Post-Project Analysis:
A Case Study of the Jolu Gold Mine, Northern Saskatchewan

A. Faye Bres

A Manuscript Report Prepared for the Canadian Environmental Assessment Research Council
February 1992

Post Project Analysis: A Case Study of the Jolu Gold Mine, northern Saskatchewan

A.F. Bres

Abstract

Post-project analysis provides a means of improving Environmental Impact Assessment by learning from the experiences gained from past projects (ECE 1990). In this paper, the results of a post-project analysis of the **Jolu Gold** Mine **in Northern Saskatchewan are presented. An Environmental Impact Assessment** for the Jolu mining operation was conducted in 1988. and the mine and mill were in operation from 1988 to 1991. The site is presently undergoing decommissioning.

The study consists of three parts. First, the formal Saskatchewan Environmental Assessment and Review Process is described, and compared to the process applied during the Jolu Environmental Impact Assessment. This provided an opportunity to study the effectiveness of the Saskatchewan process, and to determine how closely the official process is followed in practice. Second, the Jolu Environmental Impact Statement is critiqued. The critique concentrates on the scientific and technical soundness of the Environmental Impact Statement, its clarity, and its focus on important issues (as discussed in Ross 1987). Third, an evaluation is conducted on the accuracy of the predictions of environmental impacts made during the Jolu Impact Assessment. Because mitigative measures were recommended in the Impact Statement for many of the potential impacts, the evaluation of accuracy of impacts also involved an evaluation of the effectiveness of mitigative measures applied. The evaluation of the accuracy of impact predictions and of the effectiveness of mitigative measures applied involved conducting a detailed study of the environmental management program of the Jolu Mine from start up to decommissioning.

The Jolu Gold Mining operation had an impressive history of sound environmental management. Although many deficiencies were found during the critique of the Environmental Impact Statement, the Jolu Impact Assessment provided a solid base for future environmental management of the project. The Environmental Impact Assessment process as applied for the Jolu mine appears to have been effective at predicting the majority of potential impacts and ensuring that they were adequately mitigated. Where impact predictions proved to be inaccurate (specifically in regards to natural degradation rates of the tailings effluent), the Jolu Management responded quickly to prevent serious environmental problems.

INTRODUCTION

Environmental Impact Assessment (EIA) is a predictive mechanism. The implementation of a project which has undergone an EIA provides an opportunity to test the predictions made during the EIA (Davies and Sadler 1989). Post-project analyses are "environmental studies undertaken during the implementation phase (prior to construction, during construction or operation and at: the time of abandonment) of a given actively - after the decision to proceed has been made" (ECE 1990). Post-project analysis (PPA) allows us to learn from the successes and failures of projects to permit others to benefit in future projects of a similar nature. PPAs can contribute significantly to the advancement of EIA in many ways. They may focus on EIA process development, or on the improvement of management techniques (ECE 1990). They may address procedural and administrative issues or scientific and technological issues (ECE 1990).

In this paper, a post-project analysis of the Jolu Gold Mine in northern Saskatchewan is presented. The results of this paper are a part of a larger study which addresses both EIA process development and management issues (Bres in preparation). This paper will concentrate on EIA process development. Both scientific and technical issues and procedural and administrative issues will be addressed.

The study has four main objectives:

- To study and report on how the formal Saskatchewan Environmental Assessment and Review Process is applied in a case study.
- To provide a critique of an Environmental Impact Statement (EIS).
- To study and report on the accuracy of biophysical impact predictions made during an Environmental Impact Assessment.
- To study and report on the effectiveness of mitigation procedures at reducing adverse environmental impacts.

A detailed methodology for this study is provided in the hope that it may help others in the future who are conducting similar studies. This is followed by a background to the Jolu Gold mine, and a very brief summary of the Saskatchewan Environmental Assessment and Review Process as it was at the time of the Jolu EIA in 1988. The Jolu EIA process is then described, and compared to the official Saskatchewan Process. A detailed critique of the content, clarity, and scientific soundness of the final Environmental Impact Statement submitted by the Proponent is presented. The final analysis includes a comparison of the predictions of biophysical impacts in the Jolu Environmental Impact Statement to the actual impacts observed during the three years of operation of the Jolu Mining Project.

METHODOLOGY

The following is a brief summary of the methodology applied for this study.

1) Prepare a general research proposal.

The general proposal identified objectives, set criteria for selection of a case study, and included a general methodology for the study. It was decided that the case study would be of a mining operation, and would address biophysical issues rather than socioeconomic issues.

2) Select a case study.

Selecting an appropriate case study was critical to the success of this study. The following criteria were used to select the case study (adapted from Davies and Sadler 1989):

> A) An adequately detailed EIA must have been completed prior to development of the project. The Environmental Impact Statement must have detailed baseline measurements and quantified predictions of expected environmental impacts.
>
> B) The mine must have been in production long enough for environmental impacts to have occurred.
>
> C) Records of the environmental management procedures followed during the life of the operation should be readily available. A detailed account of mitigative measures applied must be available, preferably with quantified predictions of residual impacts. Monitoring data must be available to compare to baseline data.

The Jolu Gold Mine in northern Saskatchewan was selected for the study, as it appeared to meet all of these criteria. With ever increasing industry standards for Environmental Impact Assessment, a recently completed Environmental Impact Statement (EIS) such as the 1988 Jolu EIS was expected to be of higher quality than many older studies. An initial review of the EIS indicated that up to date and thorough methods were employed. It was thought that a critical analysis of such an EIS could be of great value to future efforts in impact assessment. The Jolu case study had the added advantage of being a short lived operation. Because the Jolu ore body was small, the mill was only in.

operation for three years. This PPA was therefore able to evaluate impacts over the entire operating life of the project.

3) Conduct a literature review.

A general literature review was conducted. The review included information related to Environmental Impact Assessment, Post-project Analysis, relevant Provincial and Federal guidelines and regulations, research methods, and technical aspects of the mining industry including tailings disposal methods, effluent treatment methods, mining, milling and benefaction processes.

4) Prepare a case specific research methodology.

Based on the initial review of the Jolu EIS and on a literature review of PPA methods, a case specific research methodology was designed. A draft of the methodology was submitted to the Jolu mine manager and International Corona Corporation's Director of Environmental Affairs in order to solicit their comments.

5) Evaluate the EIS.

The EIS was evaluated in terms of its scientific and technical soundness, its clarity and its focus on important issues as discussed in Ross (1987). In addition to evaluating the EIS as a document, this phase involved identifying the predictions made in the EIS which would be tested for accuracy in this study. Data requirements for the analysis of accuracy of predictions were identified during the initial review of the EIS.

6) Conduct a study of the history of the Jolu Environmental Management program.,

Environmental management practices at the Jolu Mine were very well documented. The Proponent submitted Monthly Environmental Reports to the Mines Pollution Control Branch (MPCB) of Saskatchewan Environment and Public Safety. These reports contain results of monitoring programs, explanations of anomalies in the monitoring data, and explanations of events of environmental significance which occurred at the site. Reports were also prepared by the MPCB summarizing the results of monthly environmental inspections conducted by the MPCB. Annual Environment Reports were prepared by the Proponent for 1989, 1990, and 1991, summarizing all of the monitoring results and discussing operating highlights for each of these years. Files containing letters of correspondence and internal documents relating to environmental issues were maintained in an orderly manner by the Proponent. All of the above documents were reviewed in order to conduct a comprehensive study of the project's environmental management history. Depth interviews with the staff and management of the Jolu operation, and interviews with representatives of Saskatchewan Environment and Public Safety were conducted in order to clarify the written documentation.

7) **Analyze** the accuracy of predictions of environmental impacts made during the EIA.

The impact predictions made during the Jolu EIA can be divided into two categories. **Some** quantified predictions were made, the accuracy of which could be tested by comparison with subsequent monitoring data. Other predictions were not quantified, but included detailed descriptions of the mitigative measures which would be applied to reduce the impacts to acceptable levels For this second category of impact predictions, the analysis of accuracy was tied very closely with an evaluation of the effectiveness of the mitigative measures applied.

8) Document Jolu EIA process and compared it to the official Saskatchewan Environmental Assessment and Review Process.

A detailed account of the Jolu EIA process was compiled from. a review of correspondence, a review of the Saskatchewan Environment and Public Safety's Technical Review Comments, and interviews with the Proponent, Saskatchewan Environment and Public Safety, and the consultants involved in the EIA. The Jolu experience was compared to the official Saskatchewan Environmental Assessment and Review Process.

9) Compile the results of the study and send a draft of the final document to the Proponent for review.

Much of the information used for this study was pieced together from letters of correspondence, internal documents and memos, and personal communication. Because of the fragmented nature of the information on which the study was based, it was important to have the Proponent review the initial draft of this document. This helped to ensure that the document accurately portrayed the environmental management history of the Jolu mining project.

It should be noted that the steps described in this summary of methodology were not conducted in the exact order presented. The methodology described above represents a somewhat idealized version of what actually transpired during the study. Although an initial review of the EIS was conducted early in the study, the detailed review was conducted considerably later. To a large degree, the details of the environmental management history were determined during the analysis phase. Even in the final stages of analysis, interviews were being conducted in an attempt to clarify information collected during the review of the environmental management history of the operation.

It was necessary for this study that the author have a thorough understanding of all that transpired during the environmental management history of the operation. This was a complicated process which required the study be conducted in a flexible manner rather than sticking to a strict step by step methodology. This approach allowed the author to selectively address issues which provided constructive lessons for future improvements in EIA. Berkes (1988) suggests that a few subject areas of interest be selected at the outset of a PPA based on the priority of the issues to people living in the area of the development. Focusing on a few selected issues would considerably shorten the time required to conduct a PPA, and could be important when there are time limitations on a study. Selecting the issues to be addressed too early in the PPA however, may reduce the opportunities to discover unexpected impacts, or unique and creative mitigative measures which were applied during the life of an operation. It is important to maintain flexibility during the design of a PPA in order to deal with unforeseen environmental problems (ECE 1990).

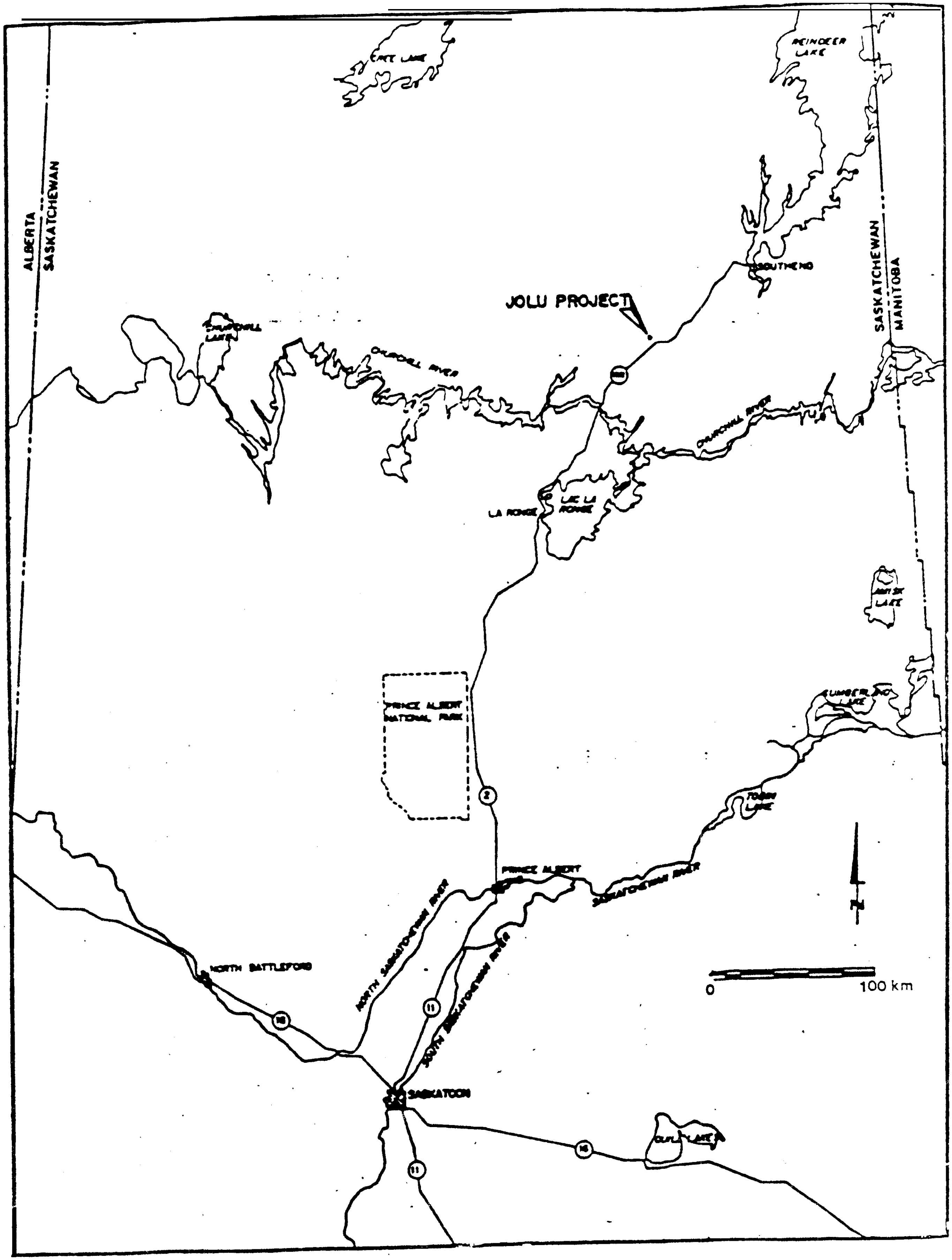
BACKGROUND TO THE JOLU GOLD MINING OPERATION

The Jolu Gold Mine is located approximately 140 km north of La Ronge, Saskatchewan (Figure 1). The project is a joint venture between International Corona Corporation (30%) and Mahogany Minerals Resources Inc. (70%), with Corona Corporation acting as the operator.

The Jolu ore body occurs in the La Ronge Greenstone Belt, which hosts a number of gold deposits including the Star Lake and Jasper gold deposits (Royex 1988). During the early 1970's a small mining and milling operation, the Decade Operation, was active at the Jolu Mine site. This operation was unsuccessful due to limited available technical and financial resources, and low gold prices (Royex 1988).

Exploration work for the present day Jolu mine began in the early 1980's (Royex 1988). In March of 1985, a Project Proposal was submitted 'to Saskatchewan Environment. The Proponent began working on an EIA in November of 1986, and in February of 1988, Ministerial Approval was granted for the operation under the Saskatchewan Environmental Assessment Act.

The Jolu project involved operation of a commercial underground mine, and a 500 ton per day mill. The milling process included a two stage gold recovery process involving gravity separation and leaching. Gravity separation of coarse gold particles was achieved using a jig and a shaking table. The remaining gold was dissolved by adding cyanide to the slurry. The dissolved.



'Figure 1: Location of the Jolu Gold Mining Operation
From Royex 1988.

gold was removed from solution by adsorption onto activated carbon, a process known as the Carbon-In-Pulp process. The gold was then stripped from the carbon using a cyanide solution. The final gold bearing solution was passed through an electroplating cell where the gold was deposited onto steel wool cathodes.

The Jolu tailings management area was constructed within the basin of a small natural lake, Mallard Lake. The tailings management area retained the liquid portion of the tailings for treatment prior to discharge to the environment, and will permanently retain the solid portion of the tailings. The tailings management area also permitted fresh surface water to be diverted away from the tailings minimizing contamination from waste water.

Figure 2 provides a schematic representation of the Jolu tailings area. Fresh surface water which would have naturally drained into Mallard Lake from the northeast was collected in Cell A, was diverted around the tailings management area, and was discharged directly to Yew Lake (Figure 3). Ditches were installed along the flanks of the tailings ponds to divert any fresh surface water flowing from the east and west away from the waste water in the tailings ponds. Tailings were discharged from the mill into Cell B, where the solid component was allowed to settle. The supernatant was then decanted from Cell B into Cell C.

At the time of the Jolu Environmental Impact Assessment, it was expected that natural degradation of the effluent in Cells B and C would be adequate to achieve dischargeable quality. During the operation of the project natural degradation was found to be inadequate, and a chemical treatment plant was installed to treat the supernatant as it was decanted from Cell B to Cell C. A muskeg treatment system was also established at the north east end of the tailings pond. The chemically treated effluent from Cell C was pumped up to the north end of the tailings pond and was sprinkled over the muskeg treatment area. The effluent trickled through the muskeg, collecting in Cell A. In Cell A, the final treated effluent mixed with fresh surface water. This water was piped around the tailings management area, and discharged to Yew Lake.

Production at the Jolu Mine began in October 1988, and continued until August 1991. A total of 520,000 dry tons of ore were milled during the three and a half years of operation of the Jolu mill. Average gold recovery was 97.5%, yielding a total of 205,224 ounces of gold. The operation is presently undergoing decommissioning according to a plan approved by Saskatchewan Environment and Public Safety.

