca	510
Mg	370

all the above are in mg l^{-1}

These figures, supplied by the Company, show some discrepancy between TDS and SO_4.

The design of this pond will also have to be approved by the Public Works Department.

4.4.3 . Effluent to the Elgin Drain.

The Company proposes to combine three process liquor effluents streams. These are:

- liquids from the in-plant dedusting system and the kiln cooler;
- the lime neutralised acid leaching effluent;
- the kiln scrubber liquid.

The Company proposes to modify the pH of this effluent stream to maximise the precipitation of dissolved metals. The major metal contaminant removed will be zinc. Other metals including copper, chromium and nickel will also be precipitated out of solution.

Following pH adjustment the decant liquor will be passed through a man-made wetland (a biological filter) and into a drain which leads to the Elgin Drain. The Elgin Drain connects with the Gynudup Brook, a tributary of the Capel River which in turn drains into the Geographe Bay. The Company considers that the pH adjustment and the biological/ wetland filter will enable it to achieve final water discharge to the Elgin Drain of a quality in keeping with the criteria laid down for aquatic ecosystems in "A compilation of Australian Water Criteria" as prepared by B T Hart for the Australian Water Resources Council.

RECOMMENDATION

If the three major environmental impacts of this proposal are rectified, and if the project is to proceed, the EPA also recommends that the Company should not be permitted to commence operation until it is demonstrated to the satisfaction of the Public Works Department that it will achieve its stated water quality criteria for its discharge water. Furthermore if the quality of the discharge diminishes below the accepted criteria the Company should cease operation until the measures can be instituted to reduce the levels of contaminants.

Farmers in the surrounding area are required to contribute towards the cost of drainage of their land and drain upkeep on a cost per hectare basis. The EPA suggests that the question of the Company contributing toward the cost of the upkeep of the Drain should be investigated as part of the discharge licensing procedure.

4.4.4 . Leachates from Solid Waste Disposal

The leachates from the disposed effluents are considered in the following section

4.5 Solid Wastes and Leachates

As stated previously the major solid wastes are:

- iron oxide solid, containing 1% ammonium chloride by weight with a moisture content of 32%
- inert solids predominantly char, coal and dust
- neutralised effluent solids, mainly a mixture of precipitated gypsum, iron oxide, unreacted lime and other materials.

4.5.1 . Iron Oxide and Inert Solids.

The iron oxide is the product of reacting the roasted ilmen with an ammonium chloride solution. The Company proposes initially to dump the inert solids and iron oxide into North Capel mine pit. Once this has been filled 1 year capacity surface pits will be used. These pits once filled will be covered with 1 metre of sand. While the inert solids are largely unreactive there is a possibility that ammonium chloride will be leached out of these dumps and will contaminate good quality groundwater with high Total Dissolved Salts (TDS) and ammonium and chloride ions.

The Company proposes to monitor the groundwater below the disposal site. If monitoring shows that leaching of ammonium chloride is occurring the Company proposes to recover the contaminated groundwater and treat it in a biological/ wetland filter. A further proposal to reduce leachates is to cap the iron oxide with a clay seal.

RECOMMENDATION

If the three major environmental impacts of this proposal are rectified, and if the project is to proceed, the EPA also recommends that:

1. The techniques employed for the disposal of the iron oxide and inert solids should be approved by the Public Works Department. Factors which should be considered are the disposal of the waste at least 1m above the highest known winter water table, capping the waste in a sound engineering manner with an appropriate material (such as clay) as dumping proceeds, and monitoring for leachates below the dump.

2. **If levels of leachate from the iron oxide disposal which are unacceptable to the Public Works Department continue to enter the groundwater even after capping of the disposed material, the Company should find alternative means of disposing of its waste and recover the waste already in situ.**

3.5.2 . Neutralised Effluent Solids

The neutralised effluent solids are the precipitate which results from the reaction of lime with the acid leaching liquor and the kiln scrubber liquid.

The Company is testing this by-product for its potential as a soil conditioner. The EPA considers the Company should continue its investigations of this method of disposing of this waste. If however these tests prove that it is unsuitable for utilisation for upgrading farm soils the Company proposes to dispose of it in one year capacity surface pits.

There is the possibility that leachates from the disposal of neutralised effluent solids containing dissolved salts, sulphate, calcium and magnesium ions could reach the groundwater.

RECOMMENDATION

If the three major environmental impacts of this proposal are rectified, and if the project is to proceed, the EPA also recommends that, if one year capacity surface pits are to be used, the Company should monitor the groundwater below these pits

for leachates. The monitoring network should be approved by the Public Works Department. Furthermore, the recommendations made above for the disposal of the iron oxide should apply for the neutralised effluent solids.

4.6 Radiation

The Company has presented a report on the assessment of radiation at the proposed plant as an appendix to the PER. The report concludes that, with some possible exceptions, radiation levels in the plant would be below the limits specified in the Code of Practice on Radiation Protection in the Mining and Processing of Mineral Sands (1982) for a controlled Area.

RECOMMENDATION

If the three major environmental impacts of this proposal are rectified, and if the project is to proceed, the EPA also recommends that the Company should have its report on the radiation assessment meet the requirements of the appropriate regulatory Authority.

3.7 Monitoring

The Company has proposed an extensive monitoring programme of the air, and surface waters and groundwaters.

RECOMMENDATION

If the three major environmental impacts of this proposal are rectified, and if the project is to proceed, the EPA endorses the monitoring programme and also recommends that a further detailed monitoring programme be prepared to monitor the leachates from the waste disposal sites. This programme should be to the satisfaction of the Public Works Department.

5. SUMMARY OF COMMENTS

5.1 The Busselton Shire

- Strongly objects to the discharge of any effluent into any watercourse reaching Geographe Bay;
- believes WSL intends to discharge treated liquid wastes into watercourses leading to Geographe Bay;
- contamination of groundwater can occur if pipes or dams leak.

5.2 Public Works Department

- Commented on the necessity for licensing the abstraction of groundwater;
- said that there were inconsistencies in the tabulated analyses of the various fluids;

- protection against pipe leakage is needed;

- recovery bores are proposed to manage spills which may contaminate groundwater. Final approval of this would require adequate demonstration that this will be effective;

- pond lining design needs to be checked. Ponds should handle overfilling risk;

- sulphur store leachates should be avoided protection should be provided against sulphuric acid spills;

- the surface water discharge should be licensed under Pt III of the Rights in Water and Irrigation Act. This licensing will require adequate demonstration that effluent quality can be maintained within acceptable criteria using acceptable methods. Final approval should be contingent upon this;

- the alternative surface water treatment methods are questioned;

- the PER is too superficial in its consideration of the possible effects of the project on the ground and surface waters.

5.3 Public Comment (one written submission and one phone call).

- The public assessment period was too short for adequate public comment.

- The technical aspects are too hard to understand.

- The site selection was considered to be purely on financial grounds. Requested that this proposed plant be placed next to the existing plants so pollution is confined.

- WSL should be charged for the use of the Elgin Drain.

- Salt water intrusion has occurred into a nearby land holder's well since the N. Capel mine pit has been operating. This raises fears that contaminated groundwater may also affect water supplies.

- Extra abstraction of groundwater could lead to increased salt intrusion into wells.

- Stated that windblown dust from the mining operations is an existing problem in summer. The UGI plant disposal pits will make this worse.

5.4 Conservation Council

- Sought assurances that the operation of this plant won't create the demand for any further mineral tenements.

6.0 CONCLUSION

The EPA considers that this project, in its present form, is likely to result in unacceptable environmental impacts on the ground and surface waters around Capel. The EPA considers that it should not proceed until the Company can adequately demonstrate that the issues highlighted in this report can be successfully accounted for.

PROPOSED UPGRADED ILMENITE PROJECT

AT CAPEL WESTERN AUSTRALIA

BY

WESTRALIAN SANDS LTD

ADDENDUM TO THE

REPORT & RECOMMENDATIONS

BY THE

ENVIRONMENTAL PROTECTION AUTHORITY

SUMMARY

The EPA considers that the original proposal as detailed in the Westrailian Sands Ltd PER was environmentally unacceptable. The Company has since submitted further information to the EPA and committed itself to strict management provisions. The most significant of these is that if contaminants in the Company's effluents exceed accepted criteria the Company will cease discharging effluents.

While the EPA considers that the new information and commitments by the Company overcome its original objections it does not consider that this procedure is the most desirable way to protect the environment against degredation. The EPA would have prefered the Company to employ better technology rather than having to commit itself to commitments as stringent as those mentioned above.

FURTHER INFORMATION COMMITMENTS & RECOMMENDATIONS

Following a meeting of representatives of the Department of Resources Development, the Company and the Director of the Department of Conservation and Environment, in which the EPA's objections to this project were discussed, the company conducted further investigations into

- the disposal of solid wastes
- dam design and monitoring procedures
- the liquid effluent treatment train.

After these investigations the Company prepared a report which was submitted to the EPA. This report was also forwarded to the Public Works Department (PWD) and the Government Chemical Laboratories (GCL). The GCL's comments on the report and the PWD's comments on the PER and the report are included in Appendix 1. Since 1st July the Water Resource Planning Branch of the PWD has been incorporated in the Western Australian Water Authority. This has been accounted for in the comments below.

The PER and the Company's subsequent report contained commitments made by the Company to protect the environment. These are listed in Appendix 2. The EPA has taken these commitments and the comments received from the GCL and PWD into account in the comments contained in this addendum. As well as containing further commitments the Company's report addressed the following matters.

- leachate control
- groundwater pollution control and recovery
- surface water discharges

These are discussed below

Leachate Control

The Company has committed itself to disposing of the solid wastes at least 1m above the water table, compacting the wastes and engineering their surface to enhance runoff. Where it is considered necessary all solid wastes will be capped with a 300-500mm thick clay layer.

The EPA recommends that the necessity to cap the wastes should be closely linked to the results of the monitoring for leachates.

If, based on the monitoring results and site inspections, the Water Authority considers that a leachate problem is developing the waste sould be caped. Furthermore if ongoing monitoring demonstrates that there is a consistant necessity to seal the dumps the capping should proceed as a matter of course for all dumps. The Company should reduce the possibility of erosion of the seal by means such as covering the seal with top soil and revegetating with plants with a high transpiration rate.

Groundwater Pollution Control and Recovery

The Company has indicated that it will use the best available liner for its liquid effluent dams. The dams will be filled with water and allowed to settle prior to commencement of plant operations. If leaks are detected the dams will be repaired.

The Company has accepted the recommendations of Groundwater Resource Consultants Pty Ltd for a comprehensive bore monitoring/recovery programme designed to detect leakage of process liquids or leachate from solids disposal. The EPA endorses the Company's commitment to monitor for leachates for at least two years after the completion of plant operations and, if necessary, until it is no longer required. The Company should also be cognisant of the Water Authority's comments on the monitoring/recovery bore field.

Surface Water Discharges

The Company said its final effluent quality will comply with a list of water quality criteria supplied by the PWD. These criteria are listed in the Water Authority's response to the Company's submission. The Company should also be cognisant of the Water Authority's comments on the location of the sand filter in the sequence of the various parts of the water treatment train.

The Company presented information that the details the PER gave on the sources of various metals in the effluent stream were taken from a worst case estimation which was unlikely to occur during plant operation. The latest submission indicates what the Company considers to be a more realistic representation of what will actually occur during plant operation. Based on this information, the use of lime treatment of the effluent and the use of other waste treatment equipment such as the washing of the iron oxide sludge to remove ammonium chloride, the Company believes it can achieve the stated effluent water quality criteria.

The EPA recommends that the company pays close attention to the pH of the effluent. It is possible that metals deposited in the neutralised effluent dam will re-enter solution and pass into the Elgin Drain if the pH is allowed to vary outside a narrow range. The recovery of the precipitated sludge from the neutralised effluent dam should take place on a regular basis to minimise the store of available metals.

Other Commitments

On completion of plant operations the Company has committed itself to rehabilitate the site by complete removal of the plant and drainage and treatment of the liquids from the various dams. Solid wastes will be placed in clay lined disposal pits and covered with clay.

All ponds and other excavations will be filled and revegetated.

The Company has also committed itself to monitor for leachates for a minimum of two years after plant closure.

Commitments of Major Importance

As indicated earlier the commitments made by the Company are contained in Appendix 2.

The EPA draws attention to the following commitments which it considers are of major importance to the minimising the environmental impact of this plant.

From Section 5 of the Company's subsequent report:

"(c) If the quality of liquid effluent discharge diminishes below the accepted criteria, the Company will cease the liquid discharge until measures are instituted to reduce the levels of contaminants.

(d) The techniques to be employed for the disposal of all solids will be submitted to the Water Authority for approval. Should clay capping of solid wastes fail to prevent the generation of contaminating leachates, the Company will use alternative methods of disposing of its wastes and will ensure that wastes already disposed will be recovered or otherwise treated to prevent further leachate generation."

CONCLUSIONS

Based on the information supplied by the Company and the comments received from the PWD and GCL the EPA considers that the major objections to this proposal have been overcome. However the EPA considers that this is dependent upon the Company strictly adhering to the commitments given in its PER and subsequent submission.

DG:fm 2/7/85

APPENDIX 1

- PWD comments on the PER
- WSL's submission to the EPA
- PWD and GCL's comments on the Company's submission.

Public Works Department

Dumas House,
2 Havelock Street,
West Perth, W.A. 6005.

Telephone 322 0331
Telex No. 92601
Telegrams "Pubworks" Perth

PUBLIC WORKS DEPARTMENT
WESTERN AUSTRALIA
P.W. 19

Address all letters to the "Under Secretary"

Your Ref.
Our Ref. PWWS 1030/74
Enquiries Mr Ventriss

DIRECTOR
DEPARTMENT OF CONSERVATION &
ENVIRONMENT

Attention: Mr D Galloway

WESTRALIAN SANDS LIMITED
UPGRADED ILMENITE PLANT
PUBLIC ENVIRONMENTAL REPORT

The above Public Environmental Report (PER) has been reviewed and the Department's comments on issues with which it is concerned are enclosed.

The noxious nature of the liquids being handled and dispoed of by the project are of concern with respect to contamination of local surface and groundwaters. The groundwater contamination and effluent disposal problems being experienced at Australind as a result of the SCM Chemicals ilmenite treatment plant clearly indicate that the above proposal should be carefully considered in this regard. It is evident from the PER that the liquids and materials being handled are similar to those at Australind and therefore warrant these concerns.

E. A. Barker
ACTING UNDER SECRETARY FOR WORKS

May 31, 1985 HBV:KT

WESTRALIAN SANDS LIMITED

UPGRADED ILMENITE PROJECT

PUBLIC ENVIRONMENTAL REPORT

COMMENTS FROM PUBLIC WORKS DEPARTMENT

The Public Environmental Report (PER) on the proposed upgraded ilmenite plant has been reviewed with respect to water supply and water resource aspects and the following comments are made:

1. WATER REQUIREMENTS

The water requirements for the project have been defined as 2.6 million m^3 per year and it is proposed to obtain this from up to five bores exploiting the confined aquifers of the Yarragadee Formation. It is expected that such quantities will be available, however, construction of bores and drawing of groundwater in this area is subject to licensing under the Rights in Water and Irrigation Act. Conditions attached to the license will set standards for bore construction and may specify regular monitoring and review of the effects of the project's pumping on the exploited aquifers to ensure there are no adverse effects.

2. GROUNDWATER RESOURCES

The project site is located over a shallow water table aquifer, the water from which probably discharges into surface drainages through the area. Water within the water table groundwater system is understood to be of fresh, potable quality although specific information is not available at the project site.

The proposed processing will generate a number of liquids, most of which would be of concern if they penetrated to the water table. These liquids are:

(i) <u>Kiln Scrubber Liquid</u> which is of low pH, (3.0) which is expected to produce a groundwater mixture with pH about 5.2. Monitoring of groundwater is proposed with extraction bores being utilised to manage spills or leakages from the handling pits.

(ii) <u>Aeration Liquid</u> which has a very high salinity (25 540 mg/L TDS) of which major components are chloride and ammonium. It is proposed to recover any groundwater contamination by bores.

(iii) <u>Acid Leached Liquor</u> which has a very low pH (1.3), very high salinity (21 570 mg/L TDS), high sulphate (9 489 mg/L) and high level of copper (2.8 mg/L), cobalt (4.5 mg/L) and chromium (5 mg/L). It is proposed that management of groundwater contamination from pipeline spills or leaks would be as for the kiln scrubber liquid.

.../2

(iv) Neutralised Effluent Liquid which is of brackish quality (1 855 mg/L TDS) may enter the groundwater system through leakage from the solar evaporation ponds. No active management is planned as the resulting groundwater quality is not expected to have any major environmental impacts.

(v) Leachate from Neutralised Effluent Solids is of quality quoted to be high in sulphate (3 100 mg/L) and nitrate (15 mg/L). It is claimed that when it re-enters the surface water systems the sulphate and nitrate will stimulate plant growth but will otherwise be of little concern.

There are inconsistencies in the tabulated analyses of the various fluids, particularly in the case of the neutralised effluent liquid where sulphate is quoted as about 85% of the total dissolved solids, and the neutralised effluent leachate where the sulphate exceeds the total dissolved solids by about 7%. The presented data therefore needs to be checked.

