THE MANAGEMENT OF IMPACTS ON AQUATIC RESOURCES
AT NEW MINE DEVELOPMENTS IN BRITISH COLUMBIA

by

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This thesis evaluates the analytical methods and review procedures used for assessing the impacts on aquatic resources from metal mines in British Columbia. The specific objectives are to evaluate the effectiveness of pre-development assessment studies for anticipating eventual impact management problems, to evaluate analytical weaknesses in the pre-development studies; and, to develop recommendations for improving the methods and procedures currently used for impact management planning.

To evaluate the effectiveness of pre-development studies, impact management problems were reviewed for fifteen mines. Pre-development reports submitted by the mine proponents before mine production began were then reviewed to determine to what extent the problems had been anticipated. Twenty-four problems were identified amongst eight mines. Pre-development assessments anticipated 18 of the eventual problems. The relative seriousness of the problems varied considerably. The most serious problems were related to the routine discharge of material (cyanide and metals at gold mines) and to a site-runoff problem (the generation of acid in waste rock at one sulphide ore mine). However, the most common problems (46%) were associated with equipment and structural failures, mainly tailings facilities (i.e. lines, pumps, and dams). The pre-development assessments were generally more effective for identifying problems related to routine discharge sources and to general site runoff than to the more common equipment and structural failures.

To evaluate the analytical methods used in the pre-development studies, the following factors were examined: the apparent influence of government guidelines and procedures; the theoretical weaknesses in the
methods used; and, the improvements to analytical methods suggested in recent government Terms of Reference (TOR's). In addition, the types of information and methods used in monitoring and follow-up studies were examined for comparison with the pre-development studies. The approaches and methods used in Stage I studies have been strongly influenced by the 1979 "Procedures" prepared by the B.C. Ministry of Energy, Mines and Petroleum Resources. The Procedures recommend a checklist of topics to address but provide poor guidance on how impact analyses are to be used for developing impact management measures. The more recent site-specific TOR's are, in a sense, pre-assessments of potential sources of effect. The TOR's request more detailed information than generally presented in previous reports submitted by mine proponents. The main analytical weaknesses are: the unclear relationship between the management plans and monitoring programs and the specific resources at risk; and, the absence of critical appraisals of impact management measures, in order to develop a fall-back strategy in the event that the chosen measure is found to be inadequate.

Recommendations include: the development of an early and explicit description of the linkages expected between a particular mine and important resources; the preparation of alternate or "fall-back" measures that would be implemented in the event that the chosen methods did not work; the preparation by government agencies of the types of information required to develop effective contingency plans; and, the clear separation of information intended to describe important resources from that which is quantitative baseline data to be used during follow-up monitoring and assessments. Opportunities are identified for the mining industry to undertake a stronger role in the development of analytical standards for impact assessment, both to absorb some of the costs of developing
assessment procedures and to increase understanding amongst proponents as to the kind of analytical and impact problems that exist.
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CHAPTER 1.0 INTRODUCTION

Mining represents a large and diverse natural resource industry in British Columbia. Although the mining industry makes a substantial contribution to the provincial economy, it also has the potential to cause serious adverse impacts on the natural environment, particularly to aquatic ecosystems (Clarke 1974; Ripley et al. 1978; Marshall 1982).

The government of British Columbia has responded to the threat of environmental damage from mining operations by instituting processes by which mine development can be reviewed prior to government approval. Proposals to develop metal hardrock mines and coal mines are reviewed by the Mine Development Review Process (MDRP). Other types of mining activity, in particular metal mines and coal mines that are in the exploration phase and placer gold and sand/gravel operations, are reviewed by other review processes. Placer gold applications are reviewed by Regional Placer Coordinating Committees. Metal and coal mines in the exploration phase and sand/gravel operations are examined by means of interagency referrals. Applications by metal and coal mines to alter or expand activities once operations begin are examined by interagency referral, if the changes are relatively minor, or by the MDRP, if the changes are major.

The MDRP requires the proponents of metal and coal mines to undertake environmental impact assessment (EIA) and to submit reports indicating the results of the EIA studies. The EIA reports are reviewed by various government agencies, and the reports, together with agency comments, are used by the provincial government to determine whether a proposed mine development should be approved, modified or rejected.
1.1. Nature of the Problem

Recently, a common criticism of review processes for environmental impact assessment has been that well-defined institutional procedures are developed without fully considering the scientific and analytical requirements for conducting the assessments (e.g. Munn 1979; Beanlands and Duinker 1983; Rosenberg et al. 1981). This situation is felt to be one of the major factors leading to the generally poor quality of impact assessment studies. In B.C., impact assessments are now routinely submitted by metal mine proponents, but environmental problems still occur, particularly in relation to nearby aquatic resources. A systematic study has not been undertaken to examine the nature of these problems and the reasons why pre-development studies were not effective for preventing them.