The Jolu Mine has had an excellent record of environmental protection throughout its operation. The Management of the mine was clearly

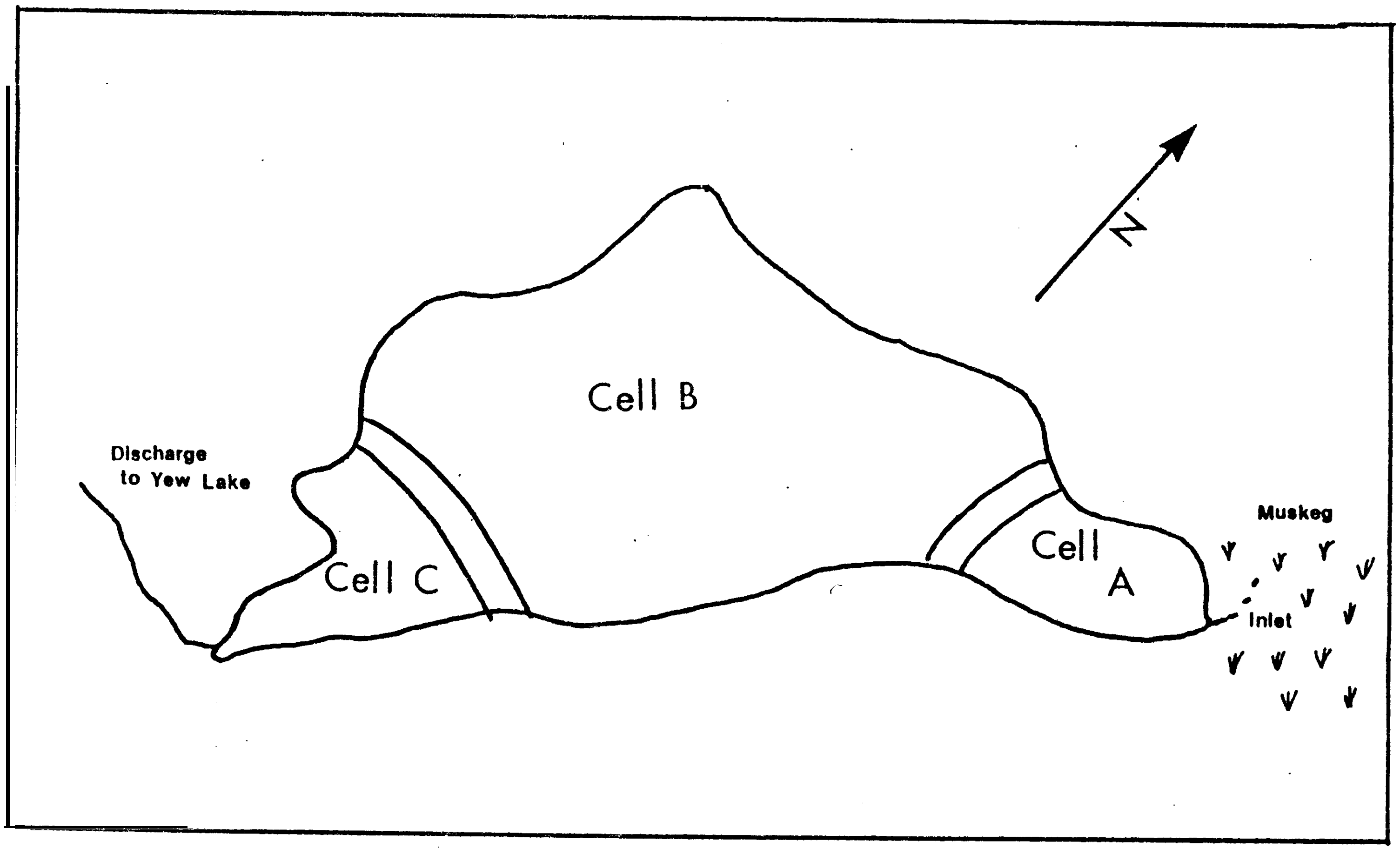


Figure 2: The Mallard Lake Tailings Disposal System

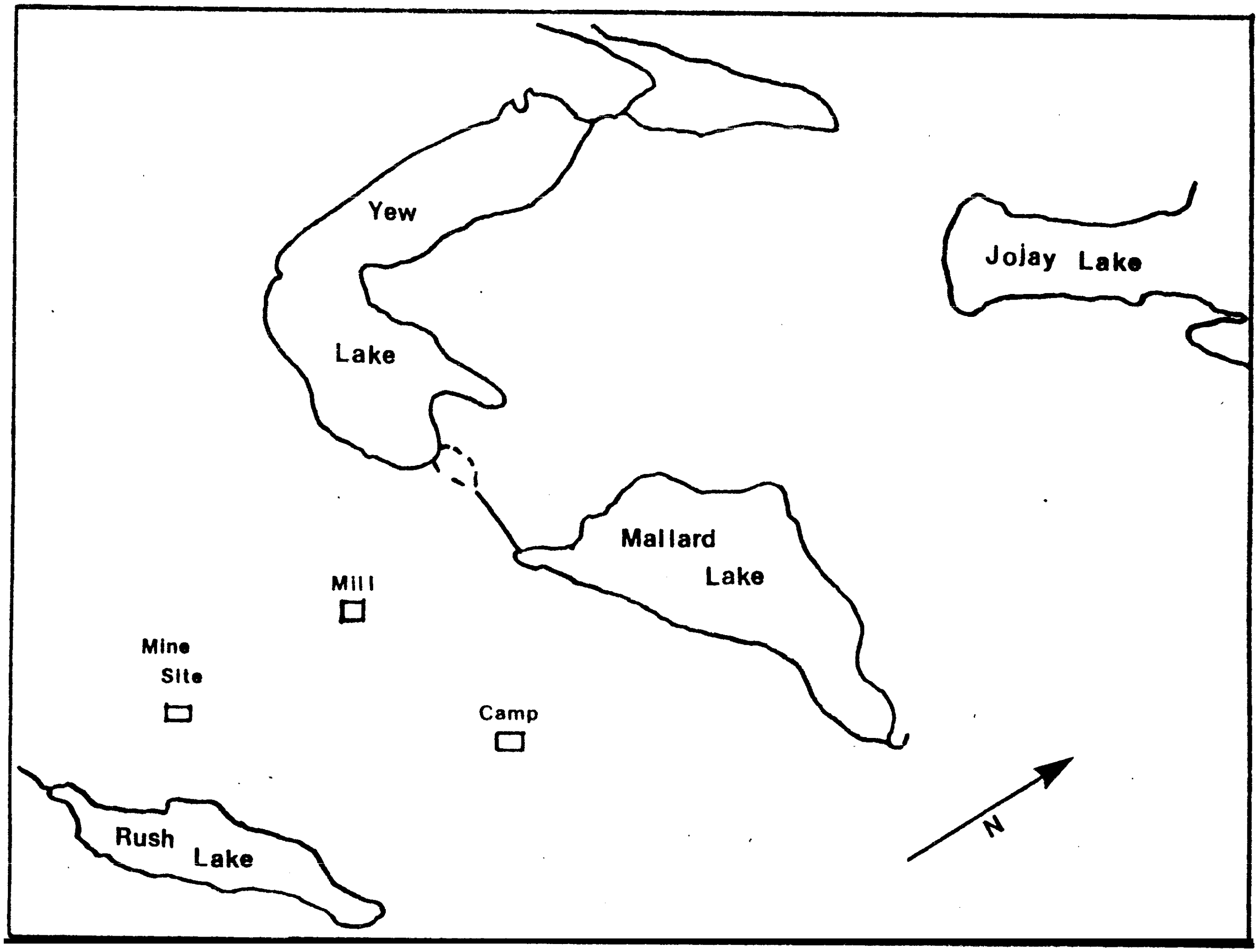


Figure 3: Site plan for the Jolu Gold Mining Operation

committed to environmental protection, a commitment which went beyond mere regulatory compliance (Barsi pers. comm. 1991, Cooper pers. comm. 1991, Sinclair pers. comm. 1991). The mine Management's dedication to environmental protection and use of innovative methods to minimize adverse impacts on the biophysical environment made the Jolu case study particularly interesting for a post-project analysis. Details of the Jolu mine's environmental management program are discussed in the author's **Master's** Degree Project (Bres, in preparation).

THE SASKATCHEWAN ENVIRONMENTAL ASSESSMENT AND REVIEW PROCESS

At the time when the Jolu project underwent its Environmental Impact Assessment (1986-1988) there were no Provincial regulations in place controlling the EIA process. Saskatchewan Environment and Public Safety (SEPS) did however, have an established policy outlining the series of steps for conducting an EIA. This process was managed by SEPS, operating under the Environmental Assessment Act and policy guidelines (SEPS August 1990). Figure 4 illustrates the steps identified by SEPS which are briefly described here (adapted from SEPS August 1990b):

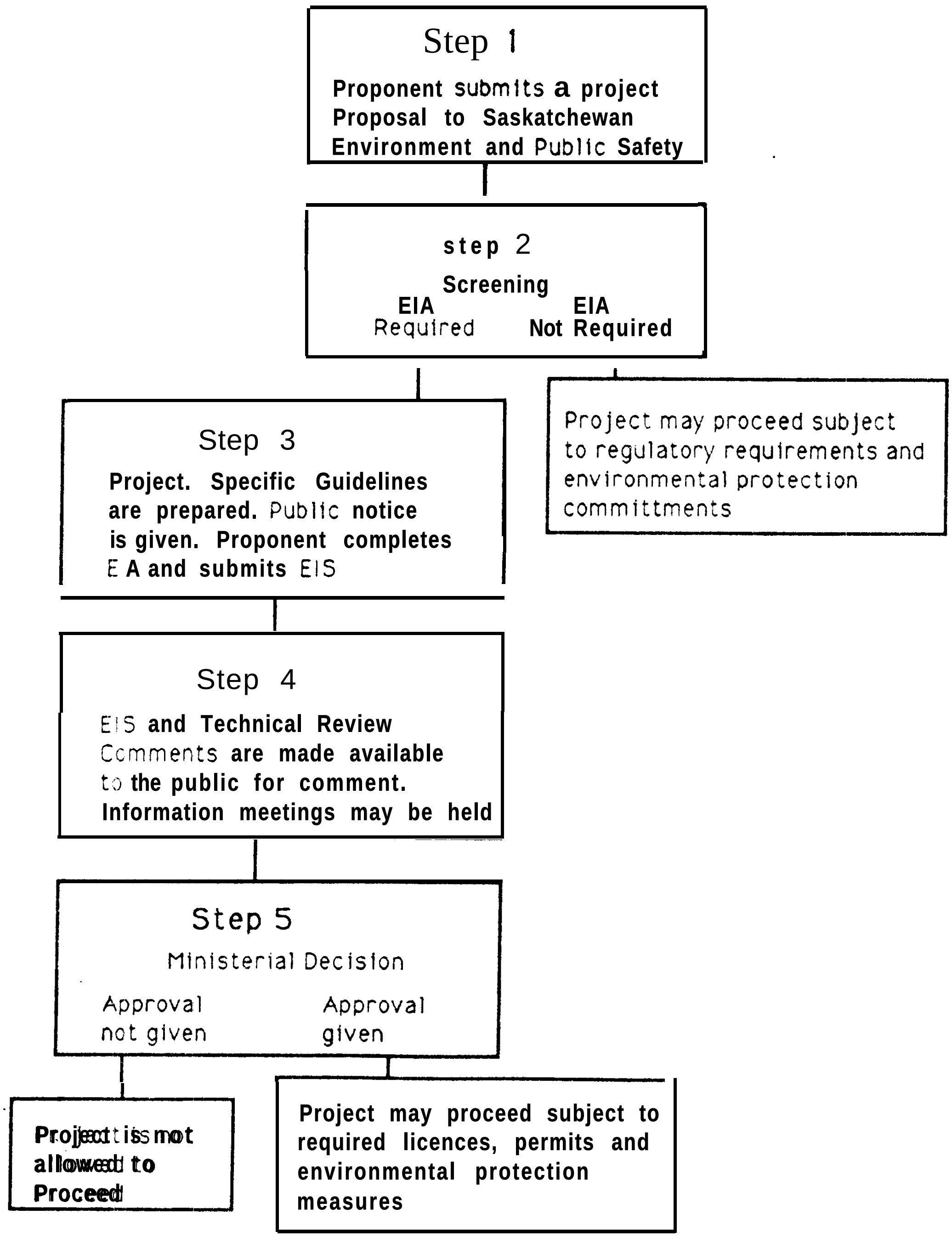
Step 1: Project Proposal- The proponent submits a proposal to SEPS.

Step 2: Screening- SEPS determines whether or not an EIA is required. This process is normally completed within 30 to 45 days of the department's receiving the Proposal. An interdepartmental review panel may be consulted when reviewing the proposal.

Step 3: Conducting the EIA- If SEPS determines that an EIA is required for the proposed project, the EIA process is initiated. Project Specific Guidelines are drafted to supplement the department's existing General EIA Guidelines (SEPS 1988). The proponent conducts the EIA, and prepares the EIS according to available guidelines.

Step 4: Technical and Public Review- An interdepartmental review of the EIS is conducted, coordinated by SEPS. Technical Review Comments are prepared (usually within 60 days of receipt of the EIS) and are returned to the proponent outlining requirements for additional studies or information required. This process is repeated if necessary until SEPS is satisfied with the EIS. SEPS then prepares Final Technical Review Comments which are made available to the public and to government decision makers along with the final draft of the EIS. The final review and preparation of final technical review comments should take 30 to 45 days. The EIS and Technical Review Comments are available for public review for a minimum of 30 days to allow public comment before the ministerial decision is made.

Figure 4: The Saskatchewan Environmental Assessment and Review Process



Step 5: Ministerial Decision- The minister determines whether or not the proponent has met all the requirements of the Environmental Assessment Act. If all the requirements are met, the decision is made as to whether or not the project will be granted ministerial approval to proceed. If,, during the operation of the project, the proponent makes any changes to the plans presented in the EIS, the proponent must request approval for these changes from the Minister. At the Minister's discretion, any changes can be approved, refused, or may be subjected to the EIA process.

THE JOLU EIA PROCESS

The case of the Jolu Mine Impact Assessment will be described to compare the regulated process to what actually happens when the process is applied. To facilitate a comparison of the Jolu process to the standard Saskatchewan process, the same format is used here to describe the Jolu assessment as was used in the previous section to describe the Saskatchewan process. Figure 4 can be referred to for further reference.

Step 1: Proponent submits a Project Proposal to Saskatchewan Environment and Public Safety (SEPS)

Saskatchewan Environment was notified of the proposed mine development on the Jolu property on March 15, 1985. At the time of the Project Proposal submission, the ore body had not been fully delineated and the mine and mill designs were only in the very early stages of development. At this time there was no proposed site or design for the tailings management area, and financing had not yet been acquired for the operation. The initial written proposal was therefore not very detailed, as the project was still in the feasibility stage. The details of the Project Proposal were not decided upon until well into the EIA process.

According to the General Guidelines (SEPS 1988), the minimum requirements for a Project Proposal include a description of:

a) what is proposed (i.e., the physical characteristics of the project);
b) where it is to be located (preferably by use of both regional and local maps with easily recognizable reference features);
c) when, how and by whom it is to be constructed, operated, maintained and decommissioned; and
d) why it is being proposed at this time (i.e., what will be achieved if the project proceeds and, if pertinent, how it will contribute to the achievement of a broader plan, program or policy).

The General Guidelines provide a detailed list of information that should be provided in a proposal wherever possible, but clearly state that this information is not required unless specifically requested by the Department. The Proposal serves only as a basis for the decision on whether an EIA will be required, and does not require detailed information on the project. The Project Proposal submitted for the Jolu mining operation was adequate according to these defined requirements even though the details of the project had not yet been decided on by the Proponent.

Step 2: Environmental Assessment Branch decides whether an EIA is required

Today, any new mining operation would likely require an EIA. At the time of the Jolu Proposal, some consideration had to be given as to whether the project required an EIA. Saskatchewan Environment reviewed the Jolu Proposal, and informed the Proponent on April 22, 1985 that an EIA would be required.

Step 3a: Project Specific Guidelines are prepared

On July 19, 1985 Project Specific Guidelines were completed by Saskatchewan Environment. The Project Specific Guidelines were compiled from comments on the proposal by the government agencies that would be involved in reviewing the EIS later in the EIA process. These agencies included Saskatchewan Environment (which became Saskatchewan Environment and Public Safety shortly afterwards); The Northern Affairs Secretariat; Tourism, Small Business and Cooperatives; Human Resources, Labour and Employment; Energy and Mines; Parks, Recreation and Culture; Saskatchewan Water Corporation; and the Department of Highways. The Project Specific Guidelines were presented to the company to outline questions and concerns that had been raised about the proposed project, and to identify the information that Saskatchewan Environment felt should be included in the EXS (Sask. Env. 1985).

The Project Specific Guidelines were not very thorough (Clifton pers. comm. 1991). Although they did highlight major areas to be addressed,, they would not have been sufficient on their own to guide a company through the EIA process (Clifton pers. comm. 1991). The Project Specific Guidelines were in fact quite general; and probably could have been applied to any gold mining operation in Saskatchewan. This was probably partly due to the lack of detail in the Project Proposal submitted by the Proponent.

Although the process of compiling comments from all the government agencies involved in the review process did ensure that major issues of concern are identified in the Project Specific Guidelines, the **process did not** result in a tightly focused set of-guidelines. The guidelines could have been improved if some kind of scoping system such as Beanlands and Duinker's Valued Ecosystem Component System (1983) or Bonicksen and Becker's Cross

Impact Assessment Process (1983) had been applied. Scoping is recognized to be an important component in the EIA process (Ross 1987), but it is rarely done in practice (Beanlands and Duinker, 1983).

The consultants who were hired to conduct the EIA had gone through the EIA process for a gold mine in the area, the Star Lake Mine, and were already familiar with what was expected for such an EIA. This experience, along with the consultants' extensive experience working in northern Saskatchewan for a variety of other projects,, greatly facilitated the Jolu EIA (Clifton pers. comm. 1991).

Step 3b: Public notice is given

According to the official Saskatchewan Environmental Assessment Process, public notice is to be given following the development of Project Specific Guidelines. Although there was no official Public Notice Statement, local communities were made aware of the project through a series of public meetings held by the Proponent while the EIA was being conducted.

In order to acquaint the local communities with the scope of the proposed project, a series of public involvement meetings was held during December of 1986. Besides informing the public about the project, the public meetings provided an opportunity for the public to express any concerns they might have had over the proposed mining development. No significant environmental concerns were identified during this initial set of public meetings (Royex 1988 vol. 2 p. 8). A second series of public involvement meetings was held in March of 1987. Meetings were held with the public, several community organizations, northern groups and agencies. The minutes of these meeting reveal little public concern over environmental issues. Only a few general comments were made regarding concern over the effects of the project on water quality and fisheries resources.

Overall the public input process did not appear to be very effective in addressing biophysical issues. The minutes from meetings which are provided in the EIS concentrate almost entirely on socioeconomic considerations. The public appeared to be far more concerned with job opportunities than with the effects of the project on the environment. The Proponent cannot be faulted with the local public's lack of concern over the environment. There is however little evidence that the Proponent did anything to stimulate further discussion on biophysical issues. At each meeting, a representative from Royex presented information on the proposed project. The information presented concentrated almost entirely on socioeconomic factors, primarily on employment opportunities. Although the public had an opportunity to express concerns over environmental issues, the meetings did little to educate them on the possible environmental impacts of the study. There were no further public meetings held after the meetings in March 1987.

Step 3c: Proponent completes the EIA and submits impact statement

Although the Project Specific Guidelines were issued in July of 1985, work on the EIA did not start until November of 1986. During this time, the Proponent continued the work delineating the ore body and assessing the feasibility of the project. Several more drafts of the Project Proposal were submitted during this time as the project gradually became more clearly defined. Because the mill was expected to start up in 1988, there was a very tight schedule to complete the EIA once the Proponent initiated the study.