The potential for groundwater contamination from the plant liquids appears to exist principally through pipeline breakages and in the case of the neutralised effluent liquid and neutralised effluent leachate, through leakage from the evaporation ponds.

The PER claims that pipeline breakages will be detected through monitoring systems such that only small amounts of liquid will escape. Liquid storage facilities and piping will be located on bitumen or concrete surfaced areas with bunds to prevent escape of liquid. These will probably be adequate for small spills. Recovery bores are proposed to manage any spills which may contaminate the groundwater. The effectiveness of such recovery should be better demonstrated before the project is approved.

It is stated that leakage from the evaporation ponds is only expected to be small if it occurs, however, this may be over a long period. The quality of such leachate may be of considerably higher concentration than stated in the PER as the liquids will concentrate in the ponds as a result of evaporation.

Further, no information is presented on the means of lining the pond and this would need to be checked to ensure adequate desig from the point of view of protection from leakage and accidenta damage. The ponds will need to be of adequate size to ensure effluent can be handed during months of rainfall exceeding evaporation when overfilling may be a risk.

Sulphur is to be stored on site. To ensure that leachates from the stockpile do not contaminate the groundwater it should be located on either a sealed and adequately bunded and drained area or under cover.

.../3

Protection against sulphuric acid spills in the handling and storage section is being provided through location on a sealed and bunded surface to ensure spills are contained. This is considered adequate subject to appropriate design.

SURFACE WATER RESOURCES

Information available from sampling of the Capel River near Capel shows the water quality of its flows to be very fresh (< 300 mg/L TSS). No information on the quality of water in the drains is available, but is expected to be fresh.

The final liquid effluent to be discharged from the plant is a combination of kiln scrubber liquid, neutralised effluent liquid and liquid from the solids dam. This is proposed to be treated in a number of ways to improve effluent quality and it is claimed that plant discharges will conform with water quality criteria for aquatic ecosystems as documented by B T Hart.

These are quite stringent criteria and are acceptable if they can be met. The discharge should be licensed under Pt III of the Rights in Water and Irrigation Act and issue of a license would require submission of adequate documentation detailing how the effluent will be treated.

There are concerns with some of the proposed treatment process proferred in the PER. The use of "biological/wetland filters" proposed to be incorporated into the second solution storage d and into the drain taking liquid effluent from the dam discha point needs to be clarified. The quality of effluent passing through these areas (swamps?) should be of final acceptable discharge quality to ensure neither the wetland or associated groundwater system is contaminated.

Some further management options have been suggested if necessa One of these is addition of limestone to the discharge drain to modify pH and precipitate dissolved metals. This has been attempted elsewhere and found to be ineffective except for sho periods. Installation of a sand filter is a second suggested method. This would only be effective in removing particulate matter. A third suggested method is dilution of final liquid effluent with bore water. This would not be acceptable as the plant water requirements are already quite large and use of additional water for such a purpose is not a justifiable use for the groundwater resources. The PER does not provide any information on effluent discharge volumes, but these are expected to be significant in view of the high water requireme stated by the proponents.

SUMMARY

Adequate groundwater should be available to meet the project requirements as proposed in the PER. Groundwater draw will require licensing.

.../4

The PER is considered too superficial in its considerations of possible effects of the project on both the shallow groundwater resources and the surface water resources. Liquids being handled within the plant are quite noxious and would be of concern if they contaminated the local water resources. Some protection is being offered through sealing of surfaces beneath pipelines and handling/process areas. Monitoring and recovery bores is being proposed as the means of managing spills and leakages which may penetrate to the groundwater. Final approval of this would require adequate demonstration that this will be effective. The detailed design of the solar evaporation ponds is of concern with respect to potential leakage or overfilling.

Effluent discharge will need to be licensed. This licensing will require adequate demonstration that effluent quality can be maintained within acceptable criteria using acceptable methods. Final approval should be contingent upon this.

Westralian Sands LIMITED

Registered Office:
Jenkin Road,
Capel, Western Australia

Telephone: 27 2002
Telex: 93905
Telegrams: ILMENITE Capel

Postal Address:
P.O. Box 96, Capel
Western Australia 6271

BKM:SLS

26 June 1985

The Chairman
Environmental Protection Authority
1 Mount Street
PERTH WA 6000

Dear Sir

RE: UPGRADED ILMENITE PROJECT

In response to your Authority's concerns as to the potential environmental impacts of this Company's proposed upgraded ilmenite project, the attached documents contain a series of commitments which we trust will ensure acceptance of the project by your Authority.

The documents also include evidence as to the efficiency and suitability of a number of the plant's operational aspects, in particular, in relation to waste water treatment and to a ground water monitoring/recovery bore system.

Your Authority's efforts to allow this Company to meet its 30 June deadlines are greatly appreciated and it is hoped that the attached commitments will be sufficient so as to satisfy your Authority's previously indicated environmental concerns.

Yours faithfully
WESTRALIAN SANDS LIMITED

B K MASTERS
SENIOR GEOLOGIST

Enc.

WESTRALIAN SANDS LIMITED

UPGRADED ILMENITE PROJECT

CAPEL, WA

FINAL SUBMISSION TO THE ENVIONMENTAL PROTECTION AUTHORITY OF WA

(1) Leachate Control

(2) Groundwater Pollution Control and Recovery

   (a) Choice of Liner

   (b) Monitoring and Recovery Bore Network

(3) Surface Water Discharges

(4) Final Site Rehabilitation (after plant closure)

(5) Other Committments

25 June 1985

1. Leachate Control

(a) All solid wastes will be placed into final disposal sites which are at least one metre above the height of the winter water table. For one-year-capacity surface pits, there will be up to 6 metres of clean sand separating winter water table from the base of the pits. For the North Capel mining pit, mining will extend to the water table or deeper but, prior to the pit's useage for disposal of solids, a layer of clean sand tailings sufficiently thick to give a one meter clearance will be placed on the pit's floor.

(b) As part of normal procedure, all solid wastes will be compacted during disposal and their upper surfaces will be sloped so as to facilitate rainwater to flow off the solids without soaking in.

All solid wastes will be covered by a 30 to 50 centimetre thick layer of clay, wherever necessary, to prevent rainwater from entering. This capping will be carried out using normal engineering practices and will be on-going throughout the life of waste disposal operation.

(c) The P.E.R. was based upon the worst-case assessment of envinronmental impacts. As a result, the amount of rainwater assumed to enter the groundwater, and hence could become leachate, was 25% of total precipitation. Groundwater Resource Consultants have advised that a figure of 5 to 10% is far more realistic, whilst other sources, Carbon, B.A*, have confirmed the latter figure of 10%.

* Carbon, B.A. (1976). Groundwater resources of the Swan coastal plain. Symposium jointly organised by the EPA and CSIRO Division of Land Resources Management, Murdoch University, WA.

2. Groundwater Control and Recovery

(a) Choice of Liner

The Company will line all liquid effluent dams with high density poly-ethylene (HDPE) synthetic liner of one millimetre thickness. This material is the most secure, long-lasting and expensive liner generally available for dam membrane purposes and has been recommended to WSL by its consulting engineers, GHD-Dwyer Pty Ltd.

The risk of dam liner failure is extremely low. The edges of the individual sheets will be joined using heat fusion, hence there are no new chemicals introduced which could dissolve or otherwise fail during dam usage. All dams will be constructed from clean mine sand tailings which have been screened to remove particles coarser than one millimetre. Unlike in the Perth area, there are no limestone pinnacles or other potential sources of membrane-damaging solids.

All dams will be constructed some months prior to the commencement of the plant's operation. They will be filled with water to ensure that settlement is largely completed before they begin to accept plant effluents. Should leaks occur, they will be repaired.

During plant operation, a dam failure such that there is significant pollution of the groundwater will require immediate action, the dam will be emptied of its contained liquids and the leak repaired. Should the action require temporary closure of the plant, then this will take place.

(b) Monitoring and Recovery Bore Network

Attached is a report compiled by Groundwater Resource Consultants Pty Ltd. In summary, the report concludes that a monitoring/recovery bore network will work effectively and efficiently.

WSL accepts the report's recommendations and commits itself to adoption of the recommended bore spacings, sizings and test pumping procedures.

REPORT ON REQUIRED GROUNDWATER MONITORING FOR UPGRADED ILMENITE PROJECT AT CAPEL, WESTERN AUSTRALIA FOR WESTRALIAN SANDS LIMITED

1. INTRODUCTION

A planned mineral processing plant at North Capel will upgrade natural ilmenite to synthetic rutile. The proposed site is about 4.5 km north-northeast of the centre of Capel townsite.

A number of liquids, which are used in various stages of the process, will be stored in holding dams. All the dams will be lined with a synthetic polyethylene membrane.

Iron oxide and neutralised effluent solids will be disposed of into surface pits in the vicinity of the plantsite.

Contamination of groundwater could occur as a result of pipe bursts, or small long-term leakages as a result of failure of dam liners, or leaching of surface disposal pits.

An appropriate groundwater monitoring programme, with provision for recovery of any contaminated groundwater, is described in this report.

2. POTENTIAL CONTAMINANTS

Four process liquors and two leachates have the potential to contaminate groundwater by leakage; their composition is shown on Table 1.

For the first eight years of plant operation iron oxide solids will be disposed of into the North Capel mine-pit. Subsequently they will be disposed of in surface pits to the west of the processing plant; each pit will have the capacity to receive one years disposal. The production of leachate can be minimised by capping each pit with synthetic membrane or clay to prevent percolation of rainwater.

Neutralised effluent solids will be disposed of into pits, each with one-year capacity, to the south of the iron oxide disposal area.

The process liquids will all be stored in dams within the plantsite itself.

Potential contaminants include sulphate and chloride from the Aeration Liquid and Iron Oxide Solids Leachate, with Total Dissolved Solids (TDS) content of 25540 mg/L, and from the Acid Leached Liquid with TDS of 21,570 mg/L. Other potential contaminants are heavy metals (Zinc, Copper, Cobalt, Chromium, Vanadium and Nickel) from the Kiln Scrubber and Acid Leached Liquids, Ammonia- Nitrogen from the Aeration Liquid and Iron Oxide Solids Leachate, and phosphorus from the Acid Leached Liquid.

3. TOPOGRAPHY, RAINFALL and EVAPORATION

The site is on the Swan Coastal Plain, on the east side of a dune ridge with maximum elevation of about 24 m AHD; the dune trends north-northeast.

The ground slopes from the dune to Gynudup Brook on the west, and Elgin Drain on the east; opposite the plantsite Gynudup Brook has an elevation of about 3 - 4 m, and Elgin Drain 7 - 8m.

The area of the plantsite has been built up with mine tailings to a maximum elevation of 19m.

Rainfall in the area averages 847mm per year, and evaporation 1516mm per year.

4. GEOLOGY

The area is underlain by Quaternary superficial deposits which conformably overlie the Leederville Formation, of Early Cretaceous Age.

The Leederville Formation consists of dark grey silty micaceous clay and clayey sand. The overlying unconformity surface appears to be irregular but is generally at about 3 to 4m below AHD.

The superficial deposits consist of a lower zone, 5 - 10m thick, of clayey sand, overlain by an upper zone of sand. The lower clayey sand is generally medium-coarse grained and subangular; the upper sand is fine to medium grained and subrounded.

To the east the superficial deposits are commonly ferruginous, with laterite at the surface. Towards Gynudup Brook and Elgin Drain the superficial strata become generally more clayey.

5. HYDROGEOLOGY

Static water-levels have been reported for the plantsite itself by Golder Associates, and range from 12.5 - 13.5m AHD.

For the surrounding area there is no unequivocal water-level information. "Water-table" levels recorded on drillers' logs are not an accurate measurement of the static water-level, but rather the depth at which a significant water-return was noted.

Water-content was recorded in drilled samples, and the upper limits of high water-contents are shown, with contours, on Figure 1. The contours show a coherent pattern which corresponds to the topography, and to the water-levels reported by Golder Associates. The contours are therefore believed to show the general configuration of the water-table within the accuracy of the sampling interval (1.5m). Seasonal water-table fluctuations of 1 - 2m can be expected.

The contours indicate that the groundwater flows towards Gyundup Brook on the west, and Elgin Drain on the east, from a NNE - trending divide along or near the dune-ridge crest. The gradient of the water-table becomes steeper towards the two water- courses reflecting the lower permeability of the more clayey strata in those areas.

A laboratory test of the dune sand, forming the upper zone of the superficial deposits, gave a hydraulic conductivity value of 25 m /day. The more clayey lower zone would be expected to have a significantly lower hydraulic conductivity, no more than 10m/day.

The salinity of the groundwater is thought to be about 800 mg/L T.D.S.

6. DISCUSSION

If leakage of contaminants does occur the contamination will spread in one of two ways.

Contaminant fluids which are not significantly more dense than the groundwater (i.e. Kiln Scrubber Liquid, Neutralised Effluent Liquid, and Neutralised Solids Leachate) would move in the direction of groundwater flow, dispersing and advecting to form a downstream plume.

The direction of groundwater flow beneath the plantsite area is apparently to the southeast towards Elgin Drain. Assuming an average hydraulic conductivity of 10m/day, average water-table gradient of 1.7×10^{-2}, and effective porosity of 0.3, the average linear groundwater velocity would be about 0.6 m/day or 200 m/year.

Using likely aquifer parameters the width of a contaminant plume, within limits of detection, would be about 50m wide at a distance of 50m from the leakage source, 100 days after the start of the leak. This prediction is made using a groundwater computer model for advection and dispersion from a continuous point source (Walton, 1984). The spacing of monitoring bores should therefore be no more than about 50m to ensure detection of any contamination.

Contaminant liquids which are denser than the groundwater (i.e. Aeration and Acid Leached Liquids, and Iron Oxide Solids Leachate) would sink to the bottom of the superficial deposits, and move laterally along the surface of the underlying Leederville Formation aquiclude. The lateral movement will be controlled mainly by the slope of the aquifer/aquiclude interface. If this interface is more or less horizontal, the denser contaminants will disperse laterally in all directions, but preferentially in the direction of groundwater movement.

Trace metals are adsorbed by clays, hydrous oxides of iron and manganese and by organic matter. Adsorption and precipitation reactions generally cause fronts of trace metals to move very slowly compared to the groundwater velocity (Freeze and Cherry, 1979, Robertson-Pincock Inc., 1980). Except in very acid waters, the solubility of trace metals is very low, and they are rapidly removed from groundwater by cation exchange.

Phosphorus in the groundwater will be fixed by iron compounds.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 The plantsite area is underlain by Quaternary superficial deposits consisting of an upper sand zone and lower clayey sand zone. The Quaternary deposits are underlain by the Leederville Formation, which forms an aquiclude.

7.2 The direction of groundwater movement beneath the plantsite is apparently to the southeast towards Elgin Drain. The rate of groundwater movement may be as much as 200m/year.

7.3 As the rate of groundwater movment is fairly rapid, a quick response will be necessary if contamination is detected.

This can be effected by constructing all bores as dual purpose monitor/recovery bores, using machine-slotted 100mm diamter PVC casing. Each bore would be capable of recovering 250 m3/day using a submersible pump. This would provide an immediate and flexible recovery system.

7.4 Spacing of monitor/recovery bores is provisionally estimated at 50m. This spacing should be verified by test-pumping of the first two monitor/recovery bores constructed, so that the hydraulic characteristics of the aquifer can be quantified.

A total of about 30 - 40 monitor/recovery bores is anticipated.

7.5 The monitor/recovery bore network should be installed as soon as possible, so that baseline geochemical and water-level data can be established, against which any future contamination can be identified.

Groundwater from each bore should be analysed on completion, a standard analysis being supplemented by analyses for those elements which are potential contaminants.

7.6 Detection of more highly saline contamination can be made by measurements of groundwater conductivity profiles to be made monthly. Chemical analysis should then be made if anomalous conductivity is recorded.

Trace metals are unlikely to move far from any leakage source, because of adsorption and precipitation, but as a precaution analyses for Zinc, Copper, Cobalt, Chromium, Vanadium and Nickel, which are in the highest concentration in the source liquids, should be made every three months, in samples taken from the base of bores downstream from potential sources of leaks containing these metals.

7.7 Additional supplementary small-diameter observation bores may be required to define the shape of the water-table (and hence the precise direction of groundwater movement) and the form of the Leederville unconformity interface.

7.8 A monitor/recovery bore system as described above, and modified where necessary in the light of additional data from the testing of the initial bores, will ensure the detection of any leaked contaminants, and will enable their prompt recovery by pumping.