1.2 Purpose and Objectives

This thesis evaluates the methods and procedures used for assessing the impacts on aquatic resources from metal (hardrock) mines in British Columbia. The specific objectives are:

a) to evaluate the types of impact management problems that have occurred, and the effectiveness of pre-development assessment studies for anticipating them;

d) to evaluate the analytical weaknesses in the methods and procedures used for pre-development impact assessment studies; and,

c) to develop recommendations for improving the methods and procedures currently used for impact management planning.

1.3 Approach

The study has been conducted in four steps. The first step was a review of the provincial EIA review process for new metal mine development (Chapter 2.0) and of the theoretical concepts and methods that can be used for EIA (Chapter 3.0). The review of the provincial process was undertaken to examine the institutional framework within which impact management
strategies are developed. The review of EIA concepts and methods was undertaken to determine what analytical tools are available for assessing impacts from new mine developments.

The second step was an assessment of the effectiveness of impact management strategies presented in pre-development reports (Chapter 4.0). Firstly, the literature describing the impacts of metal mines on aquatic resources was reviewed. Secondly, recent impact management problems at metal mines that have entered the provincial review process were identified. The problems were identified through discussions with personnel at the mining companies and in government agencies. Thirdly, the pre-development impact assessments prepared by the mine proponents and submitted to the provincial government were examined to identify what problems had been anticipated.

The third step was a detailed examination of the analytical methods that are used in pre-development studies to develop the impact management strategies (Chapter 5.0). Given the evolutionary nature of the B.C. review process and the requirements for doing impact assessments, three factors were considered during this step. The first was the influence of government guidelines and procedures; the second was the possible weaknesses in methods used by the analysts working for the mine proponent; and, the third was the improvements evident in site specific terms of reference that are now prepared by provincial review agencies.

The fourth step was the development of recommendations (Chapter 6.0), based on the results obtained during the earlier steps, for improving the analytical methods and review procedures used to develop impact management plans.

1.4 Scope of the Study

The study has been limited to analysis of impacts and impact
assessment methods as applied to aquatic resources and in particular, fisheries resources. Aquatic resources have been chosen for specific study:

a) so that a single component of reports submitted by mine proponents can be used as a consistent and manageable focus for analyzing a large number of proponent reports; and,

b) because, in terms of environmental damage generally attributed to the mining industry, many of the effects impinge either directly or indirectly on the aquatic environment (Ripley et al. 1978).
CHAPTER 2.0  THE INSTITUTIONAL FRAMEWORK FOR MANAGING IMPACTS FROM NEW MINE DEVELOPMENT

This chapter provides a review of the nature and evolution of the institutional framework for managing impacts from new mine development in British Columbia. The requirements of agencies responsible for managing impacts on aquatic resources are emphasized. The review is necessary to understand how changes in institutional requirements have influenced the analytical methods used in pre-development impact assessment studies. Pre-development studies are examined in detail in Chapters 4.0 and 5.0.

The provincial review process for new mine development is described in section 2.1, and the requirements of provincial and federal agencies responsible for protecting the aquatic environment are described, respectively, in subsections 2.2 and 2.3.

2.1 The Provincial Mine Development Review Process

The review process for the mining industry in British Columbia has been evolving since the mid 1970's, within the framework of the broader provincial review process for new project development. An overview of the general provincial review process is presented below, and is followed by a description of the evolution, structure and requirements of the Mine Development Review Process (MDRP).

2.1.1 The General Provincial Review Process for New Project Development

Basically, the government of British Columbia has adopted a "staged, flexible assessment process" for examining potentially significant impacts from new projects (O'Riordan 1981). This process allows the government to appraise the impacts from a proposed project in stages, as the project evolves from a general project description to an advanced engineering design.

The decision-making framework for approving or rejecting proposals
submitted for review is based on provisions of the Environment and Land Use Act (1971). Under this legislation, a committee of selected Cabinet members (the Environment and Land Use Committee) has been established as the decision-making body. The Environment and Land Use Committee (ELUC) is presently comprised of the ministers of:

- Environment (Chairman)
- Agriculture
- Industry and Small Business Development
- Energy, Mines, and Petroleum Resources
- Forests
- Lands, Parks and Housing
- Municipal Affairs
- Transportation and Highways

A second committee, the Environment and Land Use Technical Committee (ELUTC), comprised of deputy ministers from the same ministries listed above, reports to ELUC on the policy implications of technical issues (O'Riordan 1981). The chairman of the ELUTC is the Deputy Minister of the Ministry of Environment.