In September of 1986 Clifton Associates, one of the consultants hired by the Proponent, prepared a written proposal for the Jolu EIA program. This proposal outlined the studies that would have to be conducted for the EIA, presented a proposed schedule for the work, and provided estimates of the labour costs and personnel requirements. The preparation of an overall study strategy is recognized as perhaps the single most important factor in insuring effective deployment of time and resources when conducting an EIA (Beanlands and Duinker 1983).

In November and December of 1986 a series of meetings were held between the Proponent and representatives of various government agencies to discuss the methodology for the Jolu EIS. During these meetings, the table of contents for the EIS was discussed, along with detailed discussions of requirements for technical studies. This was the beginning of a long series of informal discussions between the Proponent and government representatives regarding the methodology and requirements for the EIA. This open communication was very effective in assuring that the EIA was conducted in a manner satisfactory to the regulating authorities involved, and in defining exactly what the Proponent was required to do in the EIA (Cooper, pers. comm. 1991) This process may have been especially important considering the lack of detail in the Project Specific Guidelines which resulted from the relatively incomplete Project Proposal available at the time of the drafting of the guidelines. Beanlands and Duinker (1983) strongly encourage cooperation between the Proponent and regulating agencies in designing the methodology for an Impact Assessment prior to its initiation to cut down on the need for lengthy, excessively detailed EIA guidelines.

A copy of the Task Description Flow Chart from Clifton Associates' proposed EIA program is presented in Figure 5. A very tight time schedule was required to complete the study on time due to the late start on the EIA.

The studies relating to the physical environment progressed according to the proposed timeline in Figure 5 (Clifton pers. comm. 1991). The tailings design

TASK	OCT 86	NOV 86	DEC 86	JAN 87	FEB 87	MAR 87	APR 87	MAY 87	JUN 87	JLY 87	AUG 87	SPT 87	OCT 87	UNDERTAKEN BY
I .O PROJECT DESCRIPTION	xxxx													OWNER
2.0 PHYSICAL ENVIRONMENT														
2.1 Climate		xx	-	-	-	-	-	-	-	-	-	-	-	OWNER/LABORATORY
2.2 Geology	xx -													OWNER
2.3 Terrain Analysis	xx	-												CONSULTANT
2.4 Hydrology	xx	-	-	-	-	-	-	-	- -	-	-	-	-	CONSULTANT/OWNER
2.5 Hydrogeology	xx	x												CONSULTANT
2.6 Water Quality	x				x	x			x			x		CONSULTANT/OWNER
2.7 Aquatics	xx	x						xx		xx				CONSULTANT
2.8 Wildlife	xx	x					x	x	xx					CONSULTANT
3.O DESIGN STUDIES														
3.1 Tailings Siting		xx	x											CONSULTANT
3.2 Wart. Management				x	xxxx	xxxx								CONSULTANT
3.3 Surface Water Management					x	x								CONSULTANT
4.0 SOCIO ECONOMICS														
4.1 Public Participation		xx					xx							OWNER/CONSULTANT
4.2 Impacts								xxxx						OWNER/CONSULTANT
5.0 IMPACT ASSESSMENT	•	•	•	•	•	•	•	•	•	•	•	•	•	CONSULTANT/OWNER
6.O REPORTING - EIA						xxxx	xxxx	xx	•	•	•	xx	•	CONSULTANT/OWNER
7.0 EIA APPROVAL											•	•	•	DEPT. OF ENVIRONMENT

Figure 5: Task Description Flow Chart
From Clifton Associates September 1986

study also progressed on schedule, and the public participation programs were slightly ahead of schedule.

The design of the waste management and surface water management schemes did not follow according to the proposed schedule. At the time, the Proponent was still in the process of designing the mill process, and the impact assessment was held up (Cooper pers. comm. 1991). Early in 1987, there was a change in operators from Mahogany Minerals to Royex Gold Mining Corporation (later amalgamated into International Corona Corporation) which further contributed to the slowing down of the EIA and the writing of the EIS (Cooper pers. conun. 1991, Clifton pers. comm. 1991). As can be seen in Figure 5, it was anticipated that the majority of the EIS would be completed by mid-May 1987, with the final results of monitoring studies being incorporated in September 1987. This scheduling would have allowed preliminary review of the majority of the EIS during the Summer of 1987. In fact, the initial draft of the EIS was not submitted until late September of 1987, with additional information being added until February of 1988.

In addition to presenting a timeline for the Jolu EIA, Clifton Associates' EIA program proposal identified a significant amount of existing data that could be incorporated in the EIS. Many of the baseline studies could be taken directly from the Star Lake EIA, including information on hydrology, socioeconomic considerations, fisheries, wildlife, vegetation and climate. Other existing studies that could be incorporated in the Jolu EIS included draft studies on aquatic organisms and habitat in Yew and Mallard Lakes undertaken by Integrated Environmental Sciences Inc.; a preliminary evaluation of surface water quality and mine hydrology undertaken by Environmental Management Associates; water quality sampling undertaken by the owner; and a substantial amount of geologic and test hole information available from the Jolu exploration program (Clifton Associates,, September 1986).

Step 4a: Statement and Department's Technical Review Comments are made available to the public for comment

The Technical Review of the Jolu EIS was coordinated by the Environmental Assessment Branch of SEPS. The EIS was sent to each of the agencies identified in step 3a for comment, and all the comments were compiled by a project officer in the Environmental Assessment Branch. The review comments identified issues that were inadequately addressed in the draft of the EIS, and included many detailed technical criticisms of the contents of the document. The technical review also served to challenge the validity of conclusions drawn by the Proponent from data in the EIS, which should be done for any EIA conducted by a proponent (Beanlands and Duinker 1983). Unfortunately, the review concentrated entirely on technical soundness of the EIA, and did not serve to critique the clarity of the EIS or its appropriateness for public review.

The initial draft of the EIS was submitted in late September of 1987. Because the Technical Review required incorporation of comments from several government agencies, it could not be done quickly. To satisfy the company's requests for rapid input, SEPS provided the company with preliminary review comments on the draft of the EIS. These comments were generated by SEPS, and did not incorporate any of the comments from the other agencies. Although this is not an official step in the Saskatchewan Environmental Assessment Process, it was effective as it gave the company an indication of what work remained to be done while it awaited the official Technical Review Comments (Cooper pers. comm. 1991).

In mid-November of 1987, the Initial Technical Review of the first draft of the Jolu EIA was completed, and Preliminary Technical Review Comments were presented to the Proponent. The Technical Review classifies deficiencies in the EIS into three types:

- •Type 1 - "outstanding deficiencies considered sufficiently important to justify withholding a decision under The Environmental Assessment Act"
- •Type 2 - "'Deficiencies not considered sufficiently important to justify withholding a decision but which,, should approval be granted, must be resolved before subsequent regulatory approvals are issued"
- •Type 3 - "Relatively minor issues, the clarification of which will add to the quality and accuracy of the EIS".

At the time of the Preliminary Technical Review, many deficiencies were identified. Because SEPS had been in contact with the Proponent throughout the review process, many of the comments had already been addressed before the official review comments were presented to the Proponent. By December 8, 1987, the Proponent completed and submitted a revised draft of the EIS.

As with the first review, SEPS provided the Proponent with preliminary comments so that it could work on revisions during the 'Technical Review Process. These comments were provided to the Proponent on December 16, only 6 days after the Proponent had submitted the draft. At this time, several Type 1 deficiencies were still present in the EIS. Official Supplemental Technical Review Comments were issued on February 11, 1988. Because of the open communication between SEPS and the Proponent, most the comments had already been addressed by the time the official comments were presented to the Proponent, and the revised Draft EIS was submitted on February 15.

The initial Technical Review of the EIS and preparation of review comments is generally expected to be completed in 60 days (SEPS August 1990b). For the Jolu project, it was completed in approximately five weeks (unfortunately, the exact submission date was not recorded). The review of the revised EIS is expected to take approximately 30 to 45 days (SEPS August 1990), and actually took 24 days.

On February 22, SEPS issued the final Technical Review Comments for distribution to the public review centres along with copies of the EIS. The Technical Review Comments presented to the public include a brief description of the project, and address biophysical considerations, public awareness and socioeconomic considerations, and monitoring. The document is only 7 double spaced pages, and contains very little information that would help educate the public on the contents of the EIS. It did however serve to inform the public that the EIS had undergone a thorough technical review and was considered by SEPS to be an adequate assessment of the potential environmental impacts of the mining development. Any members of the public who wanted more information on the environmental impacts of the project had to refer directly to the EIS.

Step 4b: Public hearings may be held

The Saskatchewan Environmental Assessment and Review process suggests that public hearings may be held during the EIA Review. There were no public hearings held for the Jolu mining project. From March 2 to April 1 1988 the EIS was made available to the public, along with the Final Technical Review Comments, and the public was invited to comment on the Jolu EIS. During this time, no comments were submitted by the public raising concerns over the environmental impacts of the project. No meetings were held to present the final EIA to the public, which may have limited the chances of stimulating public comment on the EIS.

Step 5: Approval given, Project allowed to proceed subject to required licenses, permits and environmental protection measures

When all the Type 1 deficiencies were addressed in the EIS to the approval of SEPS and the public review period ended without any concerns having been raised by the public, the Jolu gold mining project was approved. Official Approval under the Environmental Assessment Act was granted on April 12, 1988.

CRITIQUE OF THE EIS

A critique of the Jolu EIS is provided to develop recommendations on how EISs could be improved in the future. The EIS was evaluated on its scientific and technical soundness, its content, and its clarity as described in Ross (1987).

Scientific and Technical Soundness

In accordance with the Saskatchewan Environmental Assessment and Review Process, the EIS for the Jolu Mine underwent a thorough interdepartmental. Technical Review. During this process the document was scrutinized for its scientific and technical soundness by experts within the government. The technical reviewers were well trained, experienced scientists from a wide range of disciplines (Cooper pers. comm. 1991). A review of the comments generated by the Technical Review suggests that the reviewers concentrated their criticisms on their specific areas of expertise. The comments generated ranged from specific statements on inadequacies in content to highly specific criticisms of scientific and technical accuracy and methodologies. The fact that the Jolu EIS was approved after this thorough scrutiny suggests that its contents are scientifically and technically sound, but there are some indicators of scientific and technical soundness that were not addressed d tiring the Technical Review Process.

For example,. Ross (1987) stresses the importance of identifying clearly the methodologies used in conducting an EIA and its various technical studies. The methodology for the EIA described in the Jolu EIS is very brief, and gives little insight into the organization of the assessment. There is no information provided on who conducted what studies, and no information on how the various members of the assessment team worked together to integrate the study. Methods used for various technical studies in the EIS are reported inconsistently, as the studies were conducted by several different consulting agencies. Methods are clearly stated in the Biological Resource Assessment and Socioeconomic Impact Assessment. In the rest of the technical appendices, methods are described randomly throughout the text. This may lead to confusion for anyone hoping to follow the methodologies used for the Jolu assessment for future projects, and undermines the scientific credibility of the EIS. The lack of detailed descriptions of methodologies in the Jolu EIS also created difficulties during this post-project assessment. To analyze the accuracy of predictions, it is important to understand how predictions of impacts were derived. It should be noted that the inadequacies in reporting of methodologies were not identified during the Technical Review Process,

Other indicators of scientific soundness identified by Ross **(1987)** that were dealt with inadequately in the Jolu EIS include referencing of appropriate scientific literature, evaluation of cumulative and indirect impacts, explicit statement of data gaps, and description of the qualifications of the contributors to the assessment. Again, none of these inadequacies were identified during the Technical Review Process.

Many EIA researchers have emphasized the importance of quantifying predictions made in EISs (Beanlands and Duinker 1983, Davies and Sadler 1989). It is also widely recognized that quantification of environmental impacts is very difficult, and often impossible given available time and resources (Hollick 1986, Holling 1978). It would appear reasonable that a scoping process should be implemented to identify which impacts require quantification in order to control the time and costs involved in doing an EIA. Although it is not explicitly stated in the EIA Guidelines or the Technical Review Comments, it is apparent from correspondence between SEPS and the Proponent that the impact of effluent discharge on downstream water quality was the major area of concern of SEPS during the Jolu EIA process. During the technical review phase of the EIS, this was the only impact which the reviewers specifically identified as requiring quantification. The EIS does include quantified predictions of effluent quality, but unfortunately the model on which these predictions were based was not completed until very late in the assessment process. The results of the effluent quality modeling were not well integrated with the predictions of impacts on biological resources. If a scoping process had been applied during the development of the Project Specific Guidelines to identify which predictions required quantification, the issue of impacts on downstream biological resources would likely have been addressed more adequately. No other impact predictions in the EIS are specifically quantified, nor were there any other requests for quantification generated during the Technical Review Process.

The Environmental Effects and Mitigation section of the EIS has some serious deficiencies. Environmental issues derived from the Guidelines and the public consultation process are addressed individually, each with a description of how the impact is to be mitigated. This section. of the EIS appears to the reader to be the culmination of the EIA, when in fact the decisions on mitigation measures appear to have been made independently of the assessment studies. Many of the predictions are not based on the technical studies conducted during the EIA, and mitigative measures are proposed which are not mentioned or justified anywhere else in the document.

For example, with regards to the potential for adverse effects of sewage disposal on surface and ground water, it is stated that the sewage will be discharged to the tailings pond. The options for sewage disposal are not addressed anywhere in the EIS and there are no data to suggest that discharge to the tailings pond is the best option. The mill superintendent suggested that disposal of sewage to the tailings pond was required by SEPS, but this fact is not recorded in the EIS (Kazakoff pers. comm. 1991).

An other example is the proposed mitigation to reduce the impacts of domestic solid waste disposal. The mitigation measure recommended involves installation of an incinerator. There are no data or predictions in the EIS that indicate the expected volumes of domestic waste that would be generated in the camp. This information would be critical in determining the size of incinerator required. Other options for domestic waste disposal are not discussed in the document.

Although a review of the operational history of the mine suggests that the majority of the proposed mitigative measures were effective, they were not presented satisfactorily in the EIS. This is a common flaw in EIAs. Most of the mitigative measures proposed in EIAs include well established mitigation techniques, environmental planning techniques, and construction practices, and are not designed based on the results of studies conducted during the EIA process (Beanlands and Duinker, 1983). Where the mitigative measures are not derived from studies conducted during the assessment, the rational for selecting the mitigative measures should be clearly stated in the EIS.

Clarity

In order to serve its purpose as the basis for public review, an EIS must be clearly written and well organized (Ross, 1987'). The clarity of the Jolu EIS was evaluated based on the document organization, the use of appropriate language, and how well the information was integrated.

The Jolu EIS consists of five volumes; an Executive Summary, the Environmental Impact Statement, and three volumes of technical appendices. Both the Executive summary and the EIS are concise enough to be reviewed in a relatively short period of time, with the detailed technical information being provided in the appendices. This is a common method of organizing the documentation for an EIA (Ross, 1987, Davies and Sadler 1989) and allows the reader to review the EIS without having to go through excessive amounts of detailed technical material.

The Executive Summary consists primarily of excerpts from the EIS. The Executive Summary should be directed at the public (Ross, 1987), but because the text was lifteci directly from the main body of the EIS, it is probably too technical for the average layman to understand. More time should have been spent writing an Executive Summary that would have been understandable to the public.

The EIS is organized into the following major sections:

1) Introduction- This section is brief and informative, giving a general introduction to the nature of the Jolu proposal.

2) Project Alternatives- This separate section of the EIS is included to explain how alternatives were addressed in the project design. Unfortunately, the section does not give an adequate representation of the amount of technical work which went into alternative selection. Clearly, it would not be practical to repeat all of the technical rational for alternative selection that is presented in the appendices, but the alternatives section is so brief that it gives the reader the impression that alternatives were not thoroughly addressed, rather than summarizing how they were addressed. This section therefore appears to be counter-productive.

3) Project Description- The project description provided in the EIS includes all of the information required by SEPS. Very detailed information is provided on the geologic setting of the ore body and the design of the milling and processing facility. Although this information is important in the EIS, its importance is not discussed. There should have been some references made on why this material was included, and what it contributed to the Environmental Assessment.

4) Background Environmental Data and Issues- A brief but adequate summary of the background conditions is presented. As with the previous section, this section could have been made clearer if it had included some indication of how the material presented was used in the Assessment. Although the title of the section suggests that 'issues' will be discussed, there is no direct reference to 'issues' in this section.

5) Environmental Effects and Mitigation- This is perhaps the most clearly presented portion of the EIS. The section is organized such that an environmental issue is stated, followed by a discussion of the mitigative measures proposed to minimize adverse effects on the environment. Residual Impacts are clearly stated at the end of the section. The section provides the reviewer with a concise summary of all expected impacts, and addresses concerns raised over "perceived impacts" identified during public consultation meetings.

6) Environmental Monitoring- This section is very brief. Monitoring requirements were addressed in detail during the licensing stage of the mine, and were not yet developed at the time of the EIA. Although. a detailed monitoring plan may be a useful component of an EIS, it was not required in the Saskatchewan. EIA process. Within the Technical Review comments, SEPS explicitly stated that monitoring would be addressed in detail during the licensing stage of the project, and did not need to be addressed in detail in the EIS. This should have been made clear in the Project Specific Guidelines..

7) Public Participation- A brief description of the public consultation process is included in the EIS. The minutes of public consultation meetings are included in Appendix J of the EIS.

Providing excessive amounts of information is a common problem in EISs **(Ross 1987).** Although the Jolu EIS does not contain excessive amounts of information, it is not clear from reading the EIS why much of the information presented was included in the EIS. There is a serious lack of integration of data and interpretation in the Jolu EIS. For example, within the main body of the EIS detailed technical information is provided on hydrology, hydrogeology, soils and surface geology, and tailings pond hydrology. Much of the information presented is too technical for laymen to understand. The EIA team had to compile all this information and create a model to make predictions on the impacts on downstream water quality, but the model linking the technical information is presented in an appendix rather than in the body of the EIS. The EIS would have been much more readable and understandable if the main body of the EIS contained a summary of how the hydrology, hydrogeology, soils and surface geology, and tailings pond hydrology had been modelled and interpreted, and how this information contributed to an understanding of the potential environmental impacts on surface and ground water quality. The technical details of the physical parameters and of the model should have been included in appendices. Only enough information should have been included in the main body of the EIS to explain the relevance of the data collected to the environmental impact assessment.