John Barnett
Senior Consultant
Groundwater Resource Consultants

26/06/1985

Project No: 555-1

TABLE 1

CHEMICAL ANALYSES

INTERMEDIATE, FINAL EFFLUENT LIQUIDS AND LEACHATES
DERIVED FROM SOLID WASTES

	Kiln Scrubber Liquid	Aeration Liquid (Iron oxide solids leachate)	Acid Leached Liquid	Neutralised Effluent Liquid	Leachate from Neutralised Effluent Solids
pH	3.0	6.8	1.3	9.4	7.3
TDS	900	25540	21570	1855	2900
Na	42	44.5	49.5	86	310
K	14	43.5	13	18	38
Cl	74	10760	68.2	72	230
HCO_3	< 1	48.8	< 0.6	1	88
SO_4	260	51.4	9489	1569	3100
NO_3	<0.05	< 0.05	39.3	<0.05	15
NH_3-N	5.5	5006	10.8	<0.05	1.0
Solids	60			40	< 5
As	0.007	<0.005	0.01	<0.005	<0.05
Cd	<0.005	<0.005	<0.005	<0.005	<0.01
Pb	< 0.01	< 0.05	< 0.05	<0.01	<0.05
Zn	17.5	0.05	1.95	<0.01	0.38
Cu	0.1	0.05	2.8	<0.05	0.12
Co	0.05	0.15	4.5	0.1	<0.01
Ba	<0.25	1.5	<0.25	<0.25	0.06
Cr	<0.05	<0.05	5	< 0.05	0.16
V	<0.25	<0.25	1.25	<0.25	
Ni	0.2	0.15	2.35	0.1	< 0.02
P (total)	0.15	<0.05	3.1	< 0.05	<0.01
Hg	<0.0005			<0.0005	<0.02
Mo	< 0.005			0.12	0.01
Mn	2.2			< 0.01	0.08
Ca	32			950	510
Mg	16			0.28	370
Fe				0.05	0.03
Ti	0.02			0.06	0.05
Al					0.7

All values in mg/l except pH.

FIGURE 1

WATER-TABLE R.L.

REFERENCES

FREEZE, R.A. and CHERRY, J.A., 1979: Groundwater; Prentice-Hall, Inc.

GOLDER ASSOCIATES, 1985: Report on Preliminary Foundation Investigation for Proposed Ilmenite Plant, North Capel, Western Australia.

GOLDER ASSOCIATES, 1985: Report on Geotechnical Investigation for Synthetic Rutile Plant, North Capel, Western Australia.

ROBERTSON-PINCOCK INC., 1980: An Investigation of Subsurface Contaminant Migration from Tailings Pond No. 5, The Shirley Basin Mine; Report to Pathfinder Mine Corporation.

WALTON, W.C., 1984: Practical Analysis of Well Hydraulics and Aquifer Pollution; Butler University, Indiana, U.S.A.

WESTRALIAN SANDS LIMITED, 1985: Environmental Review and Management Programme, Upgraded Ilmenite Project, Capel, Western Australia.

3. Surface Water Discharges

(a) The systems devised by WSL to achieve the objectives of discharging water into the Elgin drain within the levels of contamination in accordance with criteria for aquatic systems laid down in the Australian Water Councils "Compilation of Australian Water Quality Criteria" are based on extensive pilot plant trials and laboratory testing aimed at simulating plant operations under very conservative or worst case conditions.

Pilot plant trials were first conducted by Lurgi in Germany in July and August 1983 to produce data for the design of a commercial plant and to provide samples for the development of kiln scrubber effluent handling systems.

In August 1984 further pilot plant trials of the aeration step were carried out to produce large samples of aerated product which after acid leaching could produce acid effluent to be used in the development of an acid effluent handling system.

In order to test the worst case condition in kiln scrubber effluent, samples of solids from the waste gas system produced in the kiln pilot plant trial were leached at pH 3.0 for a period of 30 minutes. This effluent when analysed was found to contain 17.5 mgms/litre of zinc which when mixed with neutralised effluent at pH 9.5 gave a zinc level of 3.5 mgm/litre at pH 6.5 - 7.5.

WSL believes this level of zinc will not occur in the plant because the leaching conditions are expected to be considerably less severe, the pH being 4.0 - 5.0 and residence time 3-4 minutes. However should a problem of high zinc level occur WSL will lime addition the water to the kiln scrubber to maintain a pH 7 or higher and thus ensure that no dissolution of zinc occurs. Under these circumstances the very small amounts of zinc solids reporting in the scrubber discharge will settle in the solution storage dam and can be removed and buried at the end of the life of the project. It should be noted that zinc in the ilmenite is present in trace amounts only.

In order to test the worst case condition in the acid effluent stream, samples of aerated product made in the pilot plant were acid leached at various levels of acid usage. The highest usage of acid, based on a very conservative approach to forecasting operating costs, was selected for laboratory development of acid effluent handling systems.

In practice lower levels of acid and lime consumption will be experienced and the level of sulphate in final effluent will not exceed 500 mgm/litre.

The samples of aerated product used to produce acid effluent were not washed to lower the content of entrained ammonium chloride. As a consequence the NH_3-N in final effluent was measured at 3.3 mgm/litre.

In plant practice the circuit includes a spiral screw classifier prior to the acid leach plant whose function is to dewater aerator product and wash out entrained ammonium chloride. This will result in NH_3-N content of final effluent not exceeding 0.05 mgm/litre

WSL received from the Public Works Department on 24 June 1985, the following criteria for final effluent quality:

Physical of Chemical Character	Concentration
pH	6.0-7.5
TDS	2,500
Na	270
Cl	600
HCO_3	500
SO_4	500
NO_3	10
NH_3	0.05
As	0.05
Cd	0.03
Pb	0.02
Zn	0.10
Cu	0.01
CN^-	0.01
Cl	0.01
Hg	0.002
Ni	0.05

All values are in mg/l except pH.

WSL will not discharge effluent exceeding the quality criteria listed in the above table.

WSL in the design of the capacity of the acid effluent and final solution storage dams has taken a conservative approach and provided a total storage capacity of 14 days in the circuit. This was done to ensure that plenty of time was available to carry out maintenance of equipment or make whatever adjustments are necessary to ensure that the effluent discharging from the system conforms to the required quality standards.

As a final effluent quality polishing step WSL plans to install a biological filter. This unit will act to further lower the concentration of ammonium and sulphate ions prior to the discharge of effluent into the Elgin drain.

(b) Should there be problems with suspended particulates in the effluent water discharges, the Company will install a filtering device such that these particles are removed. Whilst the biological filter will capture some suspended particles, a sand filter through which all effluent liquid will pass will be constructed between the discharge point of the solution storage dam and the entry point into the biological filter.

Binnie & Partners PTY LTD
INC. Q.D.
CONSULTING ENGINEERS

ACEA

First Floor
Legal & General House
267 St Georges Terrace
Perth Western Australia

Postal Address
PO Box 7050
Cloisters Square
Perth WA 6000

Telephone
National (09) 322 7700
International + 619 322 7700
Telex AA 95665

Our Ref AJG/MS/265

Your Ref

Date 26 June, 1985

Westralian Sands,
1st Floor, 267 St. George's Terrace,
PERTH WA 6000

For the attention of Mr. B. Bracanin

Dear Sir,

Upgraded Ilmenite Project : pH Control of Kiln Scrubber

As requested by you yesterday, we have pleasure in submitting our comments on pH control of the kiln scrubber for the above-mentioned project.

You stated that your proposal is to correct the pH of the kiln scrubber liquid from approximately 3.0 to the range 6.0 - 7.0 to ensure that the zinc oxide remains in a particulate form and thus may be separated in a settling tank downstream of the scrubber.

Alkali scrubbing normally consists of raising the pH to 9.0 - 10.0 for removal of sulphur dioxide. However, we understand this is not a consideration for you at Capel.

We see no reason why your proposal to maintain a pH of 6.0 - 7.0 should not operate satisfactorily since pH control of such a system in itself is not a difficult process. It should be noted that we have not had access to a full description of the alkali scrubber liquid and have not attempted a full detailed analysis of this particular waste.

With respect to use made of alkali scrubbing, we have checked our Chief Chemical Engineer in Melbourne and also with our London office. They reported that flue gas desulphurisation (FGD) may be of two forms - non-regenerative or regenerative. Both use lime, or other appropriate alkalis. A 1977 survey of USA power plants indicated that 67 out of 92 used the non-regenerative lime/limestone process (using similar principles to those you propose).

We trust the above information is sufficient for your needs. However, if you have any further queries, please do not hesitate to contact the undersigned.

Yours faithfully,

A.J. Gale
BINNIE & PARTNERS PTY LTD

4. Final Site Rehabilitation (after plant closure)

Upon final plant closure, all items of plant will be dismantled and removed off-site. All effluent ponds will be drained of liquid, with water quality treatment being applied wherever necessary to ensure compliance with PWD discharge standards. Aeration liquid (containing NH_4Cl) will be solar evaporated so as to recover the dissolved salts.

All solid wastes will be disposed of into normal one-year-capacity surface pits, with a surface capping of clay preventing the formation of rainwater-derived leachate. Solids with a greater potential for underground water pollution (for example, NH_4Cl and metalliferous sludge from the biological filter) will be placed in clay-lined, engineered disposal pits and capped with clay.

All ponds and other excavations will be infilled with clean sand, with topsoil and vegetation cover applied to the surface.

Monitoring of leachates will continue for a minimum of two years after plant closure, provided that earlier monitoring shows this action to be necessary. After two years, should further monitoring be necessary, the Company commits itself to a continuation of the programme until it is no longer required. However, the need for long-term monitoring will be largely dependent upon the Company's actions to prevent leachate formation. Since all solid wastes will be capped with an impervious clay layer, leachate generation will not occur.

5. Other Committments

(a) Dust emissions from stock piles, transportation of raw materials, waste disposal and product will be controlled at all stages of the operation. The Company will submit its plans for dust control to the Dept of Conseration and Environment for approval.

(b) The storage of hazardous chemicals and contingencies to recover spillage will meet the requirements of the Explosives and Dangerous Goods Division of the Department of Mines.

(c) If the quality of liquid effluent discharge diminishes below the accepted criteria, the Company will cease the liquid discharge until measures are instituted to reduce the levels of contaminants.

(d) The techniques to be employed for the disposal of all solids will be submitted to the Public Works Department for approval. Should clay capping of solid wastes fail to prevent the generation of contaminating leachates, the Company will use alternative methods of disposing of its wastes and will ensure that wastes already disposed will be recovered or otherwise treated to prevent further leachate generation.

(e) The Company will comply with all regulations relating to radiation protection.

(d) **Supplementary Evidence to Support Lime Treatment of Acid Liquid Effluents and Biological/Wetland Filters**

(i) On 24 June 1985, a simulated sample of liquid effluent was generated in the laboratories of Analytical Services Pty Ltd. The sample had its pH adjusted to 9.5 by the addition of calcium hydroxide (slaked lime). Two sub-samples were dosed with low levels of a kaolinitic clay slurry in order to mimic the effect of clay and colloidal interactions likely to occur when the effluent water trickles through the biological filter. Results are:

	Control pH 6.6	pH 9.5	pH 9.5 0.5% clay slurry addition	pH 9.5 1.0% clay slurry addition
Zinc (mg/l)	3.54	0.53	0.24	0.14
Manganese (mg/l)	0.56	0.25	0.20	0.19

The reductions in metal contents are significant, especially since the laboratory retention time of some 12 hours will be replaced by an operational retention time in the solution storage dam plus biological filter of between 6 and 10 days.

(ii) Enclosed is a photocopy of an article from the Canadian Institute of Mining Bulletin of November 1974, entitled: "Acid Drainage Control and Water Treatment at Heath Steele" by E Busse.

The addition of lime to their 1,000 cubic metres per hour discharge of pond effluent resulted in the reduction of copper from 23.6 mg/l to 0.008 mg/l and of zinc from 47.6 mg/l to 0.044 mg/l.

(iii) In a report entitled "Combination Limestone - Lime Treatment of Acid Mine Drainage" by R C Wilmoth and J L Kennedy (6th Symposium on Coal Mine Drainage Research, 1976, Kentucky, USA), a laboratory scale study showed that, after 24 hours settling at a pH of 9.5, the following results were obtained:-

	Raw Water (mg/l)	Treated Water (mg/l)
Ferrous Iron	530	nil
Total Iron	550	0.09
Manganese	9.2	0.26
Aluminium	50	1.0

(iv) In 1974, N Blesing, J Lackey and A Spry from The Australian Mineral Development Laboratories reported on "Rehabilitation of Brukunga Mine: Nairne Pyrites Limited". The attached figure 15 shows solubilities of metals at varying pH, with a pH of 11.0 liable to give a liquid containing:-

Ferric Iron	0.4 mg/l
Manganese	nil
Magnesium	nil
Copper	nil
Zinc	nil

Acid Drainage Control and Water Treatment at Heath Steele

Egon Busse, Vice-President, Amax Lead & Zinc, Inc.,
Formerly Acting General Manager,
Heath Steele Mines Limited,
Newcastle, N.B.

Abstract

Heath Steele Mines Limited is located in New Brunswick, operates a 3,000-tpd mine and concentrator, and produces lead, zinc and copper flotation concentrates from complex massive sulphide ores.

The problem of acid drainage is caused by underground and surface water contacting metal sulphides, becoming acid and acquiring dissolved heavy metals. In sufficient concentrations, these metals are toxic to fish life. Because all water from the property eventually drains into the Northwest Miramichi River, it has a detrimental effect on the salmon migration in that stream.

Earlier attempts to treat mine water and to collect some contaminated surface drainage were not adequate. By the end of 1969, government agencies had developed stream water quality requirements for the mine. To meet these requirements, a comprehensive water pollution abatement program was started early in 1970 and became fully operational by the fall of 1972.

Areas with contaminated surface drainage were identified and isolated. All water from these areas is collected, together with all water from underground workings, and pumped to the tailings disposal area, where it is mixed with mill tailings and hydrated lime to precipitate the dissolved metals and to retain the metal hydrates and the tailings solids.

Capital cost of the project amounted to $2,500,000. Current annual operating costs are $220,000, or 20 cents per ton of ore.

The program has substantially improved the water quality in the affected streams. Average metal toxicity in the Northwest Miramichi River has been reduced by 83% and peaks have been reduced by 92%. Most important of all, salmon migration has noticeably increased during the past 2 years.

Introduction

HEATH STEELE MINES LIMITED manages the "Little River Joint Venture", owned 75% by American Metal Climax and 25% by International Nickel. The property is located in northeastern New Brunswick, 32 miles northwest of the town of Newcastle.

Egon Busse is now vice-president of Amax Lead & Zinc, Inc. At time of writing, he was acting general manager of Heath Steele Mines Limited. He joined the company in 1963 as mill superintendent and became assistant general manager in 1969. Previously associated with several other mining firms in Newfoundland, Quebec and British Columbia, he was educated in Germany and holds a degree in chemical engineering. He is a member of the CIM and the AIME.

Keywords: Environmental control, Heath Steele Mines Limited, Drainage control, Acid drainage, Water treatment, Salmon migration, Tailings disposal, Stream water, Pumps.

Exploration started in 1953 and two major ore zor were found about 2 miles apart, the A-C-D to the w and the B to the east. Mine development started 1955 and production in 1957. All operations ceased 1958 due to low metal prices and metallurgical pr lems. Reactivation of the mine started in 1960 a production resumed in 1962. Small open-pit operatio were associated with each major zone, but they are longer active.

The ore occurs as complex massive sulphide deposi associated with porphyry and chloritic tuff. The ec nomic constituents are lead, zinc, copper and silv At present, all production comes from the B zone ar is recovered by longhole-drilled open stopes. The o is hoisted to surface through the 1,700-foot-deep N 3 shaft and transported by trucks 1½ miles to t concentrator. Three flotation concentrates are pr duced and shipped by rail or boat to custom smelter Production was increased in 1970 from 1,500 to 3,0 tons of ore per day, and a further increase to 4,0 tons of ore per day will take place in 1976.

The problem is not so much that of acidity and t usually accompanied dissolved iron, but that of di solved copper and zinc in the water. The two mai sources of this water originate from undergroun workings and from surface drainage through sulphid minerals.

During the initial phases of mining activities b tween 1955 and 1958, secondary mineralization wa found in both the A and B pits and later also unde ground close to surface. Because mine water associate with primary mineralization also slowly turns acidi and carries increasing dissolved metals, it is conclude that the metals are released in soluble form throug the process of oxidation and acid formation that i characteristic of the bacterial oxidation of metal sul phides.

When operations were restarted in 1960, mine wa ter was at first discharged untreated to the Little Sout Tomogonops River. As soon as the occurrence of rive pollution was recognized late in 1960, some form treatment commenced. This took place in small settlin ponds into which the mine water was discharged to gether with hydrated lime. The resultant precipitat is very voluminous, the ponds had to be cleaned ou frequently and the disposal of the material becam quite a problem.

Past collection and treatment facilities were developed between 1964 and 1966. They consisted of a holding pond, with an effective capacity of 4½ acre-feet, in which drainage from the plant area and No. 3 sha mine water was collected and pumped to the tailing pond via a 12-in. pipeline and 1,800-(US)gpm pumping installation. During spring run-off or heavy rain conditions, the pond could not handle the volume of water and overflows resulted from the holding pond into the Little South Tomogonops River. Even when no overflows occurred, metal concentrations in the river were high, indicating the existence of other sources of contamination.

ll drainage from the property discharges into the South Tomogonops and Little South Tomogonops and thence into the Northwest Miramichi River, approximately 15 miles below the property.