In addition to the broad environmental impact review process that has been established under the Environment and Land Use Act, environment and land use concerns from proposed projects are also subject to review by individual regulatory agencies (e.g., the Waste Management Branch of the Ministry of the Environment) responsible for the issuance of various approvals, permits and licenses. The separate review by a regulatory agency is authorized by the appropriate legislation covering that agency (e.g., activities of the Waste Management Branch are authorized by the Waste Management Act, formerly the Pollution Control Act). Generally, reviews by the regulatory agencies incorporate a referral process such that applications from development proponents are referred for comment to other agencies, including those in other levels of government, who might have an interest in the applicant's proposed activities.

The intent of the broader review process is not simply to add a more complex process to the separate regulatory review processes, but is to
provide a mechanism for conducting a comprehensive review of projects that will likely have a number of possible concerns relating to potential impacts.

2.1.2 Evolution, Structure and Requirements of the Mine Development Review Process

As indicated above, the MDRP has evolved its own procedures within the framework of the broader provincial review process. The evolution of the review procedures has also been influenced by complex interactions amongst interested groups. These include the interests of politicians and technical staff at different government levels (local, provincial, and federal), representatives of the mining industry, and different groups within the general public (R. Crook pers. comm.). Initially, coal mines were reviewed by the Coal Guidelines Review Process and metal mines were reviewed by the Metal Mines Guidelines Review Process. Review requirements were outlined in the "Guidelines for Coal Development" (ELUC 1976), for coal mine proponents, and in the "Procedures for obtaining Approval of Metal Mine Development" (Ministry of Energy, Mines and Petroleum Resources 1979), for metal mine proponents. In March 1984 the ELUC outlined a set of principles for consolidating the coal and metal mine review processes to form the MDRP. Based on the ELUC principles, a new combined procedures manual is to be produced. An outline of the current review process is shown in Figure 2-1. The review stages and report requirements and the composition and activities of the government review committees are outlined below.

2.1.2.1 Review Stages and Reports

Review of a mine is comprised of a preliminary stage, whereby the proponent can initiate the review by providing a Letter of Intent or a Prospectus, and two or three further stages depending on project complexity. Projects must proceed to Stage I unless they are very small and straightforward (such as small pilot-scale activities) and would be
Figure 2.1 Flowchart and report requirements of the Mine Development Review Process. (Source: adapted from MacDonald 1984; R. Crook pers. comm.)

FLOWCHART FOR REVIEW PROCESS:

Committee which may be involved at each stage
Mine Development Steering Committee

Stage I Report
- Project Rejection
  - Simple Project - Fast Track
  - Complex Project - Full Review

Stage II Report
- Acceptance of Stage II Report
- Project Approval - In-Principle
- Project Approval - Full Review
- Public Hearing: Other

Stage III
- Mining Operations
- Public Hearing

Committee which may be involved at each stage
MOSC | Depends if complex project
ELUC | simple or complex project

Regulatory Agencies

Content of Submissions:

—Prospectus:
  • conceptual mine project description
—Stage I report:
  • preliminary project description
  • preliminary impact assessment
  • issue identification
—Stage II report (if required due to major impacts):
  • detailed project description
  • detailed assessment of selected impact concerns
  • impact management
—Stage III
  • applications for individual licences and permits
    (applications can be submitted prior to Stage III, but permits will only be issued at Stage III)
unnecessarily impeded by the larger process (R. Crook pers. comm.). Mine projects felt by review committees to have complex issues must go through Stage II of the process. All projects must obtain relevant regulatory permits in Stage III. Mine proponents must submit one or two formal reports describing the potential effects of the mine development. A preliminary assessment is required for Stage I and, if necessary, a more detailed assessment is required for Stage II. As shown in Figure 2-1, a decision is made at the end of Stage I to approve-in-principle, to reject, or to defer the approval-in-principle decision to the end of Stage II. The decisions at the end of Stage I are made either by the Steering Committee (for simple, non-controversial projects) or the ELUC or ELUTC (for complex or controversial projects). The approval-in-principle is required before a project can proceed to Stage II and/or Stage III.

2.1.2.2 The Review Committees

The 1979 "Procedures" indicate that the previous review process consisted of a main Steering Committee, and several working committees that examined, as necessary, specific aspects of each mine proposal. The working committees were the Minesite Technical Committee, the Mine Housing Committee, the Environmental Impact Assessment Committee and the Economic Evaluation Committee. However, by 1983 there were only two working committees used in practice: the Steering Committee and the Socio-economic Coordinating Committee (R. Crook, pers. comm.).