Based on a review of correspondence files and discussions on the Jolu EIA with those involved in the process, it appears that the EIS does not really give a very good idea of all the work that went into the Assessment. As discussed above, a detailed model was developed to determine the potential effects on downstream water quality, but the model is not well presented in the body of the EIS. In December of 1986, Clifton Associated prepared a detailed report considering all the various alternatives for the siting of the tailing pond. Although the EIS does mention that several sites were considered, it does not give any indication of the detailed work which was conducted. The Biological Assessment Appendix includes some very detailed and well presented predictions of impacts which are not included in the main body of the EIS.

It is unfortunate that the EIS did not do a better job of recording the work that was done during the EIA. Perhaps the fact that SEPS was working closely with the company and understood that the work was done, along with the fact that the EIS was never to go through a panel review, contributed to the EIS not being as good as the EIA. Although the Technical Review process insured that the EIA was thorough, complete, and technically sound, it did not identify shortcomings in clarity from a layman’s perspective as the reviewers were all technical experts.

The EIA was conducted by three consultants. This is obvious when reviewing the EIS as there are a number of inconsistencies in style and presentation in various chapters and appendices. Although this is not a serious concern, it does illustrate carelessness in the final compilation of the EIS.

Content

In accordance with the Saskatchewan EIA process, the Proponent was presented with both General and Project Specific Guidelines for the EIA. The General Guidelines (SEPS April 1984) apply to all projects that are required to undergo an environmental assessment in Saskatchewan. The Project Specific Guidelines were compiled by SEPS from comments generated by the government agencies which would be involved in the Technical Review Process. The Project Specific Guidelines outlined questions and concerns raised about the proposed project by the reviewing agencies, and identified the information that Saskatchewan Environment required to be included in the EIS. In the Project Specific Guidelines it is stressed that "... these guidelines should not be regarded as either exhaustive or restrictive as concerns other than those already identified could arise during the investigations and public meetings.” Although the initial scoping is conducted by SEPS, the qualifying statement above suggests that the final responsibilitv for ensuring the content of the EIS is adequate rests with the proponent. The guidelines also stressed that the EIS was not to be simply an inventory of environmental baseline data, a common problem in EIS (Ross 1987).

For the purposes of this study, the content of the EIS was critiqued on several levels. First, the EIS was reviewed to determine if the Project Specific Guidelines were addressed as required. Second, the comments generated during the technical review of the EIS were reviewed to see if all concerns raised during the review were addressed in the final draft of the EIS. Third, the records of the mine’s operational history were reviewed to determine if there were any environmental concerns raised during the life of the operation which were inadequately addressed during the impact assessment. This final evaluation is of course made in hindsight, and it is recognized that, no matter how thorough the scoping process is, there will always be the possibility that unexpected impacts will occur (Hollick 1986). Recording these inadequacies in the EIS serves to improve the ability to foresee impacts in future projects.

As was mentioned earlier, the Project Specific Guidelines for the Jolu EIA were drafted based on the Project Proposal, which did not contain a great deal of detail about the project. As a result, many of the comments in the Project Specific Guidelines are fairly general.

The most detailed part of the Project Specific Guidelines refers to the requirements for the project description in the EIS. As a result of the detailed requirements, the project description in the EIS is presented in great detail. Much of this information is presented without drawing any conclusions on its relevance to the impact assessment. The inclusion of large amounts of uninterpreted information tends to detract from the focus of the EIS. Brief statements throughout the project description on the relevance of the material presented should have been included. This would improve the readability of the document and would have helped focus the document. Some of the material presented, although included on the recommendation of the Project Specific Guidelines, did not contribute to the reader's understanding of the environmental impacts of the project. The project description accounts for approximately half the length of the EIS (excluding appendices). Much of this material could have been presented in an appendix. The poor focus originates with a lack of focus in the Project Specific Guidelines.

The Project Specific Guidelines are far less specific for the description of the existing environment. A detailed list is not provided for what was to be included in the EIS. The Guidelines are more conceptual for this section. The Guidelines suggest that "sufficient detail should be provided to permit an understanding of existing conditions and for predictions" of how the environment will be affected by the development. They also suggest that the baseline data "should not by presented simply as an inventory", but should provide data that will be of practical use, form a sound basis for later monitoring, and will be useful for scientifically valid statistical analysis.

A large amount of baseline data were available from the Star Lake EIS and from other studies completed in the area. As a result, detailed baseline information could be presented in the Jolu EIS without too much expense to the Proponent (Clifton pers. comm. 1991). The degree of detail of baseline data appears to be sufficient, but the information was not really presented in such a way that it satisfied the conceptual requirements of the Project Specific Guidelines mentioned above. As with the project description section, and many other sections of the EIS, this section did not include statements that explained the relevance of the material presented to the EIA. The objectives of the baseline studies should have been clearly stated along with an explanation of how data were to be used (Beanlands and Duinker 1983). Unless the relationships between data collected and the potential impacts are identified, the information will likely be worthless (Bonnicksen and Becker 1983).

The Project Specific Guidelines were very ambiguous about the requirements for the Impact Assessment portion of the EIS. Only a single paragraph suggesting that impact predictions had to be made was included in the Project Specific Guidelines. Just as the Guidelines were inadequate, so was the resulting section in the EIS. There is no separate section in the EIS that summarizes impact predictions. One section includes “Environmental Effects and Mitigation”, but this section concentrates on listing the issues raised and the mitigations proposed. It contains very few quantified impact predictions.

As with the Impact Assessment portion of the Project Specific Guidelines, the requirements for mitigation are very brief, inadequate, and resulted in inadequate handling of the subject in the EIS. The Guidelines basically suggest that the EIS should outline mitigative measures to be applied. This is done in the Effects and Mitigation section of the EIS, but it is done very briefly with no details on methods or contingency plans. No costs or anticipated levels of success of mitigative measures are provided, though they were required according to the guidelines. Residual impacts are explicitly stated in the EIS as required by the Guidelines.

The Guidelines briefly state that the EIS should include proposed. monitoring programs. These are included very briefly in the EIS. During the Technical Review SEPS suggested that the monitoring program would be addressed in more detail during the permit and licensing process and that the description included in the draft EIS was adequate. This should have been explicitly stated in the Project Specific Guidelines.

The Technical Review Comments were reviewed to determine if all the deficiencies identified had been adequately addressed. The final Draft of the EIS was reviewed by SEPS before Ministerial Approval was granted to ensure that all the concerns raised in the Technical review had been adequately addressed. The most significant deficiencies, those classified as Type 1 by SEPS, had to be addressed in order for the proponent to receive ministerial approval for the project. Type 2 deficiencies, those which were identified in the technical review as requiring attention but were not significant enough to hold up the approval process, and Type 3 deficiencies, those which were considered minor but were recommended to be addressed, were followed up by comparison to the final EIS to see if they were adequately addressed. Most of these deficiencies were addressed in the final EIS. Some were not, perhaps because the comments were subjective and the Proponent did not agree with them. Enough of these small comments were addressed to indicate that the Proponent was diligent in attempting to make corrections which were recommended.

An evaluation of the accuracy of impact predictions is presented later in this paper. During the process of evaluating the accuracy of impact predictions, a number of impacts were identified which were not adequately predicted in the EIS. Although it is recognized that no EIA will ever be able to predict accurately all. the potential environmental impacts of a project, it is important to study the types of impacts that were not accurately predicted during previous EIAs. Such studies may reduce the likelihood of making the same mistakes repeatedly in future EIAs.

The impacts of mill effluent and tailings on local water quality appeared to have been the main concern at the time of the Jolu EIA. Although there was a certain degree of uncertainty about the quality of the mill effluent, the reaction of the mill effluent to natural degradation, and the dilution rates of the effluent once discharged to the natural environment, the predictions of water quality impacts were reasonably accurate. The predictions of long term stability of the tailings have not yet been tested, as the Jolu operation is still undergoing decommissioning. No major unexpected impacts have been identified to date relating to the tailings impoundment and effluent discharge.

The unexpected impacts were generally very minor in magnitude. Small fuel spills, which were not anticipated to be any problem at the time of the EIA, turned out to be a chronic problem during the operation of the mine and mill. A large fuel spill occurred, which could potentially have been avoided if a more stringent inspection program had been recommended in the EIS. The operation also experienced frequent problems with black bears as a result of poor garbage management practices. Again, these problems could have been reduced if more consideration had been given to the issue during the EIA. Although these unexpected impacts may be somewhat minor in magnitude, they do illustrate ways in which future EIAs for similar projects may be improved.

Alternatives

In most EISs, alternatives are addressed very briefly, and detailed information is only presented on the proponent's selected options (Hollick, 1986). This is of little value to external decision makers and the public as they are not provided with enough information to make the decisions themselves (Hollick, 1986). The U.S. Council on Environmental Quality regulations, (1978) stress that "alternatives should be the heart of the EIS" (as cited in Hollick 1986).

Hollick (1986) suggests that part of the problem in dealing with alternatives is a fundamental difference between project planning and the EIA process. Project planning is a convergent process, as decisions are made on selecting alternatives, progressively more detail is required. EIA requires that a wide range of options be evaluated to a similar degree of detail, which allows decision makers to do a detailed comparative evaluation on which to base decisions. Hollick. (1986) recommends that a wide range of alternatives be screened at the feasibility stage, followed by a detailed assessment of one or two of the most attractive alternatives. This is in fact what happened with the Jolu Mine in consideration of the tailings pond site selection. In December of

1986, Clifton Associated prepared a detailed preliminary siting study that evaluated five possible tailings disposal schemes. For each scheme, the basin characteristics, layout and containment concepts, operational considerations, decommissioning requirements, and environmental impacts are assessed, and the advantages and disadvantages of the alternatives are evaluated. Unfortunately, this document was never submitted to the regulatory authorities, nor was it adequately summarized in the EIS.

Objectivity

Hollick (1986) outlines several indicators of bias that should be looked for in EISs including deliberate promotion of the project, making over optimistic predictions of effectiveness of mitigative measures, using personal value judgments of significance of impacts, or leaving out or failing to collect certain information. A review of the Jolu EIS failed to identify any of the above indicators of bias. The Proponent appears to have made a conscious effort to provide all information available in an objective manner. Representatives of SEPS suggest that the Proponent's commitment to complete and unbiased disclosure of information continued throughout the operating life of the mine (Barsi pers. comm. 1991, Cooper pers. comm. 1991).

The evaluation of the Jolu EIS provided many specific criticisms regarding the scientific and technical soundness, clarity, content, and objectivity of the EIS. It is hoped that the criticisms presented here may help in improving EISs in the future. The true test of the effectiveness of an EIA however,, is whether or not the assessment process established the groundwork for a sound environmental management program for the project (Ortolano et al. 1987). In the next section of this paper, a comparison is provided of predicted and observed environmental impacts. This comparison provides further insight into the quality of the Jolu Environmental Impact Assessment.

COMPARISON OF PREDICTED AND OBSERVED IMPACTS

Introduction

Post-project review of an EIS provides an opportunity to study the accuracy-of predictions of the likelihood and severity of environmental impacts. Such a review provides an important learning experience, and may help to improve the accuracy of predictions in future assessments (ECE 1990, Ross and Tench 1981, CEARC 1988).

There are very few quantified predictions of impacts in the Jolu EIS. Because of the complexity of natural processes, there is usually a substantial degree of uncertainty in environmental impact prediction (Holling 1978, Hollick 1986). Hollick (1986) identified several proposed methods designed to help quantify impact predictions including extended cost-benefit analysis (Pearce 1976), cost-effectiveness analysis (Thomas and Schofer 1970), multiple-objective planning (Bishop et al. 1976), matrices (Leopold et al. 1971), scaled checklists (Dee et al. 1973), and map overlays (McHarg 1969). These techniques have been available for use in EIA for many years, but they are not commonly applied. The methods for quantifying impact predictions have generally been found to be of limited value in EIA (Hollick 1981, McAllister 1980).

Some predictions have been quantified in the Jolu EIS, and are analyzed accordingly in this study. For most potential impacts, a mitigation method was proposed which was designed to eliminate or greatly reduce the impact, but no quantified prediction was made of the residual impacts (after mitigation). Unless predictions are made about residual impacts it is not possible to test the accuracy of a prediction for a mitigated impact (Munro 1985). In cases where there are no quantified predictions, the best that could be accomplished in this study was to determine if the mitigative measures were applied as recommended, and to see if the mitigative measures were effective (Davies and Sadler 1989). This evaluation involved a review the Mines Pollution Control Branch Inspection Reports, Jolu's Monthly Environment Reports, monitoring data, and interviews with the mine staff and management and representatives from the Mines Pollution Control Branch. The effectiveness of the environmental monitoring programs for the operation was also evaluated.

In order to conduct an analysis of the accuracy of predictions in the Jolu EIS, all of the predictions made and all of the issues addressed in the EIS were reviewed for this study. Seven categories were selected to represent the most important impacts for which there was sufficient information to draw relevant conclusions. In each of these categories, the issues, predictions, and proposed mitigative measures were summarized from the Jolu EIS. The actual mitigative measures applied are then described, and a description of the impacts which were observed during the operation of the mine and mill is provided.

In order to simplify the referencing system for this portion of the paper, the following abbreviations will be used:

(EIS vol. x p. x)- refers to the page number and volume of the Jolu EIS submitted by Royex Resources in February 1988,

(EI date)- refers to the Mines Pollution Control Branch Monthly Environmental Inspection Report of the said date,

(MER date)- refers to the Monthly Environment Report submitted by the Proponent on the said date.

A) Construction of Access Roads, Mine, Mill and Camp Facilities

Issues and Prediction of Impacts:

Concerns were identified during the EIA regarding the effects of clearing, grading, culvert installation, graveling and ditching on wildlife, fisheries, soil cover, surface drainage, and stream flow. No quantified predictions were made in the EIS regarding this issue.

Proposed Mitigative Measures

In the EIS (EIS vol. 2 p. 141), it was proposed that the access road be routed to avoid any "unique wildlife habitats", and to minimize crossings of wetlands. The access road was to be built such that all stream crossings were perpendicular to minimize crossing length. Road construction was to take place outside of periods of fish migration or bird nesting, and culverts were to be installed in streams below existing bed levels to facilitate fish migration.

Observed impacts:

At the present time, there are no explicit regulations controlling construction of access roads and preparation of sites for construction. Permits are issued by Parks and Renewable Resources to provide some control over construction activities, but these permits tend to concentrate on timber conservation (Sinclair pers. comm. 1992). Monitoring programs to determine the effects of construction were not required for the Jolu project, and no inspections occurred during road and facilities construction.

The majority of road and camp construction took place in December 1986, with some additional work done in February 1988 (Biles pers. comm. 1991). This complied with the recommended mitigation of conducting construction outside of periods of bird nesting and fish migration. Stream crossings were established perpendicular to channels, and culverts were installed as recommended.

There is nothing particularly unique about the road and facility construction at the Jolu mine (Kazakoff pers. comm. 1991). Mitigative measures to reduce impacts due to construction are well established (Sinclair pers. comm. 1992). Although not explicitly required by any regulations, proper installation of culverts and efforts to reduce the effects of erosion and turbidity are common practices of environmentally conscious operators (Sinclair pers. comm. 1992). Corona Corporation proved throughout the operation of the Jolu Mine that it was genuinely committed to minimizing adverse environmental impacts (Barsi pers. comm. 1991, Sinclair pers. comm. 1991, Cooper pers. comm. 1991), and no concerns were ever raised by Saskatchewan Environment and Public Safety concerning the impacts of the road and site construction process.

Discussion

In the EIS it was proposed that crossing of wetlands should be minimized in order to conserve wetlands habitat. The EIS did not however identify any wetland areas which were considered to be critical habitat worthy of conservation. As construction of roads and facilities in wetland areas would be avoided in order to minimize costs (Kazakoff pers. comm. 1991), there is no evidence that conservation of wetland was actually considered during the construction program. Similarly, the mitigative measure which suggested that roads be routed to avoid "unique wildlife habitats" during the construction program was not substantiated in the EIS. The EIS did not contain a study identifying "unique wildlife habitats" which were to be conserved. There is no evidence that this mitigative measure was ever applied.

Because no areas of "unique wildlife habitat" or important wetlands habitat were identified in the EIS, it was not necessary to propose any mitigative measures for conservation of these areas. Unneeded mitigative measures should not be included in environmental impact statements as they do not contribute in any constructive way to the EIA and review process. A scoping process should be employed in order to focus the EIS on issues of significance (Beanlands and Duinker 1983, Bonnicksen and Becker 1983).

When ministerial approval is granted to a project under the Saskatchewan Environmental Assessment Act, it is explicitly stated that the Proponent "as a minimum requirement, shall comply with and implement all specifications, mitigative measures and environmental protection procedures described in the (Environmental Impact) Statement" (Jolu Ministerial Approval, April 12, 1988). The Proponent is therefore violating the terms of the ministerial approval if it does not implement a mitigative measure recommended in the EIS, even if it is clear to the Proponent that mitigation is not needed. Such recommendations in an EIS can also be detrimental to the process, as they may mislead the readers into believing that a mitigative measure will be applied, when in fact the Proponent may not apply the measure because it does not feel that the measure is required for sound environmental management. If an issue is recognized as not being a serious concern, the EIS should clearly state that no mitigation is required.

B) Construction of Tailings Area

Issues and Prediction of Impacts

The construction of the tailings management area involved the dewatering of Mallard Lake, and the building of containment dams within the dewatered basin. The concerns raised in the EIS regarding this procedure include the effect of drainage of Mallard Lake on fisheries and wildlife, on the level of adjacent surface *waters, and on the quality of downstream aquatic habitats. There were also concerns that the construction of tailings pond dams could affect downstream water quality, and that the waste rock used for dam construction could result in acid mine drainage.

Given the mitigative measures proposed below, draining of Mallard Lake was expected to have "little impact" on the quality of downstream aquatic habitats (EIS vol. 2 p 142). No predictions were made on impacts on downstream water quality due to construction. Because the water level of 'Yew Lake is controlled by the elevation of the lake outlet and an old beaver dam, it was anticipated that the water level in Yew Lake would remain "largely unaffected" by the Mallard Lake dewatering process (EIS vol. 2 p. 142). The acid generating potential of the waste rock to be used for dam construction was studied, and it was determined that the rock did not have acid generating potential.

Proposed M i tiga tive Measures

In order to minimize the impacts on shoreline spawning areas, a discharge pipeline was to be installed on floats out to the centre of Yew Lake during the dewatering of Mallard Lake. No mitigative measures were recommended for impacts to wildlife. As "little impact" was predicted from the effect of the Mallard Lake drainage on downstream water quality, no mitigation was recommended. The concern over impact on water quality due to the construction of the tailings dams was addressed by the recommendation that sediment collection ponds should be installed on the outlet from Mallard Lake during, construction.