The Miramichi is a well known and important salmon river. Even very small concentrations of copper and zinc ions are toxic to Atlantic salmon. Although total effects have not been conclusively determined to our knowledge, it seems to be established that, when the metal ions reach certain concentrations, the salmon will avoid this water, turn down-stream and consequently not reach the spawning grounds.

Stream Water Quality Regulations

Since the incident of discharging mine water directly into the river in 1960, the Fisheries Research Board of Canada has been monitoring the water quality of the Northwest Miramichi River. Studies on the effect of metal-bearing water on salmon life and migration were conducted and a toxicity index was developed from laboratory tests on salmon in a controlled environment.

One toxic unit implies a concentration of 48 ppb of copper or 600 ppb of zinc at a hardness of 20. When both metals are present, the effect is additive. The toxicity of a given metal concentration decreases at an increasing hardness up to about 100. From stream sampling and observation of fish migration it was determined that, at metal concentrations above an equivalent of 0.4 toxic units, salmon will avoid this water and return downstream.

In 1969, an increase in heavy metal levels led to renewed concern by the Federal Department of Fisheries and Forestry and the New Brunswick Water Authority. By December of 1969 the following stream quality requirements were imposed for the mine:

a) no sulphur compounds other than sulphates below the mine property;
b) at the mouth of the Tomogonops River, a pH range between 6 and 8, no greater than 18 ppb of copper and no greater than 108 ppb of zinc;
c) in the northwest Miramichi River, no greater than 0.1 toxic units.

Metal concentrations equivalent to 0.1 toxic unit are approximately 3 ppb of copper and 30 ppb of zinc combined, at a hardness of 20. At that time, we did not even know of any direct and reliable method to determine the metals in such low concentrations.

Since then, the Department of Fisheries and Forestry has been amalgamated into the Canada Department of the Environment and the requirements are now regulated by the Environmental Protection Service (EPS) of this department.

Project Planning and Initial Improvements

Following the notice of stream quality requirements, a program was formulated toward achieving some improvements as early as possible and to obtain the information necessary for the design of a drainage control system that, together with improved water treatment, would reduce metal concentrations below toxic levels.

This first phase was completed during 1970. A consulting firm, Montreal Engineering Company Limited, was engaged to review the available data and literature pertaining to the problem, to outline all individual drainage areas in contact with the property and to determine maximum water flow conditions for these areas from precipitation records. At the same time, a comprehensive stream sampling program was started and the method of water analysis changed from determining total heavy metals by dithizone extraction to individual metal determination by atomic absorption.

A pile of sulphides from the original tunnel excavation and located near the Little South Tomogonops River was removed to the tailings disposal area. Pumping capacity at the existing holding pond was improved by adding a 12-in.-diam. buried woodstave line, thereby reducing spills during high flow conditions, and the clean-water channel was re-routed away from contaminating inflow. These measures reduced average metal concentrations in the river by 40%, but did not reduce concentrations during spring run-off to a reasonable level.

Stream sampling identified four separate areas of surface drainage contamination. Underground water from the B-zone workings is pumped to surface through the No. 3 shaft and from the A-C-D zones through the No. 4 shaft. The water from both places is acid and contains dissolved heavy metals.

The tailings pond and the areas draining into the pond were outlined to determine the amount of flow into the pond together with mill tailings and contaminated water. As the pond represents the water treatment facility, all water entering the pond has to be treated. A further aim was to determine the amount of up-stream drainage that could be diverted around the pond, thereby reducing the quantity of water treated.

Design and Construction

The objective was to separate contaminated surface drainage from uncontaminated areas and streams, to collect this drainage together with all mine water, to pump it to a suitable treatment location and to remove the dissolved heavy metals.

Separation of the drainage was by means of channels and/or concrete retaining walls extending to bedrock or, at least, 5 feet below surface or the bottom of channels and streams to be separated.

The capacity of the collection and pumping system was to be sufficient to handle maximum surface drainage and maximum mine water flows. Maximum or peak flows were taken as drainage resulting from a 5-in. rain storm during a 24-hour period, which has a statistical recurrence level of once in 20 years. Due to the relatively small drainage areas, it was conservatively assumed that the precipitation would be equal to the run-off.

These requirements were to include holding ponds and pumping capacities. The construction costs of holding ponds, especially when using low-lying areas and dams for creating storage rather than rock excavation, are considerably less than those of pumping facilities and no operating costs are required. Thus, as much as possible, holding ponds were to be used. Limiting factors were the areas available and the height of the dams in respect to the elevation of inflowing channels.

Table 1 indicates mine water flows from No. 3 and No. 4 shafts and mill tailings. It also indicates sizes and flows on the four contaminated surface areas and the tailings pond drainage area. From that data and area surveys, the system requirements were calculated and shown for holding ponds and pumping installations.

The second phase of the project was started early in 1971 and substantially completed late in 1972. Only minor modifications were made during 1973 and surface restoration work planned for 1974 will complete the project.

Existing channels were improved through deepening or embankments. New channels were dug, mostly by blasting through rock. These included a 1000-ft-long channel to route clean water around the old tailings line dump, a 2800-ft-long by-pass channel for the Little South Tomogonops River and a 7200-ft-long by-pass channel for drainage around the tailings pond.

The A-Pit was converted into a holding pond (No. 1), with a capacity of 16½ acre-feet, by building a concrete dam across the entrance and installing two 6-in. valved draw-off pipes in the dam. A No. 2 holding pond with a capacity of 12 acre-feet, was also constructed, deepening a low area by ripping and removing fractured bedrock and enclosing the area by an earth embankment. A concrete overflow structure with 12-in. valved underflow draw-off pipes is used to regulate the flow from that pond. A third existing pond was increased from 8 to 47 acre-feet in capacity and a new concrete emergency overflow and pumphouse constructed. A fourth holding pond, 8 acre-feet in capacity, was constructed by building a dam across the old bed of diverted Little South Tomogonops River. Because this pond represents the last downstream collection and retention of the major contaminated drainage areas, it is sealed by a concrete retaining wall inside an earth dam to avoid seepages escaping into the river. It also has a concrete emergency overflow and pumphouse. A collection ditch at t foot of old stockpiles was dug into soft ground collect both surface and sub-surface drainage. T bottom and down-stream side of the ditch are lin with concrete to prevent down-stream seepage and has a holding capacity of 1 acre-foot.

TABLE 1

Mine Water and Mill Tailings

Flow in (US)gpm	Minimum	Average	Maximum
No. 3 Shaft	300	450	750
No. 4 Shaft	250	350	450
Total Mine Water	550	800	1,200
Mill Tailings	1,800	1,800	1,800

5-In., 24-Hour Storm Analysis

	Area in Acres	Drainage in Acre-Feet
A-Pit/Plant Area	198	82.5
Tailings Line Dump	18	7.5
Sour Springs/Hydrates	32	13.3
Stockpile Drainage	5	2.1
Total Contaminated Surface Drainage	253	105.4
Possible to Divert	555	231.3
Not Possible to Divert	542	225.9
Tailings Pond	130	54.1
Total Tailings Pond Surface Drainage	1,227	511.3

Capacity Requirements

	Holding Ponds, Acre-feet	Remaining Drainage, Acre-Feet	Required Pumping, (US)gpm
A-Pit/Plant Area and Tailings Line Dump	75.5	14.5	3,280
Sour Springs/Hydrates	8.0	5.3	1,200
Stockpile Drainage	1.0	1.1	250
Total Mine Water	—	—	1,200
	84.5	20.9	5,930

The main pumping station at the No. 3 holdi pond encloses three identical Canadian Buffalo 8-10-in. single-stage centrifugal pumps. All parts contact with water are made of 304 stainless ste the impeller diameter is 16½ in. and each pump has rated capacity of 2,000 (US) gpm at a 235-ft head. Th are driven by direct-coupled, 200-hp, 1,800-rpm moto One pump can alternatively be driven by a 250-l Caterpillar stand-by diesel generator in case of pow failure. A valved header system allows any of tl three pumps to be connected with any of three 12-i pipelines. The intakes are screened to keep debr away from the pumps and have vacuum gauges to i dicate screen blinding. At the pump discharge side vibrations are reduced by means of Flexflow rubbe lined connectors and shock is reduced by Willia Haeger check valves. Standard pressure gauges ar used. The lines are protected from water-hammer b 6-in. automatic Clayton dump valves that open whe the pumps are stopped. The piping is spiral-weld, 1 in.-diameter, schedule 10 (0.18-in. wall thicknes 12.39-in. I.D.), made of 304 stainless steel. Dependin on the discharge point at the tailings pond, the line are 6,500 or 7,200 feet long. The piping came in 20 ft lengths with rolled-on victaulic grooves, and stand ard victaulic couplings were used. The pipelines we installed with a minimum ½% down-grade towar the pumping station to ensure line drainage throug the dump valves. Each line has a Pyrotenax, 3-wire polyethylene-jacketed heat tracing and is insulate with 1-in. Pearlboard self-extinguishing urethane, en closed by an aluminum cover. The piping is supporte above ground on wooden trestles.

The pumping station at the No. 4 holding pon consists of a similar but smaller installation. Pumps are the 5-in. type, with a rated capacity of 800 (US) gpm at 140-ft head, driven by 75-hp motors and a 75-hp stand-by diesel generator. The piping is 6 inches in diameter and the lines are 1,800 feet long. The pumping station at the stockpile drainage ditch has two 4-in. vertical pumps and a 100-foot long 6-in. line discharging into the 12-in. woodstave line from the No. 3 shaft to the No. 3 holding pond.

Other installations include a separate bulk lime bin and feeding system at the mill and ten flow measuring weirs at channels and pipeline discharges.

Acid Drainage Control System

Figure 1, a plan of the system controlling drainage from the four contaminated areas, indicates the flow of mine water pumped to surface through the No. 3 and 4 shafts and shows the flow of mill tailings.

Drainage from the A-Pit/Plant area is contaminated from the exposed sulphides in the pit, old surface stockpiles, temporary storage of ore ahead of the crushing plant, and dust from milling and concentrate handling operations. It is collected by means of a dirty-water channel, connecting three holding ponds with a combined capacity of 75½ acre-feet. The No. 3 holding pond is the largest, with a capacity of 47 acre-feet. It is also the place where, with the exception of mill tailings, the contaminated water from all sources is collected and pumped to the tailings pond

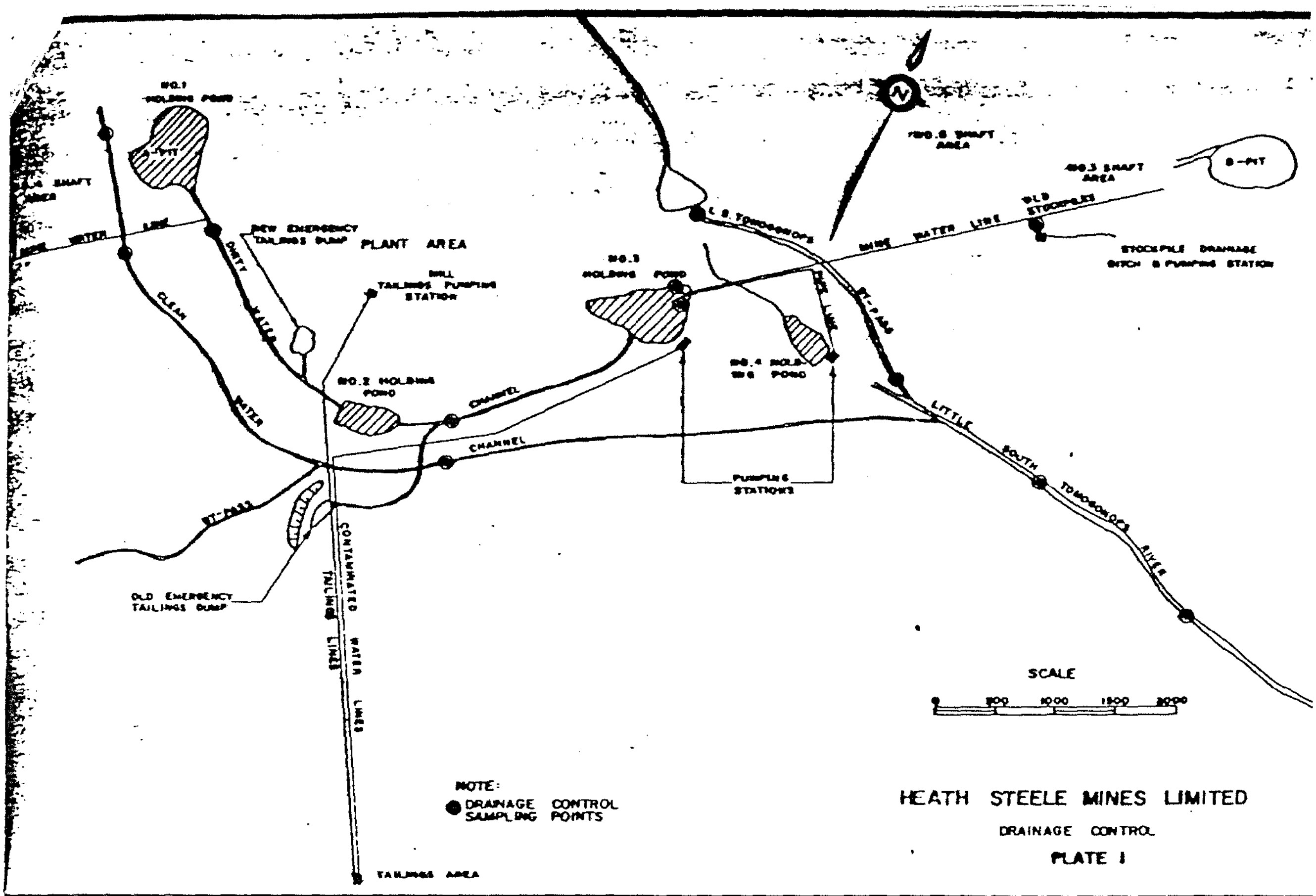

FIGURE 1 — Drainage control at Heath Steele Mines Limited.

for treatment. Fresh-water drainage is prevented from entering the area and carried around it by the clean-water channel, terminating at the Little South Tomogonops River.

Because it is not possible to maintain a down-grade on the mill tailings lines, the slurry has to be dumped at a low point when a line is not in use to prevent settling and line blockage. An area adjacent to that point contains considerable amounts of deposited tailings from such operations. The lines have since been re-graded and the low dumping point moved inside the dirty-water channel. Water draining through the old dump area becomes contaminated. Fresh-water drainage is diverted from the area by means of an embankment and channeled into the clean-water channel. Contaminated drainage is collected in a separate channel and piped across the clean-water channel into the dirty-water channel.

The sour springs/hydrates area contains contaminated water in springs of unknown origin and buried hydrates from early attempts at mine water treatment. Due to the swampy ground, it would be very difficult to remove such hydrates and the results of such removal would be uncertain. The Little South Tomogonops River runs very close to this area and became strongly contaminated by it. To isolate this area, the river was diverted north and around the area. A dam was built across the old river bed, creating a holding pond (No. 4) with a capacity of 8 acre-feet. The collected water is pumped to the No. 3 holding pond.

Drainage from old stockpiles near No. 3 shaft is contaminated and used to flow through a swamp and into the Little South Tomogonops River. A collection ditch was dug below the foot of the stockpiles. It has a storage capacity of 1 acre-foot and water from the ditch is pumped into the No. 3 shaft mine water line and hence to the No. 3 holding pond.

Mine water from the No. 3 shaft includes the drainage from B-Pit and is pumped directly to the No. 3 holding pond. Mine water from the No. 4 shaft crosses the clean-water channel and is pumped into the dirty-water channel. Mill tailings are pumped directly to the tailings pond.

Table 2 indicates the average flow of water from all areas and average metal concentrations. Flows and concentrations vary considerably. Highest flows on both surface and underground drainage occur during the spring thaw and run-off, which may extend from March to May or from April to June. During high flow conditions, metal concentrations decrease for surface drainage and increase for underground drainage.

TABLE 2 — Contaminated Drainage — Flow and Analysis

1973 Averages	(US) gpm	pH	Cu (ppb)	Zn (ppb)
No. 4 Shaft Mine Water....	350	4.5	800	98,000
A-Pit/Plant Area..........	240	3.4	7,500	95,000
Old Tailings Dump.........	30	3.5	2,500	14,500
Total Dirty Water Channel..	620	3.8	3,480	92,800
No. 3 Shaft Mine Water....	450	4.3	50,000	155,000
Old Stockpiles...........	5	3.0	400,000	750,000
Total No. 3 Mine Water Line	455	4.2	53,850	160,400
Sour Springs/Hydrates.....	75	4.0	7,500	82,000
Total Contaminated Drainage................	1,150	3.9	23,670	119,300

Water Treatment

Figure 2 shows the tailings pond, pipeline discharge points and pond outlets.

The pond covers an area of 130 acres and was created by building a dam across the head-water tributaries of the South Tomogonops River. The dam is of earthfill construction, with a slope of 2:1 on both sides and a nominal crest width of 20 feet. It is 5,000 feet long and, at present, from 10 to 55 feet in heigh Three concrete decant structures are built into tl dam, each having an overflow weir width of 8 feet. minimum 6 feet of free-board is maintained. Also, minimum of 15 million cubic feet of water is maii tained in the pond for adequate water treatment an settling of solids.