The new combined review process is comprised of a steering committee, the Mine Development Steering Committee (MDSC), and two working committees, the Mining and Environmental Technical Committee (METC) and the Socio-Economic Technical Committee (SETC). The working committees are basically the former Minesite Technical Committee and Economic Evaluation Committee, respectively. The METC and SETC have not been used for the last two years given the relatively straightforward nature of recent projects, but
nonetheless are available to review issues at complex projects should the need arise.

Ministries represented in the MDSC include:

- Energy, Mines and Petroleum Resources (Chairman)
- Environment
- Municipal Affairs
- Industry and Small Business Development
- Transportation and Highways

Of the two working committees, the METC is the more concerned with impacts on the aquatic environment. Membership in the METC is open to all Ministries having a mandate for protecting biophysical resources and includes the Ministries of:

- Energy, Mines and Petroleum Resources (Chairman)
- Environment
- Lands, Parks and Housing
  - Parks Branch
  - Lands Branch
- Forests
- Agriculture and Food
- Transportation and Highways
- Provincial Secretary and Government Services
  - Heritage Conservation Branch

Depending on the nature and location of a project, other agencies might be consulted. A full circulation of project information for review would include 14 provincial ministries, four federal departments (Environment, Fisheries and Oceans, Indian and Northern Affairs, and Energy, Mines And Resources), and all relevant regional and municipal governments (R. Crook pers. comm.).

Since 1984, the Prospectus or Letter of Intent supplied by each mine proponent has used by the Steering Committee to develop site-specific terms of reference for the Stage I report. The review of potential effects on fisheries and other aquatic resources is undertaken primarily by the Ministry of Environment. The Chairman of the Steering Committee might also request comments from the federal Departments of the Environment and Fisheries and Oceans. Within the Ministry of Environment, the Prospectus is circulated by a
Mines Coordinator (in the Planning and Assessment Branch) to appropriate branch offices. For assessment of possible impacts on aquatic resources this would include the Fisheries Branch, Water Management Branch and Waste Management Branch. Using comments received from the head and regional offices, the Mines Coordinator forwards review comments to the chairman of the Steering Committee.

2.2 Requirements of Provincial Regulatory Agencies

After a mine has passed through Stages I and/or II, it must still obtain permits or licences from regulatory agencies in Stage III. Three of these requirements (Waste Management Permits, Water Licences and Reclamation Permits) are of particular importance in relation to controlling effects on water resources. These permitting requirements are briefly described below.

2.2.1 Waste Management Permits and Approvals

By means of the Waste Management Act (formerly the Pollution Control Act), the provincial Waste Management Branch (formerly the Pollution Control Branch) approves or permits the discharge of effluents. To obtain a permit or approval, an applicant must supply information concerning the type, characteristics, and quantity of the effluent and other information that the Director, or a regional manager, of the Waste Management Branch might require. Additional information might be requested at the time application is made or at the end of the review.

In order to establish effluent standards for the industry as a whole, with respect to permit requirements, and to identify what pollution control measures should be imposed, the provincial government has held two public inquiries. The first public inquiry was held by the Pollution Control Branch in 1972 to determine what measures should be adopted by the mining, mine-milling and smelting industries for the control of discharges to water, land and air (Pollution Control Branch 1973). The results of the inquiry were
used by the Branch to develop a set of minimum objectives for effluent discharge by the industry.

The second inquiry was held in 1978, to review the objectives presented in 1973, with respect both to experience gained in the application of the earlier objectives and to technical and environmental information that had evolved over the intervening period. The results of this inquiry were published by the Pollution Control Board as a new document, the "Pollution Control Objectives for the Mining, Smelting and Related Industries of British Columbia 1979".

The 1979 "Objectives" indicate that pre-operational studies and long-term monitoring programs might be required prior to issuance of permits:

"Prior to commencement of new discharges or changes to existing discharges, studies may be required to include a comprehensive examination of site suitability, baseline documentation of physical and chemical parameters, a biological resource inventory and detailed impact predictions. Long-term monitoring of parameters specified in discharge permits (legal standards) may be required. Responsibility for compliance and for provision of data supporting compliance rests with the permit holder"

2.2.2 Water Licences and Approvals

Water licences are issued by the Comptroller of Water Rights, subject to the terms and regulations of the Water Act. The licences are issued to, amongst others, "an owner of land or a mine". Approvals, without issuance of a licence, can be made by the Comptroller for the short-term (less than 6 months) diversion or use of water. Applications for a water licence must contain information on the quantity and purposes of waters to be used and a description of the land, mine or premises where the water is to be used.