Observed Impacts

The discharge into Yew Lake was done according to the proposed mitigative plan with floats being installed on the discharge pipe. Although there was no official monitoring during the drainage of Mallard Lake to determine if there were any adverse effects on Yew Lake, a representative from the Mines Pollution Control Branch inspected the operation twice during the dewatering process. The dewatering operations were reported as having no adverse affect on the turbidity of Yew Lake (EI June 14, 1988). The water level in Yew Lake was reported to have risen by 0.3 m before the outflow reached equilibrium with the inflow (EI July 18, 1988), but quickly returned to normal (Kazakoff pers. comm. 1991). No adverse impacts from the dewatering operation were mentioned in Monthly Inspection Reports, Monthly Environment Reports, or in the Jolu Mine Annual Report.

The recommended mitigation of installing sediment collection ponds on the outlet from Mallard Lake during construction proved to be entirely unnecessary, and was never applied. Mallard Lake was dewatered prior to the commencement of tailings dam construction. All runoff during the construction of the dams collected in the Cell C depression of the tailings management area. There was no flow out of Mallard Lake during tailings dam construction (Kazakoff pers. comm.), and therefore there was no need for sediment collection ponds.

Discussion

The dewatering of Mallard Lake and the construction of the tailings dams appears to have proceeded without significant adverse impacts on the biophysical environment.

C) Increased Access

Issues and Predictions

A concern was identified relating to the potential for sudden increased fishing and hunting pressure in previously inaccessible areas as a result of construction of new access roads.

The road network built for the Jolu mine is very limited. The Star Lake access road which was already in existence came to within two kilometres of the Jolu site, and only a small stretch of road had to be constructed to provide access to the Jolu mill and mine site. An abandoned road constructed for the Decade Mine operation in the 1970's provided access to Mallard Lake, and a winter road provided access to Jojay Lake. The Jolu operation provided upgraded roads, but did not create access to previously inaccessible areas.

Because the access road to Jojay Lake was to go through the'mine site which is not open to the public, an increase in fishing pressure on Jojay Lake from locals was not anticipated. There was some concerned over fishing pressure from mine staff. Impacts were predicted to be direct but short term in duration. Because popular sport fishing species such as walleye and lake trout do not occur in the immediate area, extensive fishing by mine and mill staff was not anticipated.

Mitigative Measures Proposed

In the EIS it was stated that "access roads have been routed away from potential fishing and hunting areas". In addition, it was recommended that the Proponent not encourage such activities as "fishing derbies" which could put undue stress on fish populations (EIS vol. 5 p. IA30).

Observed Impacts

No official monitoring took place to determine if there was any increase in hunting or fishing pressure. There is no reference to this issue in either the Monthly Environment Reports or the Monthly Environmental Inspection Reports. When asked about this issue, Mr. J. Kazakoff, the mill superintendent of the Jolu mine, stated that the only people he had ever seen fishing on the lakes in the area were Corona staff members, and that fishing by staff members had been quite limited (pers. comm. 1991).

Discussion

There is no indication that fish or wildlife populations were adversely affected by increased access. There is also no indication that a mitigative measure to route access roads around potential hunting and fishing areas was ever applied. In the EIS, there are no studies identifying potential hunting and fishing areas, or recommending preferred access routes. This appears to be an other example of a mitigative measure recommended in. the EIS to address an issue which was not really of concern. The EIS should simply have stated that increased access to hunting and fishing areas was not considered to be a serious concern and that no mitigation measure would be applied to reduce potential impacts.

D) Transportation and Storage of Supplies

Issues and Predictions

Concern was raised over the potential for spills or leaks of fuel and process chemicals. During construction, the major hazardous materials to be stored at the site included diesel fuel, gasoline, lubricants and explosives. During operation cyanide, lime and acid were stored in addition to the above. The EIS contained no predictions on the likelihood or severity of impacts due to fuel or chemical spills.

Proposed Mitigative Measures

Because fuel, chemicals, and explosives were delivered by suppliers, the Proponent depended on the suppliers to ensure that transportation was done in a suitable manner. The suppliers had to comply with the Transportation of

Hazardous Goods Regulations issued by the Lands Protection Branch of Saskatchewan Environment and Public Safety.

Proposed mitigative measures to ensure safe storage of hazardous materials included constructing spill containment areas around outdoor storage tanks, providing floor drains to sumps and constructing containment curbs around inside tanks, ensuring that suitable chemicals and materials would be available for spill clean-up or neutralization, and developing a manual and employee training program to clean up any chemical spills.

Observed Impacts

Although there was no monitoring program designed specifically to monitor fuel and chemical storage areas, these areas were visually inspected by representatives from the MPCB on a regular basis. Containment areas, curbs and sumps were constructed as proposed. There were no recorded spills of any process chemicals throughout the history of the operation, and containment structures were maintained in a manner acceptable to the MPCB inspectors.

The operation did however experience chronic problems with fuel storage. Minor problems were recorded in terms of tears in liners (EI Oct 18, 1988, EI May 8, 1990), leaking gaskets (EI Apr 26, 1989), defective and damaged fuel nozzles (EI Mar 20 1990, EI Feb 7 1990), and accumulation of runoff within a fuel storage containment area (EI Mar 28, 1991). The area around the mill shop was subject to chronic small fuel and oil spills as a result of filling machinery with fuel, and of washing equipment and the shop floor (EI Dec 5, 1989). Although no quantitative analysis was done, a MPCB representative suggested that the small spills and washed out oil were "undoubtedly a significant contributor to the fuel which has been seeping into the mine yard drainage collection sump". The water from this sump drains into the ground., carrying the fuel and oil along with it.

In addition to the chronic small scale problems with fuel and oil, a major fuel spill occurred on October 18, 1988 The spill was the result of a deteriorated compressor fuel line. It was estimated by the Proponent that as much as 750 to 1000 gallons of fuel oil may have leaked into the ground adjacent to the mill shop as a result of this leak. The fuel accumulated in the mine water settling sump across the road from the spill site. Over time, the fuel seeped under an ore storage pad, and entered a muskeg which drains into Rush Lake. A considerable area of the muskeg was affected by the spill as was evident from yellowed and dead vegetation (EI June 19, 1989). It appears however that the spill did not migrate all the way through the muskeg, and no fuel was thought to have reached Rush Lake (EI June 19, 1989).

Because of freezing conditions shortly following the spill, little could be done to clean up the spill until the following spring. An extensive clean up program utilizing fuel absorbent blankets and oil booms was implemented in the spring of 1989, and continued throughout the summer. By June 1989, the vegetation in the muskeg began showing signs of recovery (EI June 1989). The recovery of the muskeg vegetation was documented through a series of photographs taken by SEPS during monthly inspections of the site. By the spring of the following year, there was little evidence of fuel oil in the muskeg (EI May 1990).

In September of 1988, just prior to the major fuel spill, Corona had developed a spill contingency plan. Requirements for such a plan are stipulated in the operating permits issued by the MPCB. The contingency plan included the following:

-a list of toxic materials on site,
-spill prevention procedures,
-spill response procedures,
-alerting procedures,
-reporting procedures,
-response team organization, and
-emergency phone numbers.

At the time of the major fuel spill, employees were not yet familiar with the new spill contingency plan (letter from Biles to Cooper, Dec 20, 1988). Shortly following the spill, all employees were required to read the contingency plan, and copies of the plan were kept on hand at all work locations in order to ensure that the plan would be readily available to the workers in the event of a spill (Kazakoff pers. comm. 1991). All workers on the site were put through a government regulated training system for hazardous materials entitled “Workplace Hazardous Materials Information System”. It is unfortunate that the contingency plan was not fully established prior to the major fuel spill, as the impacts of the spill may have been reduced if the workers and management had reacted to the situation in a more organized and timely fashion.

Discussion

A review of the Monthly Environmental Inspection Reports from SEPS and the Monthly Environment Reports submitted by the Proponent revealed that small scale fuel spills were a chronic problem at the mine. Nowhere in the monthly Inspection Reports was it suggested that the problems with small scale fuel spills were a serious environmental hazard. It was however, clear that the staff at the mine were somewhat careless in the handling of fuel at the site.

Although the occurrence of a large fuel oil spill at the Jolu Mine was unfortunate, it does not appear that the likelihood of such a spill occurring was unusually high for this operation. Nor does it appear that the mine was unusually susceptible to small scale fuel spills. It is therefore not surprising that the issue received little attention during the EIA. In retrospect however, it is unfortunate that more attention was not paid to the issue. Following the large spill, a daily inspection program was implemented for the collection ponds, the fuel storage area and the fuel lines in order to avoid future spills of this magnitude. Several small scale mitigative measures were implemented throughout the life of the operation in order to reduce small scale fuel spills, including installation of automatic shut-off nozzles on fuel hoses and installation of oil absorbent booms and blankets in sumps which accumulated petroleum products from various sources. The potential for fuel spills should have been anticipated during the EIA, and mitigative measures such as those later applied should have been recommended in the EIS.

E) Sewage and Domestic Solid Waste Disposal

Issues and Predictions

The EIS identified concerns over the possible effects of sewage disposal and domestic solid waste disposal on surface and ground water, and the effects of domestic solid waste disposal on local wildlife populations. No predictions were made on the potential for adverse impacts.

Proposed Mitigative Measures

In the EIS, it was proposed that the sewage be discharged to the tailings pond to reduce the potential impact on surface and ground water. In order to reduce the impacts of domestic solid wastes on local wildlife populations, incineration was recommended. It was proposed that the waste disposal area be constructed in an area with low permeability soil and a low water table. Waste was to be covered with fill on a regular basis.

Observed Impacts

The sewage treatment and disposal system for the Jolu mine'was inspected on a regular basis by representatives from the MPCB. Except for a very minor sewage leak from a septic tank, sewage disposal was never identified as a problem on the site.

The incinerator installed at the site was too small for the size of the operation (Kazakoff pers. comm. 1991). In addition to being too small, the incinerator used excessive quantities of propane (Biles pers. comm. 1991). The incinerator was used initially and was then abandoned in favour of burning and burying.

The garbage was generally buried two to three times a week (Kazakoff pers. comm. 1991). Burning the garbage was labour intensive as permits specified that someone had to be present at all times during burning. Occasionally burning would be delayed because of the labour requirements (Kazakoff pers. comm. 1991). A review of the Environmental Inspection reports suggested that there were minor problems with ravens dispersing domestic garbage around the site. It appears that at times burning and burying of garbage did not occur as frequently as required to discourage wildlife from frequenting the dump site (EI July 18, 1989).

The Jolu mine had on-going problems with black bears at the site throughout 1989 and 1990. In order to alleviate this problem, the dump site was moved from its location near the camp to the opposite side of the tailings pond in August of 7990. Initially, the relocation of the dump site was successful at reducing the problems of bears within the camp (Kazakoff pers. comm. 1991). The following summer however, bears were once again frequenting the camp, attracted by odours from the camp kitchen and garbage- temporarily stored in the porch area of the camp kitchen. The bears which came into the camp in the sumrnet of 1991 were not at all intimidated by people, and were considered to be a threat to the staff at the site (Biles pers comm. 1992).

Discussion

In one of the Monthly Environmental Inspection reports submitted by the MPCB, it was noted that when the sewage effluent was discharged from the septic tank it seeped "through a manmade muskeg ridge, and down a draw filled with muskeg and labrador tea". The inspector noted that within 50 m, there was "virtually no evidence of sewage or sewage smell". Based on this observation,, the inspector suggested that muskeg treatment systems may have the potential for providing low cost and effective sewage treatment. Muskeg treatment of sewage should be investigated as a potential sewage treatment option for remote northern developments (EI Nov 9, 1987).

The problems that the Jolu Mine encountered with black bears frequenting the camp area are not unique. Most northern mining operations experience similar problems (Biles pers. comm. 1992). There do not as yet appear to be any standard and effective methods of garbage disposal which prevent conflicts with bears at remote northern camps. The burying and burning system at Jolu was not effective at eliminating conflicts with bears, and moving the dump site only provided temporary relief. The use of electric fencing around garbage dumps has been proposed as a potential solution to bear conflicts in camp situations (Herrero 1983).

Only a few bears were destroyed at the Jolu mine site, and there were no injuries to the workers as a result of contact with the bears. The garbage management scheme implemented was not however, effective at significantly reducing the potential for conflicts with bears. The Jolu EIS did not address the potential for conflicts with bears in any great detail. It is recommended that more care be taken during **EIAs** in the future to try to develop garbage management strategies which will reduce the number of bears which must be destroyed, and will reduce the potential for serious injury to workers as a result of conflicts with bears.

F) Tailings Management

Introduction

At the time of the initial design of the **Jolu** tailings pond, there was some concern over the potential for generation of acid mine drainage. During a detailed siting study, Mallard Lake was selected as the most suitable location for a tailings facility as it allowed for long term subaqueous containment of the tailings. The tailings pond design involved draining Mallard **Lake** and constructing a series of dams to separate the various cells of the tailings management facility. The raw tailings were deposited directly on the old lake bottom, using linings used to prevent tailings supernatant from seeping into fresh water containment areas. The old lake was to be filled completely with tailings, and would be reclaimed as a wetland system.

This tailings disposal strategy generated several concerns over potential environmental impacts. By draining Mallard **Lake** and filling it with tailings, the lake would be lost as aquatic habitat. Downstream surface and groundwater quality could be adversely affected by discharge of effluent during the operation of the mill, and due to seepage through the stored tailings after decommissioning. Changes in water quality could have adverse impacts on downstream aquatic resources. The potential for acid generation in the mine tailings was also of concern. Each of these issues is addressed separately below.

Issue **#1:The** use of Mallard Lake as a tailings disposal site will result in the loss of the lake as a natural water body.

Predictions

Construction of the tailings management area as proposed ‘in the EIS would result in the loss of Mallard Lake as an aquatic resource. This would result in the permanent loss of the fisheries resource in Mallard Lake.

During the baseline studies for the Biological Assessment, ***Carex flava,*** a species of sedge, was identified on the site. This was the first record of this species in Saskatchewan. It is suggested in the EIS that this species may only be listed as “rare” due to a scarcity of northern Saskatchewan plant collections. Within the project area, this species was restricted to the Mallard Lake Basin.

It was predicted in the EIS that the conversion of Mallard Lake to a tailings pond would likely result in the elimination of Carex *flava* at this location.

Mitigation

The EIS recommends that fish stock be removed from Mallard Lake prior to draining, and be transferred to Yew Lake.

Although ***Carex flava*** appears to be very rare in Saskatchewan, its distribution is circum boreal, and it was decided that no mitigation would be implemented to protect the species (Appendix I, Section A, p. IA26).

Observed Impacts

No follow up studies were conducted during the operation of the Jolu project to determine how aquatic plants were affected by the Jolu operation. The fish transfer program was executed as proposed.

Discussion

The loss of Mallard Lake as an aquatic resource was identified in the EIS as the main residual effect of the proposed project (EIS vol. 2 p. 156). The only way to avoid this impact would be to employ another system for tailings disposal. During the early stages of the EIS, there was some concern that the tailings would have acid generating capacity. The subaqueous deposition in Mallard Lake was therefore considered by the Proponent to be the safest option.

Both the Proponent and Saskatchewan Environment and Public Safety identified the fact that the fisheries resource in Mallard Lake was of limited value. The fish in Mallard Lake contained elevated levels of mercury due to the existence of tailings in the lake from a previous mining operation. The poor quality of the fisheries resource in Mallard Lake, along with the apparent suitability of the basin as a tailings disposal site, resulted in the decision that the loss of the lake was an acceptable tradeoff.

A total of $7500 was spent for the capture and release of approximately 100 northern pike and whitefish from Mallard Lake (Biles pers. comm. 1991). Considering the large populations of fish in the surrounding lakes, it does not appear that this was a very productive use of funds. It should be noted that under the Saskatchewan Fishery Regulations, transfer of live fish from one lake to another is prohibited.

Issue #2: Effluent Discharge may have an Adverse Affect on Downstream Ground and Surface Water Quality

This was one of the most important and thoroughly addressed issues in the EIS. In order to present the analysis of impact predictions in a clear manner, predictions on mill effluent quality, discharge effluent quality, and downstream lake water quality will be addressed individually rather than summarizing all of the predictions, all of the proposed mitigative measures, and all of the observed impacts together.

In addition to the quality of effluent being discharged to the environment, the quantity of effluent discharge has a direct affect on the impacts to downstream water quality. Issue 2d will address efforts to reduce effluent quantity.

Issue 2a: Mill Effluent Quality

The first step in attempting to quantify the potential environmental impacts of effluent discharge involved predicting the quality of the effluent which would be discharged from the mill into the tailings treatment system.

A characteristic leach liquor was generated from ore samples which would simulate the effluent discharged from the mill. Because ore bodies are not homogeneous and because diamond drilling is expensive and time consuming, it is not possible to assess accurately the composition of an entire ore body prior to development. A composite ore sample was prepared in an attempt to represent the overall ore body in terms of ore type, metallurgical response and mineral content. The sample was subjected to a 48 hour cyanidation process in order to create a leach solution which would be representative of the tailings solutions generated by the Jolu Mill. The composition of tlhis solution is summarized in the 'predicted' column of Table 1.

Observed Impacts

Table 1 compares the concentrations of contaminants in the leach liquor created in the laboratory during the EIA to the actual measured values from the tailings box during operation of the mill (prior to any treatment). In reviewing the effluent quality measurements from the tailings box, it became apparent that the contaminant levels in the mill effluent were highly variable from day to day. The variations in effluent composition are attributed to inhomogeneity in the mineralogy of the Jolu ore body (Biles pers. comm. 1992). Although the ore was not sampled during operation of the mill, visual inspection of the ore underground and as it entered the mill revealed wide variation in mineral composition (Biles pers. comm. 1992). At times when metal concentrations were high, additional cyanide had to be added to the mill circuit to compensate for cyanide consumption by metals

Table 1: Predictions of Mill Effluent Compared to Measured **Values From Tailings Box**

Note: These values are for untreated mill effluent.