In addition to the mill tailings and contaminate water, drainage from an area of 1,227 acres was hai

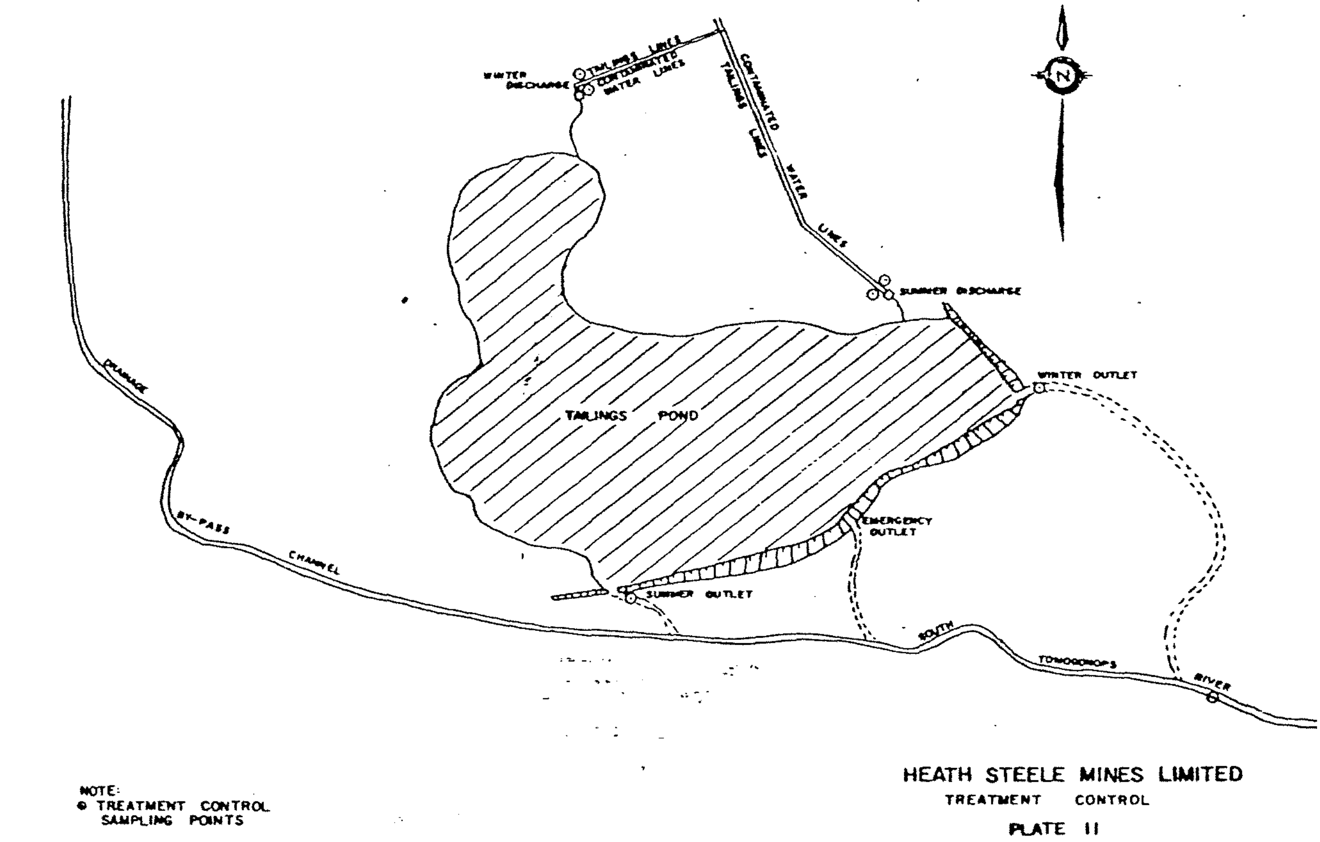

FIGURE 2 — Treatment control at Heath Steele Mines Limited.

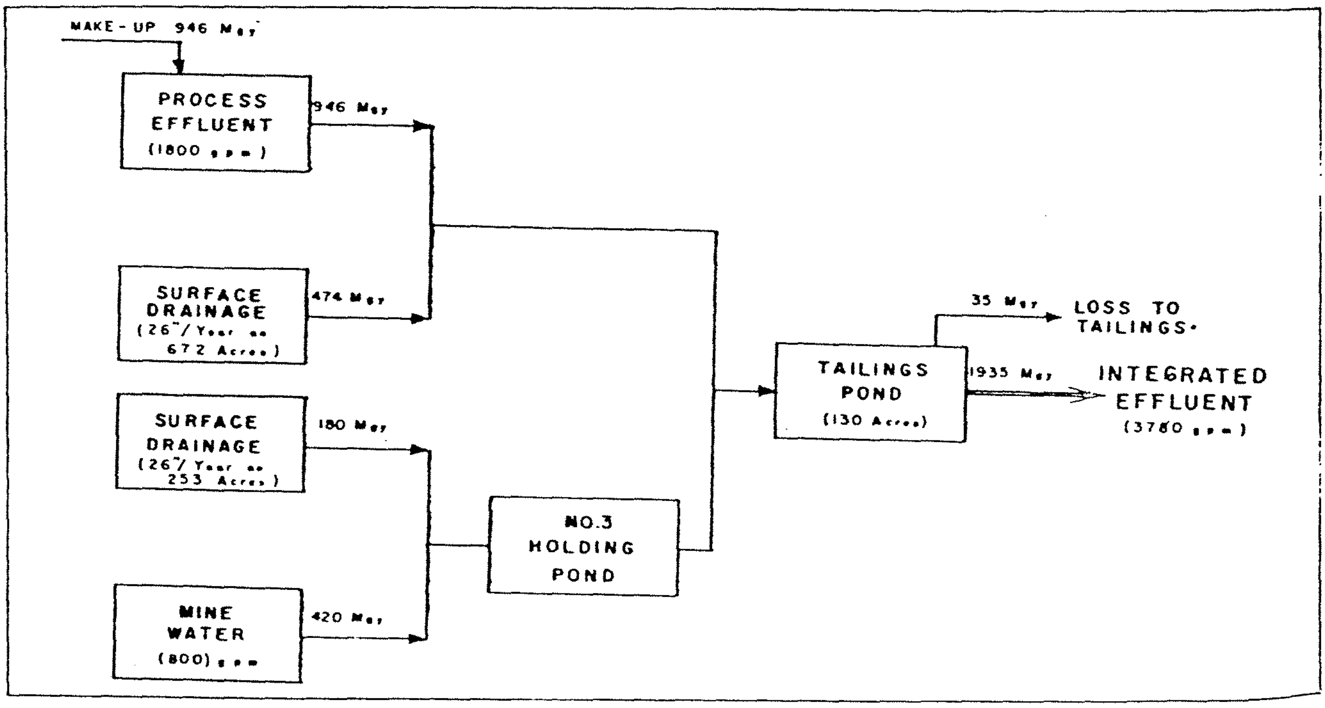

FIGURE 3 — Integrated water balance.

filled by the pond. This resulted in large flows through the pond during spring run-off, adversely affecting water treatment and increasing lime consumption. An area of 555 acres was isolated and drained around the pond, thereby reducing the natural drainage inflow by 45%. Figure 3 indicates the present water balance. Average net run-off, at 26 in. per year, is based on a total precipitation of 40 in. per year.

A second pipeline discharge point was added to allow for a better utilization of the pond area and a more uniform solids deposition pattern. The east discharge point is used during the winter and spring run-off period because the natural drainage flows through that area, thus allowing for a mixing of all inflows before entering the pond. The west pipeline discharge point is used during the summer when flows are low. The respective pond outlet is chosen to provide maximum distance between the two points. Average time of pond residence is estimated at 3 to 4 days.

Mill tailings and contaminated water are discharged together and allowed to mix prior to flowing into the pond. Hydrated lime is added at the mill to the tailings in order to neutralize the acidity of the contaminated water and to precipitate the dissolved heavy metals as hydrates. Laboratory tests indicate that maximum precipitation occurs at a pH of 9.5. In practice, lime additions are regulated to maintain a pond effluent pH of between 10.0 and 11.0. This is done to provide for a safety margin in case of sudden flow increases and due to the time-lag between changes in addition and measurements at the pond effluent.

Table 3 represents average treatment results for 1973. The flow difference between measured pond inflow and pond effluent is the natural drainage entering the pond. Removal of 99.9% of the copper and zinc, with residual effluent concentrations of 8 ppb copper and 44 ppb zinc, indicate that this is a very effective treatment scheme. It appears to be due to good settling and retention of settled hydrates by means of the mill tailings solids as well as sufficient pond residence time.

TABLE 3 — Water Treatment Results

1973 averages, flow in (US)gpm, metal concentrations in ppb

Mill Tailings	Flow	1,800
	pH	11.5
	Cu	45
	Zn	1,820
Contaminated Drainage	Flow	1,150
	pH	3.9
	Cu	23,670
	Zn	119,300
Measured Pond Inflow	Flow	2,950
	Cu	9,255
	Zn	47,617
Pond Effluent	Flow	3,780
	pH	10.6
	Cu	8
	Zn	44
Per Cent Metal Removed	Cu	99.9
	Zn	99.9
Total Lime Consumption	Tons	4,000

Operation and Control

Supervision of the operation and maintenance of water collection and treatment installations and tailings disposal is the full-time responsibility of a plant engineer. He inspects all facilities, initiates actions on maintenance, repairs and improvements, and maintains records of all pertinent data.

Collection and by-pass channels and holding ponds require little attention. Pumping is controlled by holding-pond water levels and actuated through electrode level probes. Pumps are started in sequence at rising water levels and are stopped when the level drops to within 2 feet of pump intakes. The formation of adhering deposits in pipelines is pronounced. Within a year, a 12-in.-diameter main pipeline will acquire a very rough-surfaced ⅜-in. scale, reducing throughflow capacities from 2,300 to 1,700 (US)gpm. Lines are cleaned out with Girard Polly-Pigs. These plastic, bullet-shaped forms are driven through a line by normal pumping operation, rotating as they proceed and scraping material off the pipe walls. They are collected at the discharge and re-used. Several passes are required to reduce the scale to less than ⅛ in. There are two 90-degree elbows in each line and, so far, no problems have occurred.

Hydrated lime requirements are supplied by an installation in the mill consisting of a 100-ton-capacity, bulk lime storage bin, two variable-speed screw feeders and a slurrying tank discharging into the tailings pump sump. Consumption varies from a low of 180 tons to a high of 800 tons per month. Regulating feed rates to maintain a given pH at the pond effluent is difficult due to the long time-lag. At present, lime feed rates are changed manually according to the amount of pumping time and number of pumps operating at the No. 3 holding pond. Because the amount of acid water pumped to the pond is the main factor in lime requirements, this represents a better control and will, in the future, be made automatic.

Ten flow readings and 20 water samples are taken daily, Mondays through Fridays. They are taken to monitor the efficiency of the system and its effect on the Northwest Miramichi River as well as changes in the background values of up-stream sources. The farthest sampling point is 17 miles from the property. Some sampling points are accessible only by a four-wheel-drive vehicle in the summer and snowmobile in the winter. It takes approximately 5 hours during the summer and 7 hours during the winter to collect all samples. At the same time, all pumphouses are visited and readings taken on pump running times, power, pressure and vacuum.

The samples are analysed as soon as possible after arrival at the laboratory. They are neither acidified nor filtered. After pH determination, copper and zinc are determined by a Perkin-Elmer model 403 atomic absorption spectrophotometer with a scale expansion and recording device. The detection limit for both metals is between 1 and 2 ppb, and sensitivity is 1 ppb. Hardness is determined by EDTA titration.

From time to time other samples are taken and four times a year a "complete analysis" is run on the 12 most important samples.

Capital and Operating Costs

Table 4 provides a summary of capital expenditures for both phases of the project and 1973 costs of operating the facilities. These costs do not include expenditures for tailings disposal.

Channel excavation includes culverts and flow measuring weirs. Holding pond construction includes concrete draw-off structures. Access roads were required to some remote sampling points. Buildings were needed to house the three pumping installations, and sampling and analysis includes vehicles for sampling and the atomic absorption instrumentation. Surface restoration is expected to be completed during 1974 and will include grading, spreading of earth and grass seeding.

TABLE 4

Capital Expenditures

Stockpile Removal	$ 25,000
Channel Excavation	340,000
Holding Pond Construction	370,000
Access Roads	40,000
Buildings	50,000
Pumps and Pipelines	1,380,000
Lime Feeding	50,000
Sampling and Analysis	45,000
Surface Restoration	80,000
Engineering and Construction Supervision	120,000
	$2,500,000

Annual Operating Costs

Operating Labour	$ 24,000
Operating Supplies	112,000
Repair Labour	10,000
Repair Supplies	20,000
Power	18,000
Others	36,000
	$220,000

Some quantities and unit costs involved were as follows: 250,000 tons of earth excavation and earth dam construction at 80 cents; 15,000 cu. yds of rock excavation at $10.00; 1,200 cu. yds of concrete at $100.00; and 20,000 feet of 12-in. s.s. pipeline with fittings, heat-tracing, insulation and complete installation at $36.00.

Operating costs during 1973 were $220,000, or 20 cents per ton of ore. Operating labour is primarily the cost of supervision. Operating supplies, the highest-cost item, reflect hydrated lime consumption. Due to the fluctuating demand and limited bulk rail car availability, truck haulage is frequently required. Power requirements are for pumping and, in the winter, pipeline heating. Other costs are primarily for water sampling and analysis.

TABLE 5 — Northwest Miramichi River at Curventon

Toxic units as reported by the Fisheries Research Board.

	Average	Maximum
1966	0.4[illegible]	3.60
1967	0.52	3.90
1968	0.37	2.40
1969	0.49	3.75
Ave. 1966 - 1969	0.47	3.41
1970	0.33	2.92
1971	0.17	0.80
1972	0.08	0.32
1973	0.08	0.26

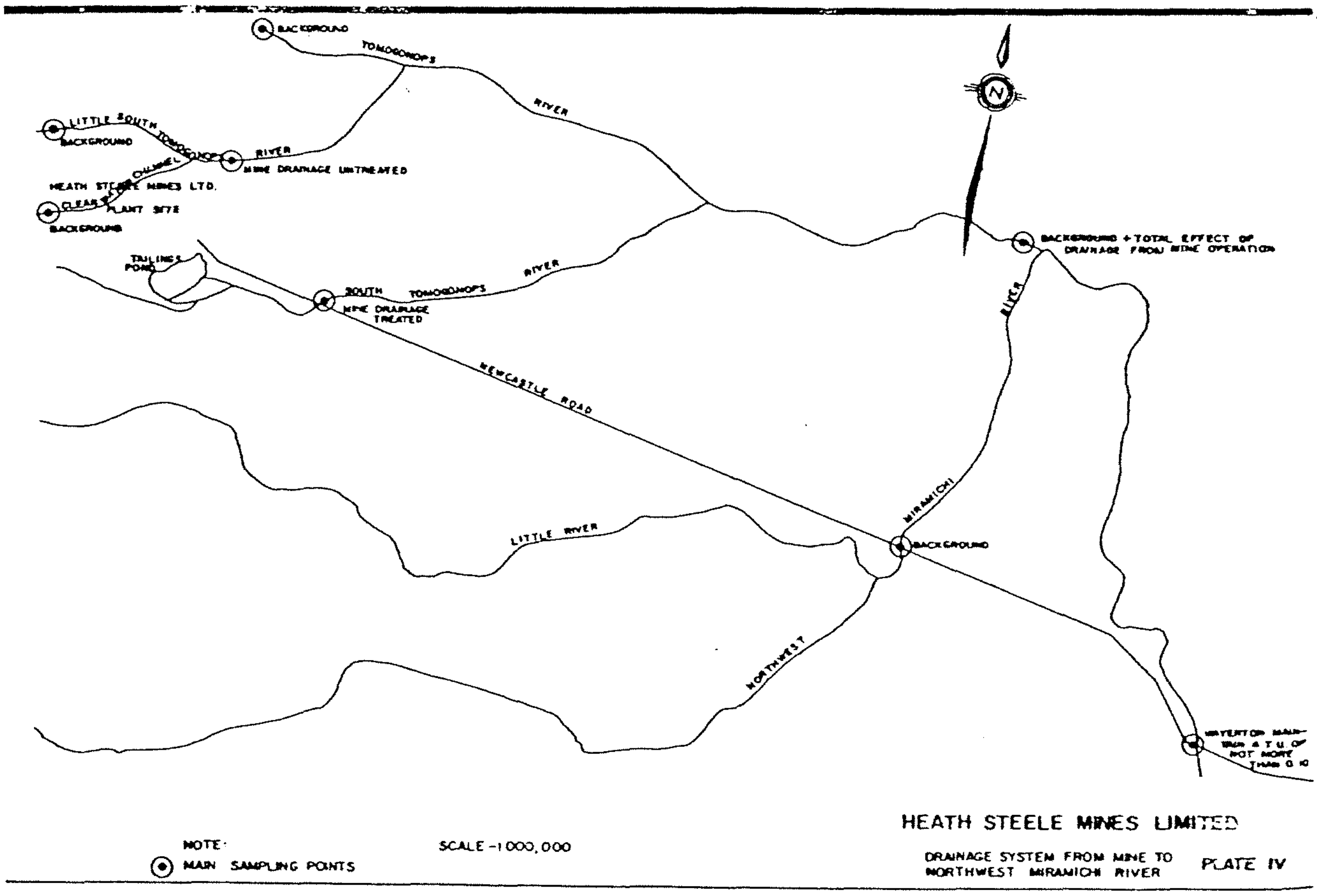

FIGURE 4 — Drainage system from the mine to the Northwest Miramichi River.

Impact of Drainage Control Measures

Figure 4 shows the drainage system from the mine to the Northwest Miramichi River, indicating the main sampling points for up-stream background, mine property effluent and impact on the Tomogonops River and Northwest Miramichi.

Table 5 indicates annual averages and peaks of toxicity in the Northwest Miramichi River as reported by the Fisheries Research Board. These come from samples collected at the Curventon Fish Counting Fence (5½ miles downstream from Wayerton) and analysed at their laboratory in St. Andrews. When comparing results during the four years preceding the start of this project with 1973, the first year after completion of the project, we find a reduction in average toxicity from 0.47 to 0.08 (83%) and a reduction in peak toxicity from 3.41 to 0.26 (92%).

In respect of the EPS stream quality requirements, the first one, "no sulphur compounds other than sulphates below the mine property", appears to be met and is not normally determined in water samples.

The second requirement was "at the mouth of the Tomogonops River, a pH range between 6 and 8, no greater than 18 ppb of copper and 108 ppb of zinc". Actual pH readings are always within the required range. Copper concentrations have been reduced substantially and average results during the last six months were within the limit. Zinc concentrations have also been reduced substantially.

The third requirement was "no greater than 0.1 toxic units in the Northwest Miramichi River". Figure 5 indicates monthly results on samples taken by the mine from 1970 to 1973 at Wayerton Bridge and corresponding results from the river up-stream of the Tomogonops at Payne Bridge for background comparison. Again, very substantial improvements have been made. With one exception, average results for 1973 have been within the limit and even peak results are close to the limit. Background results have, from time to time, exceeded the limit.

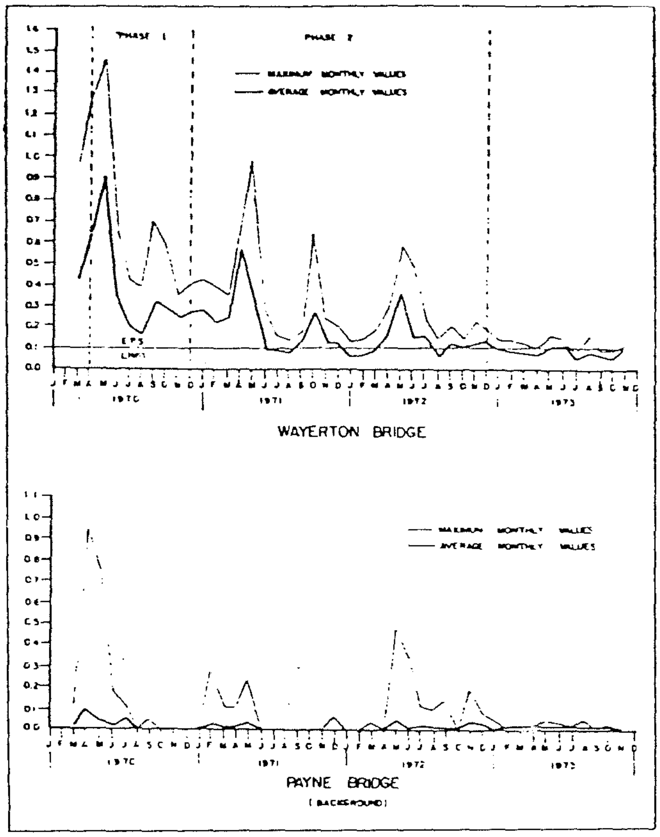

FIGURE 5—Toxicity levels in the Northwest Miramichi River.

Control of drainage from the isolated contaminated areas is good and no escape of contaminated water from these areas to fresh-water streams has been detected. The treatment of collected water is very good and the effluent quality satisfies even very strict requirements. Metal toxicity in the Northwest Miramichi River has been greatly reduced and salmon migration during the past two years has increased substantially.

New Edition of Electrical Code

THE U.S. NATIONAL FIRE PROTECTION ASSOCIATION (NFPA) announces publication of the 1975 edition of the "National Electrical Code", the world's most widely adopted set of safety requirements. The new Code supersedes all previous editions, the last being dated 1971.

Appearing in the current 640-page text are eight new articles, five articles which have been completely rewritten, 16 new parts of articles and 190 new sections. Revisions have been made in 569 other sections.

New articles pertain to copper-sheathed cable, power and control tray cable, intermediate metal conduit, electrical floor assemblies, fixed electric heating equipment for pipelines and vessels, places of assembly, electrically driven or controlled irrigation machines, and fire-protective signaling systems.

Articles completely rewritten for the 1975 Code apply to continuous rigid cable supports, storage batteries, commercial repair and storage garages, manufactured buildings, and Class 1, Class 2 and Class 3 remote-control, signaling and power-limited circuits.

Basic purpose of the National Electrical Code is the practical safeguarding of persons and property from hazards arising from the use of electricity in light, heat, power, radio, signaling, etc.

Copies of the 640-page 1975 Edition of the "National Electrical Code" (NFPA No. 70) are priced at $5.50 each, with a schedule of discounts beginning with orders for 25 copies. Orders and/or requests for detailed pricing information should be addressed to the NFPA Publications Sales Department, 470 Atlantic Ave., Boston, Mass. 02210.

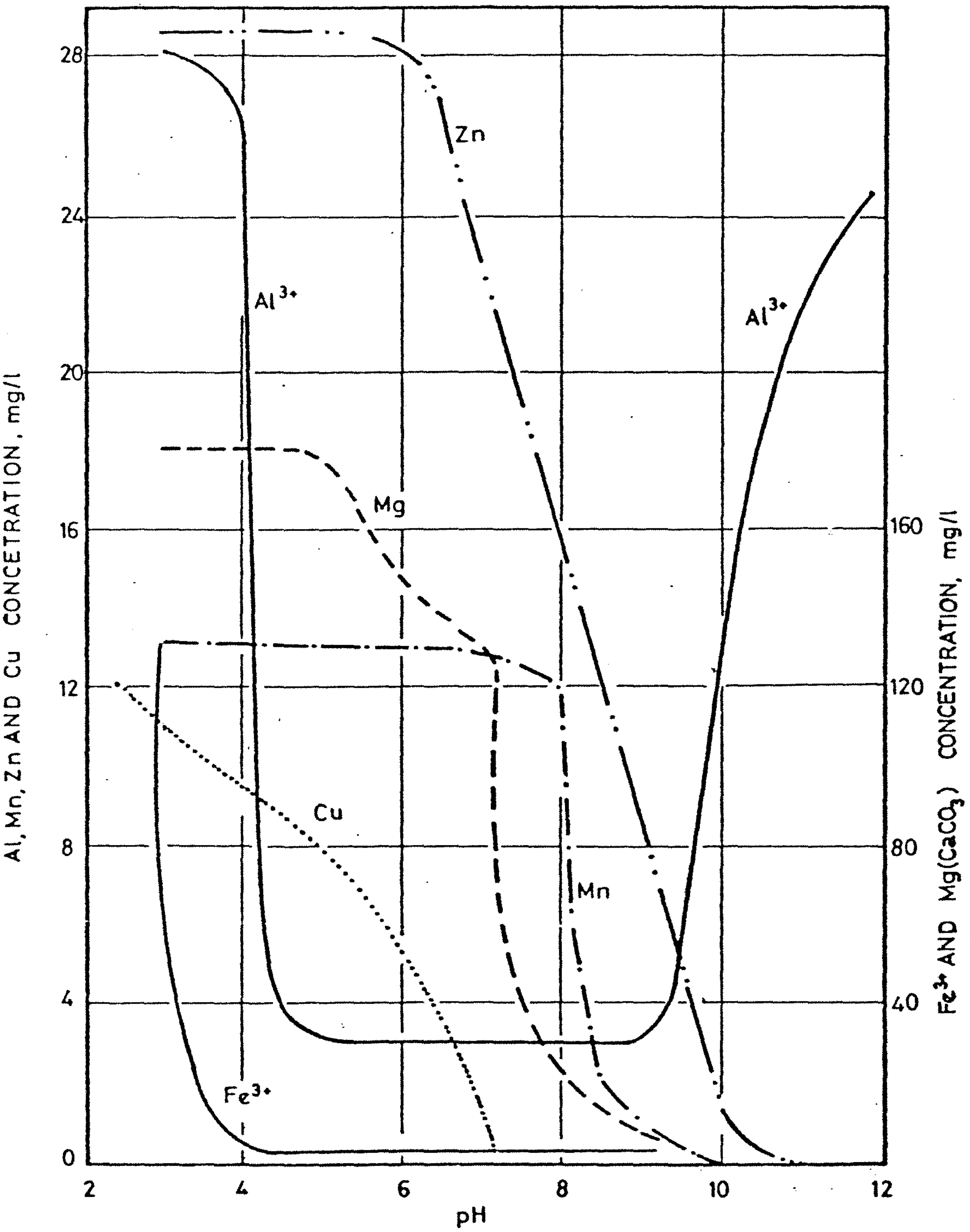

FIG.15: SOLUBILITY OF ACID MINE DRAINAGE METALS AT VARIOUS pH VALUES

(from Hill & Wilmoth, 1971)

(v) Binnie and Partners have produced a brief treatise on the effects of lime dosing on the effluent quality. They conclude that:-

lead will be reduced to less than 0.01 mg/l
zinc will be reduced to less than 0.1 mg/l
cobalt will be reduced to less than 0.01 mg/l
barium will be reduced to less than 0.1 mg/l
manganese will be reduced to less than 0.05 mg/l
iron will be reduced to less than 0.01 mg/l

Their report is attached.

(vi) In WSL's ERMP, table 6 gives the results of a water quality survey in the Capel area. Effluent escaping from AMC's plant site onto public land was found to be high in zinc, cobalt, nickel, manganese, vanadium, iron and sulphate. Within several tens of metres of the water passing through adjoining farming land, water quality had improved to the point that it would have met all of Hart's criteria.

(vii) Several quotes from "The Use of Freshwater Wetlands as a Tertiary Wastewater Treatment Alternative" by R H Kadlic and D L Tilton (November 1979: CRC Critical Reviews in Environmental Control) are useful:-

"There is no question that aquatic and semi-aquatic plant species absorb heavy metals from water and incorporate them in various structures, such as leaves, roots and stems. Ten species of emergent vacular plants absorbed 1.08 to 3.19 mg of nickel.... of dry plant weight. Water hyacinths ... and alligator weeds ... absorbed lead at a rate of 0.176 mg/g dry plant per day and 0.10 mg/g dry plant per day, respectively."

"In summary, aquatic and semi-aquatic plants absorb heavy metals, and interactions between dissolved ions and sediments cause metal accumulations in the soil as well."

Binnie & Partners PTY LTD
CONSULTING ENGINEERS

First Floor
Legal & General House
267 St Georges Terrace
Perth Western Australia

Postal Address
PO Box 7050
Cloisters Square
Perth WA 6000

Telephone
National (09) 322 7700
International +619 322 7700
Telex AA 95665

Our Ref AJG/MS/265

Your Ref

Date 26 June, 1985

Westralian Sands,
1st Floor, 267 St. George's Terrace,
PERTH WA 6000

For the attention of Mr. B. Masters

Dear Sir,

Upgraded Ilmenite Project - Capel
Effects of Lime Dosing on Effluent Quality

We have pleasure in submitting our brief treatise on the effects of lime dosing on the quality of effluent eminating from the proposed expansion of your mineral sands facilities at Capel.

We trust the information supplied is sufficient to enable you to complete your submission to the Department of Conservation & Environment. However, if further information is required, please do not hesitate to contact the writer.

We confirm that our fees for this work are to be on a time and costs basis in accordance with the Association of Consulting Engineers, Australia, guideline for fees. The hourly rates for the various people involved are :

- Principal Engineer - A.J. Gale $70/hour
- Specialist Chemist - B.G. Hoyle $60/hour
- Senior Engineer $45/hour

Disbursements will be charged at cost.

We trust we have provided sufficient information for your purpose. However, if you have any queries, please contact me.

Yours faithfully,

A.J. Gale
BINNIE & PARTNERS PTY LTD

Enclosure

WESTRALIAN SANDS LIMITED
UPGRADED ILMENITE PROJECT
Capel, Western Australia

REVIEW OF EFFECTS OF LIME DOSING ON EFFLUENT QUALITY

1.0 BRIEF

The following report is based on a request from Mr. B. Masters of Westralian Sands to provide technical comment on the effects of treatment of waste effluent from the proposed Capel development by the addition of lime to a pH of 9.5 - 10.0. No attempt has been made in this report to determine or to comment upon the level of treatment required prior to discharge.

2.0 Background Information

The following table lists the potential concentrations of the major constituents of the effluent produced by Westralian Sands.

Physical or Chemical Character	Likely Concentration in Liquid Discharge
pH	6.5 - 7.5
TDS	780
Na	49
K	19
Cl	74
HCO3	66
SO4	590
NO3	1.3
NH3-N (NH4-N)	3.3
Suspended solids	48
As	<0.05
Cd	<0.005
Pb	0.02
Zn	3.5
Cu	<0.02
Co	0.01
Ba	0.15
Cr	<0.01
V	<0.25
Ni	<0.02
Total P	0.3
Hg	<0.0005
Mo	0.01
Mo	0.51
Mn	0.51
Ca	220
Mg	9.4
Fe	2.7
Ti	0.01

It is our understanding that the above effluent is a combination of the kiln scrubber liquor, the neutralised effluent liquid and one other unknown source apparently of reasonably good quality. It also our understanding that the proposed treatment system is to comprise pH correction using lime followed by settlement of the effluent for 10 days in a pond. The overflow from the pond will form the final effluent.

3.0 Findings

A review of the chemistry was undertaken by the Group's Chief Chemist, Mr. B. Hoyle.

Based on the above information, the review indicated that the following limits would be expected from the final effluent :

- Bicarbonate alkalinity reduced from 66 to 40 mg/l;
- Lead reduced from 0.02 to less than 0.01 mg/l/;
- Zinc reduced from 3.5 to less than 0.1 mg/l;
- Cobalt reduced from 0.01 to less than 0.01 mg/l;
- Barium reduced from 0.15 to less than 0.1 mg/l;
- Manganese reduced from 0.51 to less than 0.05 mg/l;
- Iron reduced from 2.7 to less than 0.01 mg/l.

Both Total Dissolved Solids and Calcium will increase slightly. Sulphate concentrations are unlikely to change as the concentration indicated is well below the solubility limit of 2,500 mg/l. If sulphate reduction was required, then treatment of a proportion of the waste by a process such as reverse osmosis or ion exchange would be the most likely solution. Of course (final) effluent pH would be in the range 9.5 - 10.0.

The process of pH correction for precipitation of heavy metals, amongst other constituents is a common method of treatment and is well documented.

WATER AUTHORITY
of Western Australia

629 NEWCASTLE STREET
LEEDERVILLE W.A.
Postal Address: P.O. Box 100 Leederville
Western Australia 6007
Telephone: (09) 420 2420 Telex: AA 95140

Your Ref
Our Ref A17095
Enquiries Mr Ventriss
Tele Direct 420 2938

The Chairman
Environmental Protection Authority
1 Mount St
PERTH WA 6000

Attention: Mr D Galloway

WESTRALIAN SANDS LIMITED
UPGRADED ILMENITE PLANT

The report "Westralian Sands Limited Upgraded Ilmenite Project, Capel, WA, Final Submission to the Environmental Protection Authority of WA June 25, 1985", has been examined by the Water Authority and the following comments are made.

Leachate Control

Control of leachates from the solid waste disposal sites is proposec through disposal to no deeper than one metre above the water table, compaction and capping with a sloping clay layer to minimise rainwater leaching rates. The proposal is considered adequate to minimise the possibility of leachates entering the groundwater at concentrations which may be of concern. Final design of the disposal pits should be subject to approval of the Minister for Water Resources.

Liquid Storage Dams

The proposed method of construction of the liquid storage dams using high density poly-ethylene liners as described in the report is approved in principle. It is expected there will be some degree of leakage from these dams. Small leaks can be controlled through a recovery bore network as proposed by the Company. Major leaks would require more immediate action and the Company have committed to emptying of any leaking dam and repair of the leak. If such action requires temporary plant closure this is also acknowledged.

Final design of the liquid storage dams should be subject to approval of the Minister for Water Resources to ensure the proposed construction is adequate to minimise leakage or overflow.

.../2

Monitoring and Recovery Bore Network

The commitment by the company to install a monitoring/recovery bore network as recommended by Groundwater Resource Consultants is approved in principle. The approach of designing the network to match aquifer parameters determined from test pumping should ensure an optimally designed system. It is considered that the bore network should comprise every third bore being specially constructed to detect and recover denser liquid contaminants which may move laterally at the base of the surficial formations.