	Predicted	1989			1990			1991		
		high	low	ave	high	low	ave	high	low	ave
Cyanide (T) mg/l	277	400	48	149	265	82	169	190	90	154
Dissolved solids mg/l	1238	1360	533	970	2130	1030	1521	1640	1330	1497
Conductivity umho/cm	1940	2290	711	1402	2840	1630	1994	2520	2190	2303
Total Alkalinity Mg/l	420	414	188	289	497	237	349	306	226	276
Cl mg/l	16.7	496	160	264	640	381	478	526	305	432
Mg mg/l	0.12	7.9	0.1	1.53	4.7	0.02	0.78	3	<1	1.5
Na mg/l	394	326	148	240	466	274	366	426	341	379
SO4 mg/l	117.3	440	42	141	385	217	286	330	186	256
Cu mg/l	5.81	18	4.7	11	28	3	14	26	22	24
Zn mg/l	0.62	1.6	0.24	0.59	1	0.24	0.51	1	0.24	0.51
Pb mg/l	0.05	0.14	co.005	0.01	0.03	<0.005	0.01	0.03	<0.005	0.01
Ni mg/l	<0.05	1.7	0.049	0.24	1.4	0.14	0.46	1.4	0.14	0.46
As mg/l	co.05	0.46	0.002	0.04	0.15	0.002	0.02	0.15	0.002	0.02

and to maintain efficient gold extraction. At times when the ore being processed was rich in metals, the effluent would have both high metal content and high cyanide content.

Discussion

Considering the wide variation in effluent quality encountered during the operation of the Jolu mill, it is surprising that the predictions based on the simulated leach liquor created during the EIA were as accurate as they were. In general, the predicted values fell within the range of the contaminant concentrations measured at the tailings box. The only inaccuracy in the predicted values which lead to any problems in the effluent treatment process was the prediction of copper concentrations. Although the predicted value did fall within the range of values encountered, it was significantly lower than the average concentration encountered during the operating life of the mill. It was never determined why copper levels were so much higher in the mill effluent than in the simulated effluent, but it is likely that the composite ore sample used for the simulation was simply not representative of the copper concentration in the ore body (Kazalcoff, pers. comm. 1991). Reduction of copper to allowable concentration for discharge became one of the most challenging problems for the Jolu management.

Issue 2b: Discharge Effluent Quality

The second step in quantifying the potential impacts of effluent discharge involved determining the quality of the effluent to be discharged to the environment. At the time of the EIS, it was thought that natural degradation of the mill effluent would be sufficient to reach dischargeable quality, without the use of any chemical treatment processes. Two different approaches were taken to predict how the effluent would respond to natural degradation.

Bench tests were conducted, with a simulated leach liquor being aged at room temperature for a period of six weeks. One sample was subjected to natural light, and a second was subjected to ultraviolet light. The results of the study are summarized in Table 2. Cyanide degraded very rapidly under the bench test conditions. The EIS suggested that the polished tailings effluent would be of approximately the same quality in terms of cyanide as the aged samples (EIS vol. 2 p. 59). It was however noted in the EIS that "testwork to simulate the operation of a natural degradation system is difficult to achieve on a laboratory scale basis due to the influences of location, local geography and climate" (EIS vol. 4 p. F26).

In addition to bench tests, a computer model was used to predict how aging would affect relative concentrations of cyanide and of various other contaminants in the mill effluent. A detailed methodology for this modeling exercise is not provided in either the EIS or the Appendices. Although it is

Table 2: Bench Top Effluent Aging Results
Modified From Royex 1988

	Light Conditions	pH	temp	Cn (T)	Cn (F)
Week 0	1 -natural	9.6	18	60.1	21.4
	2 - w			66.2	30.2
Week 1	1	9.6	18	8.1	0.4
	2			7.2	0.3
Week 2	1	9.1	17	0.18	0.07
	2			0.32	0.03,
week3	1	8.9	15.5	0.1	0.05
	2			0.2	0.02
Week 4	1	8.8	17	0.07	co.05
	2			0.14	<0.05
week5	1	8.8	15	0.07	co.05
	2			0.08	<0.05
Week6	1	8.8	16	0.07	co.05
	2				

suggested in the EIS that the computer model used a "rate of aging relationship typical for this type of solution in a northern lake environment", the parameters used are not explained in the EIS.

In Figure 6 the model's predictions for cyanide degradation during the first year of operation are presented along with the results of the monitoring program for 1989. The model suggested that cyanide would degrade rapidly once ice cover thawed from the tailings pond surface.

It is unclear exactly how the results of the bench tests and computer modeling were integrated in order to generate predictions on final effluent quality after natural degradation, as adequate methodology for the study was not provided in the EIS. The EIS does however provide predictions of final effluent quality following natural degradation. It appears that the rate of cyanide degradation was derived from the computer modeling program, and that reductions in other contaminant species were calculated based on anticipated dilution due to runoff and seepage into the tailings pond. The predictions, along with actual values assembled from Jolu's environmental monitoring data are presented in Table 3.

Observed Impacts

As can be seen in Figure 6, cyanide levels in the Jolu tailings pond did decrease during the summer months due to natural degradation. The concentrations did not however, decrease to dischargeable levels as had been anticipated by the computer model or the bench tests. Table 3 compares the predictions of final effluent quality to the values measured on July 21, 1989 in Cell B. As can be seen from Figure 6, these values represent the highest degree of natural degradation achieved in the tailings pond. Although the levels of most contaminants were reduced to dischargeable levels due to the effects of natural degradation in tailings Cell B, copper and cyanide levels remained elevated beyond allowable discharge levels. Unexpectedly high levels of suspended solids were also encountered in the tailings pond.

In July of 1989, the Jolu management recognized that natural degradation was not progressing as rapidly as had been predicted, and it began to consider alternative options for effluent treatment. Attempts were 'made to decrease suspended solids in the Cell B tailings pond by adding hydrated lime directly into the pond. Tests were also conducted on the effects of hydrogen peroxide on the effluent quality. Although these experiments did improve the quality of the effluent, dischargeable qualities were not achieved.

In late August 1989, a temporary test permit was issued by Saskatchewan Environment: and Public Safety (SEPS) to allow the Jolu management to experiment with the possibility of using a natural muskeg treatment system to polish the effluent. Muskeg systems had been successfully employed at

Figure 6: Natural Degradation of Cyanide in Cell B of the Jolu Tailings Pond

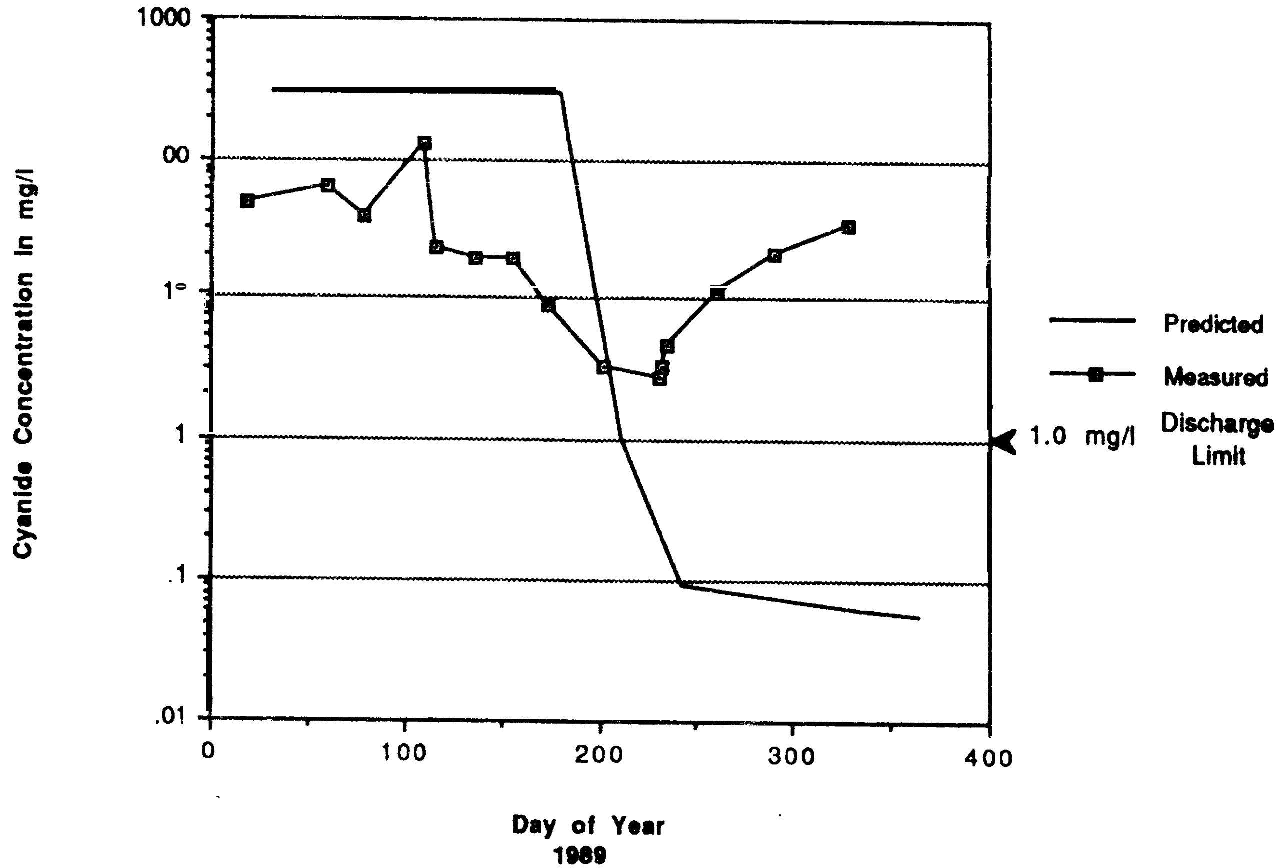


Table 3: Effluent Quality Following Natural Degradation
note: measured values are From Cell B, July 21 1989.
These values represent the lowest values **acheived** in the tailings pond **due** to natural degradation.

mg/l	Predicted	Measured	Discharge Limit
CN(T)	0.05-0.5	2.1	1.0
CN(F)	<0.05		
Fe	2.0-4.0	1.6	
Cu	0.05-0.2	2.2	0.3
Ni	0.1-0.3	0.095	0.5
Zn	0.02-0.1	0.06	0.5
Co	0.1-0.2		

Table 4: Discharge Effluent Quality
Note: Predictions based on natural degradation only, measured values taken after chemical treatment process and muskeg polishing process

mg/l	Predicted	1990 average	1991 average	Discharge Limit
CN(T)	0.05-0.5	0.26	0.16	1.0
CN(F)	<0.05			
Fe	2.0-4.0	0.34	0.53	
Cu	0.05-0.2	0.022	0.014	0.3
Ni	0.1-0.3	0.011	0.013	0.5
Zn	0.02-0.1	0.014	0.071	0.5
Co	0.1-0.2	0.1	0.095	

both the Star Lake and Jasper Lake mines. During the two month test at Jolu, dischargeable effluent quality was achieved, and effluent was discharged to the environment. The system had to be shut down in mid October when the muskeg froze up.

Although the muskeg treatment system appeared to be effective, SEPS did not automatically issue a permit for long term use of the treatment system. Muskeg treatment is still a relatively new technology. SEPS decided that additional research was required to gain a better understanding of processes involved in muskeg treatment systems, and the long term viability of these systems (Kazakoff pers. comm. 1991). A study was commissioned by SEPS to evaluate the Star Lake, Jasper Lake, and Jolu muskeg treatment systems.

While this study was being conducted, the Jolu Management was left in the uncomfortable position of not knowing whether or not they would receive a permit for the muskeg treatment system. The Management decided to develop a chemical treatment process to ensure that effluent could be discharged regardless of whether or not a permit was issued for the muskeg treatment system. An ferric sulphate/hydrogen peroxide system was developed, and a treatment plant was started up on June 10, 1990. On July 19, 1990, Ministerial Approval was issued to allow the muskeg treatment system to be incorporated into the Jolu effluent treatment system. The Jolu management decided at that time that both the chemical treatment plant and the muskeg polishing system would be utilized to achieve the best final effluent quality possible.

Table 4 summarizes the average final effluent quality for 1990 and 1991. Although the treatment process applied was considerably different from the EIS's proposed natural degradation process, we can make a comparison between the predictions of final effluent quality from the EIS and the actual measured effluent quality. The effluent quality achieved using both the chemical treatment process and the muskeg polishing process was higher than the effluent quality predicted in the EIS for natural degradation alone. Average contaminant concentrations in the final effluent were far below the discharge limits stipulated in the Jolu operating permits.

Discussion

The predictions that natural degradation would produce effluent of dischargeable quality were not realized. It appears that static bench tests are inadequate to predict the effects of aging on tailings effluent. In a tailings pond,-there is -constant discharge of fresh tailings into the system. Such a dynamic system appears to behave significantly differently than the static system simulated in bench tests (Kazakoff pers. comm. 1991, Biles pers. comm. '1991). It would be very interesting to conduct a laboratory study where the dynamic processes of a tailings pond would be more closely simulated in order to see if more accurate predictions on natural degradation could be made.

The computer program that was used to simulate the effluent aging process was inaccurate. Because of the lack of information available about the methodology used in the study, it is impossible to determine the cause of the inaccuracy of the model. It is recommended that the consultant who used the model review the actual aging characteristics of the effluent and modify the program or the parameters so that in the future it can be more accurate.

Based on the studies of natural degradation conducted during the EIA it was assumed that natural degradation would be sufficient to achieve effluent of dischargeable quality. It was however recognized during the EIA that dischargeable effluent quality may not be achieved by natural degradation alone. Although the EIS did not go into any detail on potential alternative treatment methods, it did state that if dischargeable effluent quality was not achieved, a chemical treatment plant would be installed. The design of the tailings pond was such that all of the tailings and supematant from the first year's operations could be contained without any discharge to the environment. This provided Jolu with ample time to study and develop strategies to treat the effluent when natural degradation was found to be inadequate. In cases such as this where it is very difficult to make accurate predictions, it is important that contingency plans be prepared to allow mitigative measures to be improved during the operation of a project, without compromising environmental protection. In the case of the Jolu tailings management program such an approach was successfully employed.

Issue 2c: Yew Lake Water Quality

The final effluent from the tailings management area is discharged into Yew Lake (Figure 3). Concentrations of selected contaminants were predicted for Yew Lake based on the predictions for final effluent quality in Table 4. Because the effluent was expected to mix primarily within the active zone above the Yew Lake thermocline, dilution rates in the short term (1 to 3 months) were only anticipated to be approximately 50%. It was suggested that the concentrations would however, drop rapidly as further mixing occurred with water below the thermocline, and as natural degradation progressed (EIS vol. 2 p. 61).

Observed Impacts

Table 5 compares the predicted values for Yew Lake water quality to both baseline data and monitoring data from 1989 to 1991. It is clear that the predictions made in the EIS were fairly conservative. For total cyanide (Cn(T)), Fe, and Cu., the predicted values corresponded quite closely with the

Table 5: Water Quality from Yew Lake Outlet

mg/l	Baseline	Predicted	1989 ave.	1989 high	1990 ave.	1990 high	1991 ave.	1991 high
CN(T)		0.03-0.25	0.042	0.28	0.016	0.045	0.017	0.026
CN(F)		<.05						
Fe	<0.1	1.-2.	0.28	1.1	0.26	1.1	0.22	0.48
Cu	0.002	0.03-0.1	0.011	0.036	0.01	0.05	0.015	0.05
Ni	<0.001	0.05-0.15	0.003	0.012	0.003	0.009	0.007	0.016
Zn	0.009	0.01-0.05	0.025	0.019	0.013	0.061	0.011	0.018
Co	<0.001	0.05-0.1	<0.001	<0.001	0.007	0.022	0.023	0.023
pH		7.-8.	6.48		7		6.93	

highest values which were recorded during monitoring. Predicted values for Ni and Co were much higher than any values measured in the field.

Zn values measured in Yew Lake were unusually high for a short period of time. It is not clear what caused this temporary condition. On average, zinc levels were consistent with concentrations predicted in the EIS.

Discussion

The predicted values for contaminant levels in Yew Lake were considerably higher than average due to very conservative dilution factors used for the predictions., The EIS appears to have presented a worst case scenario, quoting the lowest dilution which would be likely to occur in the short term. The worst case figures are important in determining whether or not there is a potential for acute toxicity. The impacts of changes in Yew Lake water quality will be addressed in more detail in the section on Biological Resources.

Issue 2d: Reduction of Effluent Volumes

Although permits and regulations tend to concentrate on ensuring that effluent meets certain quality requirements, reducing the quantity of effluent discharged to the environment can also contribute to lowering downstream contaminant loading. In the EIS, it was proposed that all fresh ground and surface waters be diverted away from the tailings basin to help reduce the total quantity of effluent to be treated and discharged (EIS vol. 2 p. 151). The mill process was designed to reclaim process water from the tailings pond, thus further reducing the volumes of effluent to be discharged. At the time of the EIS, it was anticipated that 50% of the water in the tailings would be reclaimed for use in the mill process (EIS vol. 2 p. 53).

Observed Impacts

The recommendation to divert fresh ground water around the tailings pond was not implemented. This is an other example of a recommended mitigative measure which was not practical to implement, and which should never have been included in the EIS.

In order to intercept fresh surface water which flowed into Mallard Lake; a fresh water diversion cell (Cell A) was built on the north end of the tailings management: area. A secondary diversion system was constructed to divert fresh water which drained from the south east and north west into Cell B, the main tailings containment area. Although the Cell A system worked well, the ditches installed for the secondary diversion system proved to be inadequate (EI May 1989). The ditches were not lined, and considerable seepage occurred into Cell B. This was of particular concern as the resulting volumes of water in Cell B were significantly higher than the pond had been designed for, and it became apparent that if a 1:25 year flood event had occurred, the pond would not have been large enough to contain the runoff (EI May 1989). The MPCB suggested that the EIS had not placed as high an emphasis on the importance of the secondary drainage diversions system as it should have (EI May 1989). The freshwater diversion system was upgraded by installing a pipeline to divert water past Cell B from the south east side inflow, and by widening and deepening ditches.

The mill process water recycling program turned out to be even more effective than had initially been anticipated. The recycling process virtually eliminated the fresh water usage for the mill. Totals of 230,200 m^3 and 187,600 m^3 of reclaim water were reported for 1990 and 1991 respectively, significantly reducing the volumes of effluent which had to be treated and discharged to the environment. In addition to reducing the volumes of effluent, recycling of mill water reduced the volumes of fresh water extracted from Jojay Lake.