Final design of the bore network should be to the approval of the Minister for Water Resources.

Surface Water Discharges

The documentation provided on the treatment of plant effluents which are proposed to be discharged into the Elgin Drain are considered sufficient to indicate that quality criteria to be imposed on such discharges can be met.

In those cases where component levels presented in the Company's draft ERMP were well within water quality criteria suggested to the Company by the PWD, the criteria have been modified to more closely match the Company's presented quality levels. The ammonia (NH_3) criteria suggested to the Company has been reviewed and it is felt that 5 mg/L is a more realistic level to impose than the original 0.05 mg/L limit. In the draft ERMP the Company indicates a worst case level of 3.3 mg/L NH_3, which is within the revised criteria.

The criteria which will be imposed through the effluent license conditions will be:

pH	6.0 to 9.0	
TDS	1500	mg/L
Cl	400	"
HCO_3	400	"
SO_4	500	"
NO_3-N	10	"
NH_3-N	5	"
As	0.10	"
Cd	0.005	"
Pb	0.02	"
Zn	0.10	"
Cu	0.01	"
CN	0.02	"
Cr	0.02	"
Hg	0.0002	"
Ni	0.05	"
Fe	2.0	"
Mn	0.5	"
Sus. Solids	80	"

Radiation levels to be in accordance with Schedule 6C of the Mines Department Code of Practice on Radiation Protection in the Mining and Processing of Mineral Sands.

The proposal to construct a sand filter between the discharge point of the solution storage dam and the entry point to the biological filter may not be the optimum arrangement to ensure suspended solid levels in the final discharge are minimised. The potential for sloughing of slimes etc, from the biological filter suggest that the sand filter should comprise the final stage of treatment.

Final Site Rehabilitation

The commitment to final site rehabilitation by the company is acceptable to this Authority. The proposed continuation of monitoring after plant shutdown should not be necessary as it is anticipated that any groundwater contamination problems will have been resolved by this time.

Licensing

Surface discharges will be subject to licensing under Pt IIIA of the Rights in Water and Irrigation Act to ensure effluent quality is maintained within appropirate criteria. The liquid storage dams and waste disposal pits should also be licensed to ensure appropriate groundwater monitoring is carried out.

Prosecution of the company is provided for within the Act in the event of poor performance in complying with license conditions. Continued poor performance may result in the Government cleaning up affected areas at the Company's expense as provided for within the Act.

General

From the documentation provided by the Company, it is apparent that contamination of local surface and groundwaters can be contained within acceptable limits, provided the Company employs the appropriate measures. Therefore, the proposal is approved in principle in regard to its potential impact on the water resources.

MANAGING DIRECTOR

July 3, 1985 KT

GOVERNMENT CHEMICAL LABORATORIES
30 Plain St., Perth, Western Australia 6000.
Telephone: 325 5544

Director
Department of Conservation
& Environment
BP House
1 Mount Street
PERTH 6000

Address all
correspondence to
The Director

Attention : Mr D. Galloway

OUR REF

YOUR REF

ENQUIRIES TO Mr Ingraham

PROPOSED UPGRADED ILMENITE PROJECT -
WESTRALIAN SANDS LIMITED

The following documents relating to this proposed project have been examined -

1. Public Environmental Report, Upgraded Ilmenite Project, April 1985 (Westralian Sands Limited).

2. Report and Recommendations by the Environmental Protection Authority on the Proposed Upgraded Ilmenite Project, June 1985.

3. Westralian Sands Limited Final Submission to the Environmental Protection Authority of W.A., 25 June 1985.

The overall impression gained from study of these documents is that the company has responded to Environmental Protection Authority objections outlined in Reference 2. above in quite reasonable fashion in their Final Submission.

As indicated by Binnie and Partners in their letter of 26 June contained in Reference 3, lime neutralisation of acidic liquors to control levels of metals in solution is a common method of treatment and it appears that the Public Works Department's criteria for final effluent quality (Reference 3) should be met by the proposed treatment systems.

The critical factor to ensure levels of heavy metals in solution are kept as low as possible will be pH control and close monitoring of the lime neutralisation process to ensure the stated pH of 9.5 is attained.

Proposed lining of liquor holding dams with 1 mm polyethylene membranes should virtually eliminate leakage from the dams providing care is taken to ensure the liners are installed over screeded sand beds to avoid puncturing.

Due to the limited time available to study the reports, little examination of the proposed monitoring programmes to detect leaks was possible.

The PER is returned with this report.

for H.C. HUGHES
ACTING DIRECTOR

1 July 1985 PT

APPENDIX 2

- A summary of commitments in the Company's subsequent submission to the EPA.
- A summary of commitments in the PER.

COMMITMENTS BY PROPONENT IN WSL's SUBSEQUENT

SUBMISSION TO THE EPA.

The following are a series of extracts from the subsequent submission to the EPA which are either stated as a commitment or could be construed as such. In some cases these commitments are similar to those contained in the PER however, they represent an update of the commitments given in the PER. In these cases the commitments in the subsequent submission to the EPA should be read as having precedent over those in the PER.

1. All solid wastes will be placed into final disposal sites which are at least one metre above the height of the winter water table.

Sect 1, para (a)

2. As part of normal procedure, all solid wastes will be compacted during disposal and their upper surfaces will be sloped so as to facilitate rainwater to flow off the solids without soaking in.

All solid wastes will be covered by a 30 to 50 centimetre thick layer of clay, wherever necessary, to prevent rainwater from entering. This capping will be carried out using normal engineering practices and will be on-going throughout the life of waste disposal operation.

Sect 1, para (b)

3. The Company will line all liquid effluent dams with high density poly-ethylene (HDPE) synthetic liner of one millimetre thickness.

Sect 2, para (a)1

4. The edges of the individual sheets will be joined using heat fusion, hence there are no new chemicals introduced which could dissolve or otherwise fail during dam usage. All dams will be constructed from clean mine sand tailings which have been screened to remove particles coarser than one millimetre.

All dams will be constructed some months prior to the commencement of the plant's operation. They will be filled with water to ensure that settlement is largely completed before they begin to accept plant effluents. Should leaks occur, they will be repaired.

Sect 2, para (a)2

5. During plant operation, a dam failure such that there is significant pollution of the groundwater will require immediate action, the dam will be emptied of its contained liquids and the leak repaired. Should the action require temporary closure of the plant, then this will take place.

Sect 2, para (a)3

6. WSL accepts the recommendations in a report by Groundwater Resource Consultants Pty Ltd and commits itself to adoption of the recommended bore spacings, sizings and test pumping procedures. These recommendations are listed below.

Detection of contamination can be effected by constructing all bores as dual purpose monitor/recovery bores, using machine-slotted 100mm diameter PVC casing. Each bore would be capable of recovering $250m^3$/day using a submersible pump. This would provide an immediate and flexible recovery system.

Spacing of monitor/recovery bores is provisionally estimated at 50m. This spacing should be verified by test-pumping of the first two monitor/recovery bores constructed, so that the hydraulic characteristics of the aquifer can be quantified.

.../2

A total of about 30-40 monitor/recovery bores is anticipated.

The monitor/recovery bore network should be installed as soon as possible, so that baseline geochemical and water-level data can be established, against which any future contamination can be identified.

Groundwater from each bore should be analysed on completion, a standard analysis being supplemented by analyses for those elements which are potential contaminants.

Detection of more highly saline contamination can be made by measurements of groundwater conductivity profiles to be made monthly. Chemical analysis should then be made if anomalous conductivity is recorded.

Trace metals are unlikely to move far from any leakage source, because of adsorption and precipitation, but as a precaution analyses for Zinc, Copper, Cobalt, Chromium, Vanadium and Nickel, which are in the highest concentration in the source of liquids, should be made every three months, in samples taken from the base of bores downsream from potential sources of leaks containing these metals.

Additional supplementary small-diameter observation bores may be required to define the shape of the water-table (and hence the precise direction of groundwater movement) and the form of the Leederville unconformity interface.

A monitor/recovery bore system as described above, and modified where necessary in the light of additional data from the testing of the initial bores, will ensure the detection of any leaked contaminants, and will enable their prompt recovery by pumping.

Sect 2, para (b) + GRC's report.

7. In order to test the worst case condition in the acid effluent stream, samples of aerated product made in the pilot plant were acid leached at various levels of acid usage. The highest usage of acid, based on a very conservative approach to forecasting operating costs, was selected for laboratory development of acid effluent handling systems.

In practice lower levels of acid and lime consumption will be experienced and the level of sulphate in the final effluent will not exceed 500 mg / litre.

Sect 3, para (6+7)

8. The samples of aerated product used to produce acid effluent were not washed to lower the content of entrained ammonium chloride. As a consequence the NH_3-N in final effluent was measured at 3.3 mg / litre.

In plant practice the circuit includes a spiral screw classifier prior to the acid leach plant whose function is to dewater aerator product and wash out entrained ammonium chloride. This will result in NH_3-N content of final effluent not exceeding 0.05 mg / litre.

Sect 3, para (8+9)

.../3

9. WSL received from the Public Works Department on 24 June 1985, the following criterial for final effluent quality:

Physical or Chemical Character	Concentration
pH	6.0-7.5
TDS	2,500
Na	270
Cl	600
HCO_3	500
SO_4	500
NO_3	10
NH_3	0.05
As	0.05
Cd	0.03
Pb	0.02
Zn	0.10
Cu	0.01
CN^-	0.01
Cl	0.01
Hg	0.002
Ni	0.05

All values are in mg/l except pH.

WSL will not discharge effluent exceeding the quality criteria listed in the above table.

Sect 3, para (10)

10. WSL in the design of the capacity of the acid effluent and final solution storage dams has taken a conservative approach and provided a total storage capacity of 14 days in the circuit. This was done to ensure that plenty of time was available to carry out maintenance of equipment or make whatever adjustments are necessary to ensure that the effluent discharging from the system conforms to the required quality standards.

Sect 3, para (11)

11. As a final effluent quality polishing step WSL plans to install a biological filter. This unit will act to further lower the concentration of ammonium and sulphate ions prior to the discharge of effluent into the Elgin drain.

Sect 3, para (12)

12. Should there be problems with suspended particulates in the effluent water discharges, the Company will install a filtering device such that these particles are removed. Whilst the biological filter will capture some suspended particles, a sand filter through which all effluent liquid will pass will be constructed between the discharge

.../4

point of the solution storage dam and the entry point into the biological filter.

Sect 3, para (13)

13. Upon final plant closure, all items of plant will be dismantled and removed off-site. All effluent ponds will be drained of liquid, with water quality treatment being applied wherever necessary to ensure compliance with PWD discharge standards. Aeration liquid (containing NH_4Cl) will be solar evaporated so as to recover the dissolved salts.

All solid wastes will be disposed of into normal one-year capacity surface pits, with a surface capping of clay preventing the formation of rainwater-derived leachate. Solids with a greater potenti for underground water pollution (for example, NH_4Cl and metalliferous sludge from the biological filter) will be placed in clay-lined, engineered disposal pits and capped with clay.

All ponds and other excavations will be infilled with clean sand, with topsoil and vegetation cover applied to the surface.

Monitoring of leachates will continue for a minimum of two years after plant closure, provided that earlier monitoring shows this action to be necessary. After two years, should further monitoring be necessary, the Company commits itself to a continuation of the programme until it is no longer required. However, the need for long-term monitoring will be largely dependent upon the Company's actions to prevent leachate formation. Since all solid wastes will be capped with an impervious clay layer, leachate generation will not occur.

Sect 4.

.4. (a) Dust emissions from stock piles, transportation of raw materials, waste disposal and product will be controlled at all stages of the operation. The Company will submit its plans for dust control to the Dept of Conservation and Environment for approval.

(b) The storage of hazardous chemicals and contingencies to recover spillage will meet the requirements of the Explosives and Dangerous Goods Division of the Department of Mines.

(c) If the quality of liquid effluent discharge diminishes below the accepted criteria, the Company will cease the liquid discharge until measures are instituted to reduce the levels of contaminants.

(d) The techniques to be employed for the disposal of all solids will be submitted to the Public Works Department for approval. Should clay capping of solid wastes fail to prevent the generation of contaminating leachates, the Company will use alternative methods of disposing of its wastes and will ensure that wastes already disposed will be recovered or otherwise treated to prevent further leachate generation.

(e) The Company will comply with all regulations relating to radiation protection.

Sect 5.

COMMITMENTS BY PROPONENT IN THE PER

The following are a series of extracts from the PER which are are stated as a commitmentor could be construed as such:

All new roads will be built by WSL on WSL-owned land. Water will be taken from deep bores installed on company land and maintained by the company. All feed materials other than ilmenite will be purchased by direct negotiation between WSL and suppliers. Ilmenite is being supplied by WSL from its existing or future mining operations at a price which will be directly related to the current market price. Electricity is being purchased from the State Energy Commission of Western Australia at normal market rates. (Sec 2.3.5, para 4)

The project will not affect WSL's mining rate and will not in itself provide justification for the mining of young, coastal ilmenite deposits. (Sec 2.6.1, para 1)

Most feed materials entering the plant, together with the final product, will be carted in covered dump trucks. Sulphuric acid will be delivered in sealed tankers and lime will arrive within pressurized sealed tankers. Solid wastes will be moved by standard covered dump trucks but self-elevating scrapers may be able to pick up and move the iron oxide solid wastes. (Sec 2.7, para 1)

The UGI plant will consume some 180,000t of feed ilmenite annually, derived from WSL's normal mining operations. No increase in mining rate is necessary and purchases from other producers are not envisaged. (Sec 2.7.1, para. 1)

The use of natural gas is being examined as a substitute source of energy and may prove to be more cost efficient. Technical and financial evaluation is continuing. (Sec 2.7.2., para 1)

Upgraded ilmenite from WSL's plant will be sold almost entirely for conversion into titanium dioxide pigment via the chloride-route process. (Sec 2.8, para 1)

(The Yarragadee Formation. It is the current source of water for the North Capel mining operation and will be tapped to supply water to the UGI plant. (Sec 3.3, para 3)

The proposed UGI plant will utilise modern production and control technology. As a consequence, the plant's likely environmental impacts will be minimal. It will comply with all existing laws, regulations, codes and standards. The plant will be remote from residents and well screened from Bussell Highway. These factors coupled with appropriate control technology will minimise the impact of odour or aesthetic disruption. Secure containment, treatment and monitoring of liquid and solid effluents will reduce potential impacts to acceptable levels. (Sec 4.0, para 1)

All holding dams will be lined with a synthetic membrane. (Sec 4.1, para 1)

The acid handling and storage section will have a bunded, sealed surface, so that any leakage or spillage will be completely contained. Full recovery of spilled acid is therefore assured. Delivery and storage will be in mild steel tanks. (Sec 4.1, para 2)

If the dried neutralised effluent solids are not used as fertilizer, they will be disposed of into one-year capacity surface pits. (Sec 4.1, para 9)

The escape of kiln scrubber liquid under the worst-case situation would produce a groundwater mixture with a pH of about 5.2. Groundwater below all pits will be monitored. If necessary, management will involve extracting the affected groundwater and treating it as it if were normal kiln scrubber liquid. (Sec 4.1, para 11)

Any contamination of groundwater by aeration liquid will be managed by recovering the affected water by bores. The recovered liquid would be pumped to the solution storage dam where dilution would lower the overall TDS content and the action of the biological filters would remove most of the contained NH_3-N. (Sec 4.1, para 14)

Biological filters will be installed for the final removal of nutrients and heavy metals (Figure 8). (Sec 4.1, para 15)

Acid leach liquid would produce similar environmental impacts as kiln scrubber liquid and similar management methods would be used. (Sec 4.1, para 16)

Neutralised effluent liquid with slightly elevated TDS and sulphate levels may enter the groundwater system from the solar evaporation area. No active management is planned since the resulting mixed liquid is not expected to have any major environmental impacts. (Sec 4.1, para 18)

Leachate from solar evaporation ponds and from neutralised effluent solids will be monitored but is not expected to cause a deterioration of general water quality. (Sec 4.1, para 19)

Should monitoring show leaching of NH_4Cl is occurring, it will be recovered by bores. The recovered water would be added to the solution storage dam for dilution and biological cleaning. However, because iron oxide solids are potentially capable of generating leachate for many years (until all NH_4Cl is leached out), the most effective management solution to be adopted will involve covering the disposed solids with synthetic liner or clay capping. In this way, rainwater entering the disposed solids would be greatly reduced in volume, in turn, reducing or eliminating the amount of leachate entering the groundwater. (Sec 4.1, para 20)

Clean decant water from the inert solids dam will be added to the final liquid effluent to dilute the levels of salts and dissolved metals. Acidic kiln scrubber liquid and alkaline neutralised effluent will be mixed to promote neutralisation and precipitation of the metalliferous components. Further small additions of lime will take these reactions and pH changes to equilibrium. (Sec 4.2, para 5)

The plant discharges will conform with the "Water Quality Criteria for Aquatic Ecosystems" (Reference 5). Discharges will be analysed for:

TDS
Sulphate
NH_3-N
Zinc
Total Phosphate
Manganese
Calcium
Iron. (Sec 4.2, para 6)

Management techniques to be used to improve the quality of final liquid effluent prior to discharge include:

- Addition of a controlled quantity of lime (calcium oxide) to modify the pH and chemistry of the liquid effluent. pH will be raised to about 9.5, at which point the amount of dissolved zinc will be reduced to the lowest possible equilibrium levels. Other metals including copper, chromium and nickel will also precipitate out of solution.