In their efforts to reduce the total volumes of effluent to be treated and discharged, the Jolu Management proposed to discharge compressor cooling water and jaw crusher cooling water directly to the environment, instead of discharging to the tailings pond. Samples of this water were analyzed, and proved to be of dischargeable quality. On October 20 of 1989, discharge of cooling water directly to the environment was initiated. This reduced the tailings effluent discharge volumes by an estimated 80,000 m^3/year (MER, Jan 18 1990).

Discussion

The efforts of the Jolu Management to reduce effluent discharge volumes through recycling of mill process water and discharge of cooling water directly to the environment contributed significantly to the reduction of the environmental impacts of the Jolu mining operation (Cooper pers. comm. 1991). These mitigative measures were recognized by the MPCB to be a major accomplishment in environmental protection, and the Jolu Management was commended on its efforts (Cooper pers. comm. 1991).

Issue #3: Tailings rnay be Acid Generating

Predictions

During the EIA, samples of ore were analyzed to determine the potential for acid mine drainage generation from the Jolu tailings. Table 6 summarizes the results of the acid generating potential study conducted on a variety of ore samples. The acid production figures were calculated based on the assumption that all of the sulphur in the samples would be converted to sulphuric acid. Acid consumption was measured by adding acid to the samples until all of the acid consuming minerals present were completely

Table 6: Acid Production and Consumption
From Jolu EIS, Volume 2 p. 58

SAMPLE	%S	ACID PROD. (kg/t)	ACID CONS. (kg/t)	FINAL pH
Composite A	1.51	46.2	27.4	2.8
Tailings	1.34	41	24	2.95
Composite B	3.73	114.1	23.5	1.75
Low Grade	2.05	62.7	27.4	2
High Grade	1.46	44.7	23	2.2
Hole R-99	0.74	22.6	51	
Hole R-253	2.06	63	156.8	
Composite C	0.86	26.3	16.9	4.86
Hole R-87-A	0.42	12.85	43.1	

dissolved. Final pH values were measured by acidifying the samples, inoculating them with sulphide oxidizing bacterial cultures, and maintaining the samples under ideal temperature and oxygen conditions for an extended period of time.

The tests indicated that under ideal conditions, the tailings did have some acid generating potential. It was noted in the EIS however, that even under ideal conditions reaction rates for the Jolu ore were very slow. Under field conditions, the EIS predicted that the Jolu tailings would have a "marginal potential" for acid generation (EIS vol. 4 p. F20).

Mitigation

Given the uncertainty in the potential for acid mine drainage generation from the Jolu tailings, the Proponent opted for a subaqueous discharge and containment scheme. The tailings were to be contained within the Mallard Lake basin, and a maximum possible water cover'was to be maintained. Consideration of costs and ease of operation also contributed to the selection of Mallard Lake as the tailings disposal area. At the present time, maintaining sulphide tailings in a submerged condition to restrict the availability of oxygen is recognized as the only practical and proven long term approach to preventing acid generation (Bell, 1987).

Discussion

The Mallard Lake disposal scheme was implemented as proposed in the Jolu EIS. During the construction of the tailings dams, Mallard Lake was drained, and tailings the old Decade Mine which had been discharged into Mallard Lake in the 7970's were exposed. During this time, it was noted that the pH level dropped significantly, apparently due to acid generation from the Decade tailings (Kazakoff pers. comm. 1991). The area was quickly re-submerged, and acid generation was terminated. This event gave further support to the effectiveness of submergence in controlling acid mine drainage.

During the operation, it became apparent that the Jolu tailings were not in fact acid generating. It is unfortunate that the methdds employed for predicting the acid generating potential for the Jolu tailings could not have been more accurate. The Mallard Lake disposal scheme was however inexpensive and the design was fairly simple. It would have been. even more unfortunate had an expensive disposal scheme been devised specifically for reducing the potential for acid drainage, only to find as the operation progressed that the tailings were not in fact acid generating.

Issue # 4: Leaching of tailings may affect ground and surface water

Predictions

Mallard Lake is a groundwater discharge area (EIS vol. 5 p IA27). Some concern was raised over the possibility of downstream surface water contamination due to groundwater seepage through the tailings after decommissioning. It was predicted that downstream water contamination due to the effects of groundwater seepage from the tailings containment area would "not be detectable"(p 148 vol 2). An increase in contaminant levels in the ground water was also predicted to be "not detectable'* (EIS vol. 2 p 148).

Mitigation Measures proposed

In the EIS, it is proposed that fresh runoff water would continue to be diverted around the tailings pond until compliance was achieved with effluent quality standards.

Observed Impacts

The tailings ponds are presently undergoing the process of decommissioning. The long term effects of leaching of tailings are not yet known.

Discussion

In accordance with the operating permits issued by the MPCB, Corona has prepared a detailed decommissioning plan. Decommissioning of the tailings area involves draining all tailings supernatant from the pond, treating the effluent, and allowing the ponds to fill with seepage and runoff water. According to calclulations in the decommissioning report, contaminated seepage coming up through the tailings will be diluted by a factor of 100:1 by uncontaminated seepage and runoff. It is predicted that by the summer of 1992, water from the tailings pond will be of suitable quality to be discharged directly to the environment (Clifton Associates Feb 8 1991). Monitoring programs are not included in the decommissioning plan, but will be addressed in permits issued by the MPCB.

Issue #5: Impacts of Changes in Water Quality on Biological Resources

Predictions

During the May 1987 field survey for the Jolu EIA, plankton and benthic macro-invertebrate samples were collected from both Mallard and Yew Lakes. Benthic macro-invertebrates are the most common organisms used as biological indicators of changes in water quality (Letourneau and Castonguay 1988). No quantified predictions were made in the EIS on how these populations would be affected by the Jolu operation. No follow up studies have been conducted to date to see whether or not macro-invertebrates were affected by changes in water quality resulting from effluent discharge from the Jolu tailings ponds.

Field surveys were also conducted to collect information on the fisheries resources which would potentially be affected by the Jolu operation. Extensive background data are presented in the EIS on species composition and abundance, and on spawning conditions for both Mallard and Yew Lakes. Much of this data would be suitable for follow up studies but none have been conducted to date. A detailed baseline study was conducted to record the concentrations of various contaminants in fish flesh in Mallard and Yew Lakes. Although no quantified predictions were made in the EIS, two subsequent studies have been conducted to determine the effects of effluent discharge on fish flesh quality.

The Jolu EIS also addresses the potential for acute and chronic toxic effects on aquatic biological resources. During the EIA, a literature review was conducted to document toxicity levels of the contaminants which were expected to be discharged to the environment. Based on this literature review and the predictions of downstream water quality (Table 5) the following predictions were made regarding impacts on downstream aquatic biological resources:

pH

Changes in pH in Yew lake were not anticipated to have an impact on biological resources (EIS vol. 2 p. 148). It was noted that changes in pH could alter toxicity levels of other contaminants, but no specific predictions were made.

Cyanide

Laboratory studies have shown that CN (F) concentrations of 0.005 to .02 mg/l are acutely toxic to juvenile fish, while concentrations of 200 mg/l are rapidly fatal to most juvenile fish (U.S. EPA 1985b). Concentrations of .005 to .01 mg/l can have chronic effects on adult fish (EIS p. 148 vol 2). Unfortunately, no studies were available at the time of the EIS for lake trout or whitefish under natural conditions in northern Saskatchewan lakes (EIS p. 148 vol 2). The lack of available data on toxicity levels under natural conditions in northern Saskatchewan lakes made it difficult to predict the degree of potential impacts of cyanide on aquatic organisms (p. IA28). Based on the predictions of Yew Lake free cyanide concentrations of <.05 mg/l, it was predicted that some potential existed for acute or chronic toxicity to juvenile fish in Yew Lake.

Iron

Studies indicate that iron concentrations of 7.5 to 12.5 mg/l are safe for juvenile brook trout (Sykora et al. 1972, Smith et al. 1973). The EIA's predictions of Yew Lake iron concentrations of 1 to 2 mg/l fall well below this range, and adverse impacts on fish were not anticipated. Iron toxicity in aquatic invertebrates can occur at concentrations of 0.32 to 16.0 mg/l depending on the species (Wamick and Bell 1969). The potential for some mortality of aquatic invertebrates was acknowledged, but was expected to be minimal (EIS vol. 2 p. 149)

Copper

Chronic toxicity levels of copper for juvenile fish range from 0.0039 mg/l for brook trout to .0604 mg/l for northern pike (U.S. EPA 1985a). Copper levels of .03 to .05 mg/l were predicted for Yew Lake in the EIS. The EIS predicted that the copper concentrations in Yew Lake would not be toxic to northern pike, but that some chronic effects could occur in lake whitefish.

Nickel

The U.S. EPA (1980) indicated that nickel concentrations of 0.51 to 33.5 mg/l Ni were acutely toxic for aquatic invertebrates. Concentrations over 2.48 mg/l were reported to be acutely toxic to fish. Predicted nickel concentrations of .1 to .3 mg/l in Yew Lake are below acute toxicity levels. No predictions were made in the EIS regarding chronic toxicity of Nickel.

Zinc

No studies are referenced in the EIS regarding toxicity of zinc. It is however predicted that the expected range of zinc levels in Yew lake of 0.005 to 0.01 mg/l would not have any toxic affects on aquatic organisms.

Proposed Mitigative Measures

Aside from operation of the tailings management area to ensure that discharge effluent met required standards, no specific mitigative measures were recommended for protection of aquatic organisms.

Observed Impacts

The effects of pH, cyanide, iron, copper, nickel and zinc on fish and macro-invertebrates were not monitored during the operation of the mine. No studies were conducted to see if population sizes or compositions varied from baseline data.

It is important to note that the concentrations of Fe, Cu, and Ni predicted in the EIS for Yew lake were higher than the average values measured during the operating life of the mine (Table 5). The measured levels of Fe and Ni fell well below the toxic concentrations described above. The Cu levels measured in Yew Lake were high enough to warrant some concern over the possibility of toxic effects. Zinc levels in 1989 and 1990 averaged .025 and .014 mg/l respectively. These values fall below the Canadian Water Quality Guidelines for zinc of 0.03 mg/l (Environment Canada 1987).

The acute toxicity of cyanide is related to the concentrations of free cyanide (Cn (F)) (EIS vol. 2 p. 148). Unfortunately, free cyanide concentrations were not measured during the Jolu monitoring program, Only total cyanide and weak acid dissociable cyanide values were measured. Predictions of Yew Lake water quality from Table 5 includes estimates of both total and free cyanide. A predicted total cyanide value of 0.03 to 0.25 mg/l corresponded to a free cyanide value of' <.05 mg/l. By comparison, the average measured values of total cyanide for 1989 and 1990 of 0.042 and 0.022 mg/l respectively should correspond to free cyanide values of significantly less than 0.05 mg/l. Because the exact values are not known, it is not possible to determine whether or not free cyanide concentrations were high enough in Yew Lake to cause toxic effects in aquatic organisms.

During the EIA, whitefish were collected from Mallard and Yew Lakes in order to conduct heavy metal analyses of the fish flesh. Two subsequent fish flesh studies have been conducted since the Jolu mine began operation. The average mercury and copper concentrations in fish flesh samples are illustrated in Tables 7 and 8 respectively. Unfortunately, it is impossible to make many direct comparisons between the values due to inconsistencies in fish species sampled at various locations during the three studies. Sample numbers are too small to make any definite conclusions on the effects of the Jolu operation on metal content of fish flesh. From the data available, it appears that mercury levels for northern pike were lower in 1991 than in 1989. Copper levels do not appear to have been significantly affected by the operation.

Even at the time of the baseline studies for the Jolu EIA, the levels of mercury were elevated in the fish sampled from Mallard and Yew Lakes. Although mercury does occur naturally in the environment, elevated levels in fish from Mallard and Yew Lakes are thought to have been the result of a previous mining operation which employed mercury in the gold extraction process (EIS vol. 5 IA19). The tailings from this operation, the Decade mine, were discharged directly into Mallard Lake. The mercury levels for fish sampled in Mallard Lake ranged from 1.0 to 1.4 μg/g, and those from Yew Lake ranged from 0.61 to 1.22 μg/g. According to the Saskatchewan Guidelines for the consumption of fish containing mercury (Saskatchewan Parks and Renewable Resources 1986), such high levels of mercury warrant limitations

Table 7: Fish Flesh Mercury concentrations, Wet Weight Basis - Ug/g

	Yew Lake			Long Lake	
	EIS	1989	1991	1989	1991
Whitefish	1.22	no data	no data	no data	<0.05
White Sucker	no data	0.58	0.6	0.25	no data
Northern Pike	no data	3.27	1.93	1.53	0.53

Table 8: Fish Flesh Copper Concentrations, Dry weight Basis - Ug/g

	Yew Lake		Long Lake
	EIS	1991	1991
Whitefish	1	no data	0.9
White Sucker	no data	1.4	no data
Northern Pike	no data	1.1	1

on human consumption.. Although northern pike were not sampled during the Jolu baseline studies the EIS suggests that, because northern pike are predatory, mercury levels can be expected to be higher than those for whitefish due to biomagnification (EIS vol. 5 p. IA20).

Discussion

The biological resources assessment portion of the folu EIS was very thorough and provided both quantified baseline data and quantified impact predictions.. Predictions of potential toxicity effects on aquatic organisms were not followed up by any studies during the operation of the mill. The Proponent did not exceed effluent quality discharge limits at any time, and did not have any legal obligation to conduct further studies. It is important however that the baseline data and monitoring programs were adequate to conduct such studies if any serious environmental concerns had arisen during the operation. The quality of the baseline and monitoring data would also have been sufficient for academic research if there had been an interest in carrying out further studies on the effects of the Jolu effluent discharge on aquatic resources in Yew Lake.

Although the monitoring program during the operation of the Jolu mill was extensive, it did not include measurements of free cyanide in Yew Lake. Because acute toxicity is related directly to the concentrations of free cyanide and not the total concentrations of cyanide, this measurement should have been made. By not recording the free cyanide levels in Yew Lake, the opportunity for estimating the impacts of the cyanide on aquatic organisms was lost.

The data collected in fish flesh studies were also inadequate for detailed scientific analysis. In the baseline study, whitefish were sampled in Mallard and Yew Lakes. In subsequent studies, northern pike and white suckers were sampled from Yew Lake, and northern pike and whitefish were sampled from Long lake. This sampling method eliminated the possibility of making a direct comparison between the fish flesh analysis of any species before and after effluent was discharged from the Jolu tailings system. This was a very unfortunate oversight in the design of the fish flesh studies, and could easily have been avoided if some thought had been given to how the data being gathered would be used for analysis.

G) Impacts of the Muskee Polishing Svstem

Because the muskeg polishing treatment was not included in the original design of the effluent treatment system, there are no predictions of its environmental impacts in the EIS. In 1990, the MPCB commissioned a study entitled “Assessment of Wetlands for Gold Mill Effluent Treatment”. This study, conducted by Gormley Process Engineering, identified some of the impacts of the Jolu muskeg treatment process.

Gormley (1990) identified a very conspicuous negative impact on trees and shrubs as a result of the effluent sprinkling system. Leaf mortality was evident on every black spruce, birch, willow, and labrador tea plant that was in the direct path of the sprayed water. The leaves of trees and shrubs appear to have been intolerant of continuously wet conditions. It was noted that sedges, grasses and associated herbaceous plants were much more tolerant of the wet conditions. Gormley suggested that there could be a gradual shift in the plant community composition as a result of the sprinkling system where grasses and sedges replace the more sensitive species such as birch and willows.

Gormley (1990) also reported some interesting results concerning sedge samples (Carex sp). Several of the samples collected lacked mature achenes (seeds). Although the outer coverings of the seeds appeared to be normal, the achenes were either underdeveloped or decayed. It was speculated that the prolonged wet conditions of the foliage inhibited seed development. Gormley does not comment on the long term implications of this problem, perhaps because the system would only be operable for 3 seasons. For future projects utilizing similar systems, this observation should be followed up .

The water quality monitoring program for the effluent treatment system was designed to ensure that water quality objectives were satisfied,, it was not designed with research needs in mind. From an operational perspective, there was little need to understand exactly how the muskeg treatment system worked, as long as the final effluent was of dischargeable quality.

The monitoring data which are available are not adequate to determine the exact effect which the muskeg treatment process had on the effluent quality. Cell C contains supernatant which has undergone natural degradation and chemical treatment. This is the water which is sprinkled over the muskeg. Cell A collects the water after it has gone through the muskeg polishing process. Cell A also collects all of the-fresh water which is diverted away from the tailings management area. The polished effluent mixes with the diverted fresh water within Cell A, and is discharged from Cell A to the environment. Because the exact amount of fresh water mixing with the polished effluent. is not known, a comparison between the water quality in Cells A and C is of little value in determining the effectiveness of the muskeg treatment process.

Attempts at determining of the effectiveness of the wetland polishing process were further frustrated by problems in the data related to analytical techniques. Immediately following the start-up of the chemical treatment plant in June of 1990, cyanide measurements in Cell C increased dramatically. It is thought that some chemical resulting from the chemical treatment

Table 9: Muskeg Area Runoff Water Quality Comparison
Modified from Corona Corporation Annual Environment Report 1990

Date		**Copper (mg/l)**	**pH**
May 7 1990	Entering	co.01	5.92
	Leaving	0.04	5.98
May 12 1990	Entering	0.035	6.14
	Leaving	0.06	6.3
May 15 1990	Entering	0.035	5.96
	Leaving	0.07	6.08
May 20 1990	Entering	<0.01	6.36
		0.03	6.2
May 28 1990	Entering	0.02	6.4
	Leaving	0.04	6.3
June 2 1990	Entering	0.01	6.5
	Leaving	0.04	6.5
June 5 1990	Entering	0.01	6.4
	Leaving	0.02	6.5
Average	Entering	0.015	6.25
	Leaving	0.04	6.29

process was interfering with the analytical process used to determine cyanide concentrations (Biles pers. comm. 1991). Although the problem was rectified by changing analytical methods, the event resulted in a large gap of cyanide measurements spanning over two months of the three months of the operation of the muskeg system in 1990.

Table 9 shows a comparison of runoff water quality entering and leaving the muskeg system. These values were measured in May and June of 1990, prior to any sprinkling for that year. The muskeg had been employed for effluent polishing the previous fall. This table shows the stability of the copper removed by the muskeg from effluent sprayed in the previous fall, and the effects on pH.

The Jolu management attributes the increase in copper to a flushing of residual effluent trapped in the wetland from the previous year's sprinkling. Unfortunately, sprinkling recommenced in June of 1990, and there was no opportunity to see if the levels returned to the objective of .015 mg/l Cu. Sprinkling continued in 1991 with the last of the effluent being discharged in September, 1991. A follow up study is recommended for 1992 in order to determine the long term stability of the copper.

Overall, the results of the monitoring program for the muskeg polishing system were disappointing from an academic stand-point, not because they showed the process to be ineffective, but because they could not prove quantitatively how effective the system was. The monitoring was however adequate from an operational perspective as it showed that discharge water quality objectives were achieved. Because muskeg polishing for mill effluent is a promising, new, and relatively poorly understood technology, the cost of additional sampling for research purposed would have been justified. If the cost of implementing an adequate monitoring program was considered an excessive expense for the company, Saskatchewan Environment should have considered covering the cost.

CONCLUSIONS

The post-project analysis of the Jolu Gold Mine addressed a large number of issues and concerns relating to the Environmental Impact Assessment (EIA) process, the quality of the Jolu Environmental Impact Statement, the accuracy of predictions made during the Jolu EIA process, and the effectiveness of mitigative measures applied. The following is a summary of the conclusions drawn from the study:

1) During this study, many interviews were conducted with people directly involved in the Jolu EIA process. The general opinion of all those interviewed including the project manager, the consultant who played a key

role in coordinating the EIA, a representative from Corona Corporation's head office, and representatives from the Mines Pollution Control Branch, was that the Saskatchewan process was manageable and effective, and needed very little if any modification.

2) The Project Specific Guidelines were generated by the government agencies that would be directly involved in the EIA review process. This insured that the Proponent was aware of the major issues of concern for all the agencies that would be reviewing the final EIS. Unfortunately, the Project Specific Guidelines were based on a very early and incomplete draft of the Project Proposal. No structured scoping process was employed during the drafting of the Guidelines. As a result, the Project Specific Guidelines were of limited value to the Proponent. In the future, a more detailed Project Proposal should be required prior to the drafting of Project Specific Guidelines, and a structured scoping process should be employed.

3) Clear and open communications between the Proponent and the regulating authorities were critical to the success of the Jolu EIA (Biles pers comm. 1991, Cooper pers. comm. 1991, Clifton pers. comm. 1991). Communication during the early stages of the design of the EIA helped to clarify the Project Specific Guidelines and develop a sound methodology for the Assessment. Open communication during the Technical Review Process was particularly useful as it allowed the Proponent to continue to work to improve the EIS during the lengthy time required for an inter-agency review.

4) Saskatchewan's Technical Review Process played a major role in improving the quality of the final EIS (Clifton pers. comm. '1991). Unfortunately, the Technical Review failed to identify problems in the EIS relating to clarity of presentation and overall integration of the information included in the EIS. To improve EIAs in the future, Saskatchewan Environment and Public Safety should consider expanding the Technical Review to include an evaluation of the overall quality of the EIS, the organization of the document, the clarity of the document (especially for laymen) and the integration of data presented in the EIS.

5) Although a public participation program was conducted for the Jolu EIA, the program did not generate much discussion on the potential biophysical effects of the Jolu mining operation. Information exchange concentrated almost entirely on employment opportunities. In the future, more emphasis should be placed on addressing biophysical issues during public consultation. This may be partly facilitated by expanding Technical Review Comments presented to the public by Saskatchewan Environment and Public Safety to emphasize the environmental consequences of proposed projects. The proponent should be required to address biophysical effects of the project in greater detail during presentations at public meetings.

7) The Jolu EIS could have been vastly improved if it had undergone a thorough final edit. At the end of the EIA process, the Proponent appears to have been concentrating on incorporating required changes, and apparently did not take the time to polish the final document. The Proponent should have taken the time to ensure that methodologies employed were clearly described throughout the document, that the document flowed well, that the scientific basis for predictions and the justification for selection of mitigative measures and alternatives were explicitly stated, and that the significance of data included in the document to the environmental impact assessment was explained.

8) As in many Environmental Impact Statements, there are very few quantified predictions of environmental impacts in the Jolu EIS. Because of the complexity of natural processes, there is usually a substantial degree of uncertainty in environmental impact prediction (Holling 1978, Hollick 1986). Both Holling (1978) and Hollick (1986) recommend adaptive environmental management approaches to deal with this uncertainty, suggesting that there should be less of an emphasis on prediction and more of an emphasis on monitoring and Imanagement. Although there was room for improvement in monitoring systems (conclusions #10 and #15), the management system at Jolu appears to have been effective at responding to unexpected impacts. The management. response to unexpectedly high concentrations of copper and cyanide in the Jolu tailings pond is a good example of how management can make up for uncertainties in impact prediction.

9) Bench tests and computer modeling conducted for the EIS did not accurately predict natural degradation rates of the tailings supematant. Static conditions in bench tests do not appear to adequately simulate the dynamic conditions in a tailings pond. Despite the unexpectedly low natural degradation rates, the Jolu management was able to ensure that no effluent exceeding regulated levels was ever discharged to the environment. The tailings pond was designed to hold all of the tailings for the entire first year's production giving the company ample time to solve the treatment problems prior to discharging any effluent. Although it may not always be feasible to design a tailings containment facility to hold an entire year's worth of tailings and supernatant, such a system provides management a great deal of flexibility and time to ensure that the treatment system is adequate to achieve dischargeable effluent quality.

10) Insufficient monitoring data exist to assess accurately the effectiveness of the Jolu Muskeg effluent polishing process. The results available do however suggest that muskeg may provide an inexpensive and effective process for polishing mill effluents. Further research is required in order to gain an understanding of the biological chemical and physical processes involved in wetland treatment processes. In the future, when such experimental processes are tested, monitoring programs should be established which are specifically

designed to measure the effectiveness of the experimental processes. Observations of the Mines Pollution Control Branch inspectors suggest that muskeg treatment may also be considered for sewage treatment at remote field facilities.

11) In the Jolu EIS, it was suggested that access roads be routed to avoid unique wildlife habitat. This was not done, as no “unique wildlife habitats” were identified in the EIS. The recommendation that groundwater be diverted to avoid contamination by tailings seepage was not practical and was not executed. Mitigative measures such as these which address ‘non-issues’ or which are not practical to employ should not be included in and EIS. Such recommendations in an EIS do not contribute constructively to the EIA process. They are misleading to the public and other reviewers, and may create additional liabilities for the Proponent if the Proponent does not apply the mitigations as suggested by the EIS.

12) The potential for fuel spills was not extensively addressed in the EIS. The operation did however experience chronic problems with small scale spills. A large scale fuel spill did occur, the impacts of which could possibly have been reduced if the company had been more diligent in inspecting fuel lines. Although no major impact was anticipated, the EIS should have been more thorough in proposing mitigative measures and inspection programs. Throughout the life of the Jolu operations, minor improvements were made in monitoring and mitigation programs to reduce the potential for both major and minor spills. Mitigative measures such as installation of automatic shut-off nozzles on fuel hoses and installation of oil absorbent booms and blankets in sumps which accumulated petroleum products should be considered for all future operations which utilize large volumes of fuel. Spill contingency plans should be properly established at the very beginning of operation.

13) The potential for problems with bears on the site as a result of domestic garbage disposal was not thoroughly addressed in the Jolu EIS. The garbage management program applied was not effective at preventing problems with black bears on the site. The garbage was burned and buried periodically, but not frequently enough to prevent bears from being attracted to the site. Problems with bears related to domestic garbage disposal are not unique to the Jolu Operation, but there do not as yet appear to be any standard and effective mitigation methods applied at northern camps to prevent these problems. Research is required to try to find more effective garbage disposal methods which may reduce conflicts with bears at remote northern camps.

14) During the Jolu EIA, it was predicted that the tailings may have acid generating capacity. Permanent subaqueous containment of the tailings was recommended and employed in order to eliminate the potential for acid generation. Because acid mine drainage is such a serious environmental

hazard, and because it is extremely difficult to control acid drainage once it has been initiated, subaqueous deposition of the Jolu tailings was considered to be the safest option. During the operation of the mine, it was determined that the tailings were not acid generating. Because Mallard Lake provided an inexpensive option for subaqueous deposition, the inaccuracy in the predictions was not a serious economic burden. Apart from the loss of Mallard Lake as a natural aquatic system, no serious environmental impacts resulted from the use of Mallard Lake as the tailings pond site.

15) During the analysis of accuracy of impact predictions, several problems were encountered as a result of incompatibility in monitoring data, predictions, and baseline data. For example, Whitefish were sampled during baseline fish flesh analyses, while Northern Pike and White Suckers were sampled during two subsequent follow up studies. During the analysis of the effectiveness of the muskeg effluent polishing process, monitoring data were inadequate to distinguish between the effects of dilution from fresh water drainage and the effects of the physical, biological and chemical processes in the muskeg. When attempting to analyze toxicity of downstream lake water as a result of effluent discharge, it was found that free cyanide,, the critical factor in determining cyanide toxicity, was not measured.

Such problems in analysis of data are encountered because of a lack of consideration of how the data are to be used following their collection. During the Jolu EIA program, details of the monitoring programs were not addressed. These were addressed in detail in the operating permits. This resulted in a lack of coordination between data collected for baseline studies and monitoring data required for permits. In the future, either monitoring programs should be designed during the EIA process, or more care should be taken in designing permit requirements to ensure that baseline and monitoring data are be compatible.

16) The majority of the mitigative measures applied at the Jolu site were effective. No serious impacts were recorded from construction activities, increased access to hunting and fishing areas, transportation or storage of process chemicals, sewage disposal, or acid generation from tailings or waste rock piles. Effluent discharged from the tailings area met required standards throughout the operation without exception. The fact that the Jolu mining operation progressed without any major unexpected impacts is an indication that the Environmental Impact Assessment Process was effective.

17) During the Jolu environmental management program, two mitigative measures stood out as being particularly effective at reducing the environmental impacts of the operation (Cooper pers. comm. 1991). The mill process water recycling system contributed very significantly to the reduction of effluent which had to be treated and discharged to the environment. Discharge of compressor cooling water directly to the environment rather

than to the tailings pond also contributed significantly to the reduction of effluent volume. These mitigation methods should be considered for future mine developments.

REFERENCES CITED

Barsi, R.G., 1991, Director Mines Pollution Control Branch, Saskatchewan Environment and Public Safety, Prince Albert Saskatchewan, pers. comm..

Beanlands, G.E. and P.N. Duinker, 1983, An Ecological Framework for Environmental Impact Assessment in Canada, Institute for Resource and Environmental Studies, Dalhousie University, Published in Cooperation with Federal Environmental Assessment Review Office, 132 pp.

Bell, A.V., 1987, "Prevention of Acid Generation in Base Metal Tailings and Waste Rock",, in Acid Mine Drainage Seminar/Workshop, Nova Scotia, March 23 to 26.

Berkes, F.,1988, "The Intrinsic Difficulty of Predicting Impacts: Lessons from the James Bay Hydro Project", Env. Imp Assess. Rev. vol. 8, p. 201-220.

Biles, G., 1991, General Manager, Jolu Gold Mine, International Corona Corporation,, pers. comm..

Bishop, A.B., M. Mckee, T.W. Morgan and R. Narayanan, 1976, "Multi-objective Planning: Concepts and Methods", Proceedings of the ASCE, Journal of Water Resources Planning and Management Division vol. 102, p. 239-254.

Bonnicksen, T.M. and R.H. Becker, 1983, "Environmental Impact Studies: And Interdisciplinary Approach for Assigning Priorities", in the Journal for Environmental Management vol. 7, p. 109-117.

Bres, A.F., in preparation, Post-project Analysis: A Case Studv of the Environmental Impact Assessment and Environmental Management Program of the Jolu Gold Mine, Master's Degree Project, Faculty of Environmental Design, The University of Calgary.

Canadian Environmental Assessment Research Council, 1988, Evaluating Environmental Impact Assessment: An Action Prospectus, Minister of Supply and Services Canada, 7 pp.

Clifton Associates Ltd., September 1986, "Program to Complete Environmental Impact Assessment: Mallard Lake Project", Mahogany Minerals Resources Inc. internal document, 10 p.

Clifton Associates Ltd., December 12 1986, "Preliminary Siting Study: Waste Management Area, Jolu Project", conducted for Mahogany Minerals Resources Inc., Mallard Lake, Saskatchewan, 43 p.

Clifton, W., 1991, Clifton Associates, Regina, Saskatchewan pers. comm..

Cooper, L., 1991, Acting Manager Potash and Coal Section, Mines Pollution Control Branch, Saskatchewan Environment and Public Safety, Prince Albert Saskatchewan, pers. comm..

Davies, M., and B. Sadler, May 1989, Environmental Monitoring and Audit: Guidelines for Post Project Analysis of Development Impacts and Assessment Methodology, prepared for Environment Canada and Transport Canada.

Dee, N., J. Baker, N. Drobney, K. Duke, I. Whitman, and D. Fahringer, 1973, "An Environmental Evalulation System for Water Resource Planning", Water Resources Research vol. 9, p. 523-535.

Economic Commission for Europe Task Force on EIA Auditing, 1990, Post-project Analvsis in Environmetnal Impact Assessment: An Analvsis of European and North American Case Studies, United Nations, New York.

Environment Canada, 1987, Canadian Water Quality Guidelines, prepared by the Task Force on Water Quality Guidelines of the Canadian Council of Resource and Environment Ministers, Ottawa, Ontario.

Herrero, S., June 10 1983, Submission to C.P. Rail Rogers Pass Development Project Environmental Assessment Panel, Public Meetings, vol. IIIA, p. 113-121.

Hollick, M., 1981, "The Role of Quantitative Decision-making Methods in Environmental Impact Assessment", in the Journal of Environmental Management, vol. 12, p. 65-78.

Hollick, M., 1 986, "EIA: An International Evaluation", Environmental Management vol. 7 0, pp. 157-178.

Holling, C.S.,, 1978, Adaptive Environmental Assessment and Management, Wiley, New York, 377 pp.

Kazakoff, J., 1991, Mill Superintendent, Jolu Mining Operation, International Corona Corporation, pers. comm..

Leopold, L.B., F.E.'Clarke, B.B. Hanshaw and J.R. Balsley, 1971, A Proceedure for Evaluating Environmental Impact, Geological Survey Circular 645, USGS 13 pp.

Letourneau, C. and J. Castonguay, September 1988, Use of Biological Indicators for Evaluating Environmental Stress, Atomic Energy Contra Board Report, Ottawa, Canada.

MacLaren, J.W., 1985, "Setting the Stage", an introduction to Audit and Evaluation in Environmental Assessment and Management: Canadian and International Experience Vol. 1., Environment Canada.

McAllister, D.M., 1980, Evaluation in Environmental Planning, MIT Press, Cambridge, 308 pp.

McHarg, I., 1969, Design With Nature, Doubleday, Garden City, New York, 197 pp.

Munro, D.A., 1985, "Learning from Experience: Auditing Environmental Impact Statements", in Environment Canada, Audit and Evaluation in Environmental Assessment and Management: Canadian and International Experience Vol. 1.

Ortolano, L, B. Jenkins, and R.P. Abracosa, 1987, "Speculations on When and Why EIA is Effective", Environmetnal Impact Assessment Reveiw, vol. 7, p. 285-292.

Pearce, D.W. 1976, "Measuring the Economic Impact of Environmental Change", in T. O'Riordan and R. Hey (eds), Environmental Impact Assessment, Saxon House, Farnborough.

Ross, W.A.,1987, "Evaluating Environmental Impact Statements", Journal of Environmental Management, vol. 25, p. 137-147.

Ross, W.A. and CD. Tench, September 1987, Canadian Pacific Rail Rogers Pass Development: A Post-project Analysis, prepared for Environment Canada.

Royex Gold Mining Corporation, 1988, Environmental Impact Assessment for the Jolu Gold Mining Operation, five volumes.

Saskatchewan Environment, July 1985, "Project-Specific Guidelines for the Preparation of an Environmental Impact Statement: Mahogany Mineral Resources Inc. Proposed Mallard Lake Gold Development" (Received from MPCB).

Saskatchewan Environment and Public Safety, February 1988,'Technical Review Comments on the Environmental Impact Statement for the proposed Mallard Lake (Jolu Project) Gold Development", 7 pp.

Saskatchewan Environment and Public Safety, August 1990, The Future of Environmental Assessment in Saskatchewan: A Discussion Paper on the Environmental Assessment and Review Process.

Saskatchewan Environment and Public Safety, August 1990b, Supporting Documents for 'The Future of Environmental Assessment in Saskatchewan', 31 pp.

Gormely Process Engineering, T.W. Giggs Associates Ltd., R.U. Kistritz Consulting Ltd., A. Sobolewski, November 1990, Assessment of Wetlands for Gold Mill Effluent Treatment, prepared for Saskatchewan Environment and Public Safety, Mines Pollution Control Branch.

Saskatchewan Parks and Renewable Resources, 1986, Mercury in fish: Guidelines for Consumption.

Sinclair, L., 1991, Acting Manager Technical Service, Mines Pollution Control Branch, Saskatchewan Environment and Public Safety, Prince Albert Saskatchewan, pers. comm..

Smith, E.J., I_. Sykora and M.A. Shapiro, 1973, "Effect of Lime Neutralized Iron Hydroxide Suspensions on Survival, Growth and Reproduction of the Fathead Minnow", J. Fish. Res. Bd. Can. 30:1147-1153.

Sykora, J.L., E.J. Smith, M.A. Shapiro and M. Synak, "Chronic Effects of Ferric Hydroxide on Certain Species of Aquatic Animals", In Procedings of the 4th Symposium on Coal Mine Drainage Research, Mellon Institute, Pittsburgh, Pennsylvania, p. 347-369.

Thomas, E.N., and J.L. Schofer, 1970, Strategies for the Evaluation of Alternative Transportantion Plans, National Co-oparative Highway Research Progress Report 96, Highway Research Board, Washington, 11 lp.

U.S. Council on Environmental Quality, 1978, Regulations for Implementing Procedural Provisions 'of the National Environmental Policy Act, Federal Register 43, 55978-56007.

U.S. EPA, 1988, Ambient Water Quality Criteria for Nickel, Criteria and Standards Division, U.S. Environmental Protection Agency, Washington, DC., EPA-440/5-80-060.

U.S. EPA, 1985a, Ambient Water Quality Criteria for Copper - 1984, Criteria and Standards Division, U.S. Environmental Protection Agency, Washington, D.C., EPA-440/5-84-031.

U.S. EPA, 1985b, Ambient Water Quality Criteria for Cyanide - 1984, Criteria and Standards Division, U.S. Environmental Protection Agency, Washington, DC., EPA-440/5-84-028.