- Biological/wetland filters will be incorporated into the second solution storage dam and into the 600m long drain which takes liquid effluent from the dam discharge point to the Elgin Drain. These two filter areas will be zones of high biological activity. Water depth will be maintained at about 30cm so that interactions between plants, algae, micro-organisms and the water will be maximised. Metal concentrations will be greatly reduced and nutrients (phosphorous, nitrogen and sulphur) will also be removed

- Management to reduce the iron content of underground bore water, from which all plant process water is derived, will also occur. The bore water will be transferred to a concrete storage tank. By exposure to the air, ferrous iron (Fe^{++}) will be converted to ferric iron (Fe^{+++}) and form an insoluble iron oxide (Fe_2O_3). This material will accumulate at the bottom of the tank and will be removed for disposal on land.

Should further management of general water quality be required, there are three additional options available:

- Limestone or similar material could be laid in the 600m drain leading to Elgin Drain. This would cause a rise in pH and some calcium and carbonate ions to pass into solution, thus increasing the alkalinity and assisting in further precipitation of dissolved metals.

- o Installation of a sand filter.
- o Dilution of final liquid effluent with bore water. (Sec 4.2, para 7 →)

Within the entire plantsite, wherever there are storage or piping facilities for liquids, the ground surface will be bitumen or concrete-surfaced, with bunds to prevent the escape of liquid to the outside. Spilled liquids will then be subjected to one of the following management options:

- o Recycling
- o Dilution and discharge to the Elgin Drain
- o Adding to the plant's normal liquid effluent treatment systems. (Sec 4.2, para 16 →)

Dust emisssions will comply with all relevant regulations of the Clean Air Act and Mines Regulations Act. (Sec 4.3, para 1)

Gas produced by drying of the final product contains sulphur dioxide and dust. A small venturi scrubber will reduce both contaminants to levels below the accepted standards. The final exhaust gas will have the following characteristics:

		Final Exhaust Gas
Operating Temperature		60°C
Dust Content		$0.3 g/m^3$
Important Constituents:	CO_2	2.3%
	H_2O	19.7%
	N_2	61.6%
	O_2	16.4%
	SO_2	0.01%

(Sec 4.3.2, para 1)

In accordance with the Act, the stack required for the dryer is 14.3m high. Subject to further checking of the appropriate calculations, a chimney of this height will be installed. (Sec 4.3.2, para 2)

Acid leaching of upgraded ilmenite generates small amounts of hydrogen gas.

Ventilation hoods above each acid leach tank will be inter-connected and subjected to suction so that a mixture of outside air and emitted gas will be constantly removed from above the tanks. This gas will normally be passed to the after-burner of the main gas cleaning section and be discharged with the kiln exhaust gases.

Under abnormal conditions, this gas would be directly ventilated to the atmosphere via the emergency acid leach ventilation stack. (Sec 4.3.3, para 2,3)

Cleaning of the dedusting air, derived from suction hoods located over all dust emitting and material conveying equipment, will be carried out in two stages:

- o A venturi scrubber will reduce the dust content.
- o A centrifugal droplet separator will reduce the water content.

After emission to the atmosphere the gas will contain at most $0.3 g/m^3$ of dust and will have a moisture content of 2.5%. (Sec 4.3.4, para 1 →)

Under normal circumstances, the exhaust gas will be cleaned via a dust settling chamber, after burning chamber, venturi scrubber, droplet separator and finally an exit stack (Figure 9). (Sec 4.3.5, para 2)

The composition of the normal cleaned final exhaust gas has been calculated to be:

		Exhaust Gas
Operating Temperature		82°C
Dust Content		$0.3g/m^3$
Important Constituents:	CO_2	9.7%
	H_2O	49.5%
	O_2	1.9%
	SO_2	0.2%
	CO	nil
	H_2	nil

(Sec 4.3.5, para 3)

The kiln gas will be discharged via a 52m chimney stack to meet the specifications of the W.A. Clean Air Act. (Sec 4.3.5, para 4)

The gas quality likely to be emitted from the emergency kiln stack is shown below:

		Kiln Emergency Gas
Operating Temperature		-
Dust Content		moderate
Important Constituents:	CO_2	13.9%
	H_2O	16.9%
	O_2	5.3%
	SO_2	0.25%
	CO	1.58%
	H	trace

Such an emergency would be expected to occur rarely. If it does, shut down of the kiln will occur almost immediately and these emissions will cease within 30 minutes. (Sec 4.3.6, Para 2?)

The UGI plant will produce the following solid wastes annually:

		WEIGHT (tonnes)	VOLUME (cubic metres)
Iron Oxide Solids		66,000	44,800
Inert Solids	- Non-Magnetics	10,100	10,100
	- De-dusting solids	11,000	11,000
Neutralised Effluent Solids		17,000	11,500
Kiln Scrubber Dust		6,500	1,800
Char Non-Magnetics		2,300	5,100
Kiln Discharge Oversize		1,500	750

(Sec 4.4, para 1)

Three options are available for disposal of these solid wastes.

Option one involves the use of the North Capel mining pit to be left behind when mineral sand mining ceases in 1987. This excavation will have a volume of about 650,000m³ and it is to be located on the east side of the dunal ridge, approximately 1.5 km north of the UGI plantsite.

Option two will require the construction of surface pits of sufficient size to accomodate the volume of disposed solids. Called one-year-capacity surface pits, they will be located close to the UGI plantsite on the east side of the dunal ridge. They will have a maximum depth of four metres, and will accept three metres of solid waste and one metre of clean sand above.

Option three is to transport solid wastes to existing operating WSL minesites other than at North Capel and to bury the solids beneath up to ten metres of mine tailings. However, this option will not be considered until the North Capel mine pit is filled (after about 1996).

Neutralised effluent solids contain gypsum, which is slightly soluble in water, and this material is proposed for disposal only within one-year-capacity surface pits (Option two) so that it cannot come into direct contact with groundwater. As well, the material has potential as a fertilizer since its sulphur, iron and lime contents are desirable additives to certain acidic sandy soils near the coast (Department of Agriculture, Bunbury; pers. comm.). All other solids will be transported to the North Capel mining pit where their combined annual volume of $80,000 m^3$ will allow eight years of disposal to occur. One-year-capacity surface pits will then be employed to accept solid wastes for the remainder of the UGI plant's life. (Sec 4.4.1, para 1→)

The visual impact of operating up to four hectares of solar evaporation ponds for the neutralised effluent solids and up to 20 hectares for solid waste disposal (the North Capel mining pit plus one or more one-year-capacity surface pits) will be hidden from Bussell Highway by the dunal ridge. Since all pits will be covered in one metre of clean sand plus topsoil and revegetated, this impact will be only temporary. (Sec 4.4.2, para 2)

Wind-blown dust may be generated under extreme summer conditions. The nature of all solids should restrict this to very low levels whilst the presence of the dunal ridge should ensure that strong winds affecting the different disposal pits will be infrequent. (Sec 4.4.2, para 3)

During the 20 year minimum life of the UGI plant, accurate surveys will be regularly carried out on the surface elevations of the north Capel mining pit and all one-year-capacity surface pits. Should settling and compaction be found to be excessive, the affected land will remain zoned for agriculture. (Sec 4.4.2, para 6)

Surveyed plans will be prepared so that the location of all disposal pits is known. (Sec 4.4.2, para 7)

For pits containing neutralised effluent solids, the potential long-term reduction in surface elevation will pose no environmental problems provided that incompatible land uses are not allowed. WSL therefore undertakes to retain the subject land's agricultural zoning until engineering and survey evaluations have shown that other land uses are possible. Should WSL sell the land after plant closure, appropriate information and plans will be provided to the Shire of Capel, relevant Government departments and the land purchaser. (Sec 4.4.2, para 8)

Noise levels will comply with the appropriate standards and regulations as laid down by State legislation and no special precautions or actions apart from normal industrial, hearing-loss protection measures are anticipated. (Sec 4.6, para 2)

A monitoring and management programme will be implemented to ensure there will be no adverse radiological impacts from the project on the workforce or the general public.

The proponent will conduct routine radiation monitoring on a regular basis within the UGI plant as agreed with the Department of Mines and the appropriate radiation protection regulatory body. (Sec 4.7, para 4,5)

Dust monitoring using high volume samplers will be conducted in accordance with the Code of Practice. An initial sampling period of two weeks will be extended to longer periods as absolute compliance is assured, but in any case sampling will be at no greater than 12 monthly intervals. In particular, dry material transfer points (hopper loading stations, belt crossover points, the magnetic separation unit and the product discharge station) will be monitored. Dust from the kiln stack and product drying stack will be investigated as required by the regulatory authorities. Dust concentrations in air and gross alpha counts will be analysed and recorded.

These readings will be plotted to permit early recognition of trends away from average readings at individual stations as well as providing confirmation that ambient dust and radiation levels are well within the limits specified by the Code of Practice. In addition the data will enable radiation dose estimate records to be maintained for employees working in the monitoring zones. (sec 4.7, para 6+7)

In accordance with normal industry practice, co-operation would be maintained with the appropriate State regulatory authority and it is anticipated that independent checks on dust and radiation levels would be carried out at approximately three monthly intervals. (Sec 4.7, para 9)

From Bussell Highway, the tops of some of the buildings, storage bins and conveyor transfer towers, plus the exhaust gas stacks, will be visible. The small scale ground level "clutter" associated with industrial sites will be screened from view. (Sec 4.8, para 1)

Existing vegetation will prevent most highway users from noticing the plant. Water vapour plumes which will rise above the plant will be the most noticeable feature. (sec 4.8, para 2)

The occasional emission of black smoke during boiler startup will be regulated in accordance with the provisions of the Clean Air Act (1964-1981). (sec 4.8, para 3)

Rehabilitation of the main North Capel mining pit and of solid waste disposal pits will ensure that the long term rural usage of the land will continue. (Sec 4.9, para 1)

Some 50ha of land, additional to the 16ha required for permanent plant and dams, will be progressively disturbed and rehabilitated during the operation of the UGI plant with all of this land lying to the east of the dunal ridge. (sec 5.1, para 2)

Major tree-plantings are presently being undertaken throughout the area. One or more biological/wetland filters will be constructed to utilise plant nutrients. (sec 5.1, para 3)

Upon decommissioning, the structural units of the plant will be sold for scrap or for continued use elsewhere. The plantsite itself could become the location of other small industries. All dams and pits will be covered by one metre of clean sand taken from mined sand tailings close to the plantsite. The solar drying area will be contoured prior to receiving a cover of mixed topsoil and solid effluent wastes. All recontoured or filled-in areas will be replanted to pasture species appropriate to grazing land use in the area. (sec 5.2, para 1)

Techniques proposed for rehabilitation of disposal areas utilised by the UGI project will be largely similar to those used after mineral sands mining.

Year 1 - After recontouring and respreading of topsoil to an average depth of 25cm, the following seeds and seeding rates will be applied per hectare:

Serradella	-	25kg
South African Veldt Grass	-	10kg
Wimmera Rye	-	10kg
Cereal Rye	-	50kg
Sub-clovers	-	20kg

?

Initial fertilizer applications will be made at the following rates per hectare during early winter seeding:

Agricultural lime	-	2t
Superphosphate, Copper, Zinc, Molybdenum No. 1	-	250kg
Superphosphate potash 3-2	-	200kg
Agran 34-0	-	100kg

Follow-up spring fertilizer applications will be made at lower rates per hectare:

Superphosphate/potash 5-2	-	150kg
Agran 34-0	-	50kg

Year 2 - Further seed and fertilizer will be applied at Year 1 application rates to any areas requiring resowing.

Further fertilizer application will occur at the following rates per hectare:

Superphosphate/potash 5-1	-	150kg
Agran 34-0	-	100kg

Year 3 - Normal fertilizer applications as for Year 2 will continue. Cattle (or sheep) grazing will commence. Mild grazing pressure stimulates plant growth whilst the distribution of animal droppings encourages invertebrate usage of the soil. (sec 6.0, para 2 →)

In selected areas, tree and shrub plantings will be undertaken to provide shade and shelter belts and to improve the aesthetics of the site.

Species to be used will include the following:

River Gum	Bushy Yate
Marri	W.A. Peppermint
Swamp Mahogany	Acacia species
Flat Topped Yate	Tuart

Emphasis will be placed on Western Australian native species. (sec 6.1, para 1 →)

WSL will undertake ongoing management of their land. This will involve grazing management and maintenance of replanted trees. Appropriate advice will be sought from the Department of Agriculture and the Department of Conservation and Land Management (CALM). (sec 6.2, para 2)

Pipe leakage will be monitored in three ways:

- Visual observation at regular intervals will ensure pipe security.
- The discharge end of each pipe carrying an undesirable liquid effluent will be fitted with pressure and/or flow monitoring devices. Hence any sudden reduction in pressure or flow will register a warning in the plant's central control room.
- The production and consumption figures of all intermediate and final liquids and solids will be calculated. (sec 7.1, para 1 →)

Budget calculations on materials produced or consumed will give indications of reduced volumes for pond or dam leakage. Visual checking of liquid/slurry depths will be frequent, especially when ponds are close to being filled. (sec 7.1, para 5)

Monitoring of groundwater quality will be carried out on a regular basis to give an indication of any movement of groundwater. Twelve cased monitor bores will be established. (Sec 7.1, para 6)

Two bores will be located to the south and west of the mining pit (groundwater flow is predominantly to the west). The remaining bores will be arranged in two circles, one being around the acid and neutralising sections of the disposal system, and the other around the iron oxide solids dams (Figure 14). (Sec 7.1, para 7)

The frequency of water sampling will vary with the plant's operating time. Samples will be collected two to four weeks apart commencing prior to plant commissioning, to provide data on seasonal variation. After four to six months, sampling frequency will be increased to every week. After three months of this intensive sampling, the frequency will be reduced to once every month, as requested by the PWD. Depending on the particular bore, the following chemicals will be analysed:

pH, TDS, SO_4, NO_3-N, NH_3-N, Ca, Zn, Cu, Co, V, Ni, Cl, Cr and Total P.
(Sec 7.1, para 8)

Surface water sampling frequency will be on a monthly basis, as recommended by the PWD. (Sec 7.2, para 1)

Specific monitoring recommendations outlined by WSL's consulting ecologist (R.B. Humphries, pers. comm.) are accepted in full. They are:

Four sampling sites to be established:

- Above and below the effluent outfall in Elgin Drain.
- In Gynudup Brook above and below its confluence with Elgin Drain.
- During establishment, monitoring 2 to 3 times/week of the efficiency of the effluent treatment system, and the quality of its discharge, particularly for pH, TDS, Zn and SO_4.
- Remedial action to be instituted if satisfactory performance is not achieved.
- Daily field monitoring of pH, temperature and conductivity.
- During operation, six monthly monitoring of water quality in the Elgin Drain and Gynudup Brook.
- The detection limits for metal analyses will be low enough to permit judgement as to whether criteria for aquatic ecosystems are being met (Reference 5).
- Annual sampling of mussel tissue for heavy metal concentration at Gynudup Brook.

(Sec 7.2, para 2 →)

WSL will monitor the levels of SO_2 and particulates produced during operation of the plant at a frequency acceptable to the Public Health Department. Initially, monitoring will involve weekly air sample collections and analysis. After a period of satisfactory plant operation, the frequency of analysis will be reduced, consistent with the results achieved, and with changes in seasonal conditions if appropriate. (Sec 7.3, para 1)

(Radiation)
Monitoring will be directed towards gamma exposures using personal TLD badges and total alpha measurements of airborne dust at breathing zone levels. In addition, routine chemical analysis of feedstock, intermediate and waste products will be carried out. (Sec 7.5 para 2)

In accordance with normal industry practice, co-operation would be maintained with the appropriate State regulatory authority and it is anticipated that independent checks on dust and radiation levels would be carried out at approximately three monthly intervals. (Sec 7.5 para 3)

Monitoring is required under Western Australia's Noise Abatement Act, 1972. Within the first year of plant operation, a noise survey will be carried out by an approved noise assessor, so that specific locations and generalized areas where noise hazards exist, can be identified. A written report on the survey will be sent to the Commissioner for Public Health within three months. (sec 7.6, para 1)

Any change in the workplace that is likely to increase noise exposures or levels will result in a follow up survey. (sec 7.6, para 2)

An annual report will be submitted to the Mines Department, detailing the previous years rehabilitation. (Sec 7.7, para 2)

Aside from these legislative requirements, monitoring will also be carried out by WSL on an informal but frequent basis and submitted to the Department of Mines. It would be against the company's own interests to control non-productive land of any size, hence, there will be regular monitoring to ensure that the maximum possible area of land is properly returned to agricultural productivity. (sec 7.7, para 3)