2.2.3 Reclamation Permits

The Mines Act 1980 (formerly the Mines Regulation Act) states that "a program for the protection and reclamation of the surface of the land and watercourses affected by the mine in a form and containing the information"
the minister may require before commencing preparatory work for production from a mine" must be filed with the Ministry of Energy Mines and Petroleum Resources. The reclamation permit is particularly important for regulating non-point sources of pollution, such as general site runoff.

2.3 Requirements of Federal Agencies

Although the British North America Act 1967 has placed the ownership of land, including overlying water, in the right of the provinces, the Parliament of Canada has legislative authority over sea coasts and inland fisheries. For the boundary of provincial-federal ownership in coastal areas, the provincial crown land extends to the low water mark and federal land extends beyond the low water mark to the seaward territorial limit. In British Columbia, the responsibility for protecting fish and fish habitat is shared with the provincial government. The provincial government is responsible for the freshwater species (and anadromous trout) and the federal government is responsible for the marine and most anadromous species. Therefore, the federal government has a direct interest in the effects of waste discharge on both the marine and freshwater environments, particularly in relation to the manner in which the waste discharge might affect the management and protection of fish and fish habitat. Federal legislation concerned with the effects of waste discharge on the water environment in B.C. include, principally, the Canada Water Act, the Fisheries Act and the Ocean Dumping Control Act.

Because the federal government has a direct interest in the potential impacts of mine development on aquatic resources, federal environmental and fisheries agencies, such as the Environmental Protection Service (Department of the Environment) and Department of Fisheries and Oceans, are included in provincial permitting procedures, by referral, or, in the case of Ocean Dumping Permits, can become key review agencies. In the event that a particular development activity, including mine development, produces a
pollutant in sufficient quantity to cause serious harm to fish or fish habitat, the federal Fisheries Act contains provisions by which legal action can be taken and fines levied.

Just as the Waste Management Branch of the provincial government has developed effluent standards or objectives, for discharges from the mining industry, the federal government has also developed standards or objectives. In 1977, the federal Environmental Protection Service (Department of the Environment) published a document entitled "Metal Mining Liquid Effluent Regulations and Guidelines". In fact, the publication is a small compendium of extracts from the Canada gazette, augmented with additional explanatory notes and a Code of Practice for Mines. The extracts from the Canada Gazette are:

- Metal Mining Liquid Effluent Regulations
- Guidelines for the Control of Liquid Effluents from Existing Metal Mines
- Guidelines for the Measurement of Acute Lethality in Liquid Effluents from Metal Mines

In some cases, such as the marine disposal of tailings, the regulations might not be applied. Based on recommendations by the Minister of Environment and Minister of Fisheries, an Order-in-Council was approved in 1979 allowing Amax of Canada Ltd. to deposit tailings directly into marine waters. A provincial Pollution Control Permit was subsequently issued.

2.4 Summary

The government of British Columbia has adopted a staged process for reviewing metal mine developments. Effects on aquatic resources are assessed in reports submitted by mine proponents and reviewed by government committees. A preliminary assessment is required during Stage I and a detailed assessment is required if a mine must enter Stage II. The Stage I and/or Stage II studies are used by regulatory agencies as the basis for issuing permits and licences at Stage III.
CHAPTER 3.0 THE THEORETICAL CONCEPTS AND METHODS AVAILABLE FOR IMPACT ASSESSMENT

This chapter provides a review of the concepts and methods that are available for undertaking pre-development impact assessments. The review is used as the basis for developing criteria used in Chapter 5.0 to evaluate analytical weaknesses in pre-development impact statements submitted by mine proponents. A review of the analytical concepts and methods described in the Environmental Impact Assessment (EIA) literature is presented in section 3.1. The analytical features that could be included in pre-development studies undertaken by mine proponents, within the context of government submission requirements (described in Chapter 2.0), are outlined in section 3.2.

3.1 Analytical Concepts and Methods described in the EIA Literature

In 1969, the United States government passed the National Environmental Policy Act (NEPA), which requires all federal agencies to assess the environmental impacts of proposed projects. Following the lead of the United States government, other governments, including the federal and most of the provincial governments of Canada, have instituted similar requirements. Consequently, since 1969, a large number of strategies and methods on how environmental impacts should be assessed have been put forward. The concept of EIA, the weaknesses in the traditional approaches, and the current theories for improving EIA studies are described below.

3.1.1 The Concept of EIA

EIA has been broadly defined as "an activity designed to identify and predict the impact on the biogeophysical environment and on man's health and well-being of legislative proposals, policies, programmes, projects and operational procedures, and to interpret and communicate information about
the impacts" (Munn 1979). In addition, Munn states that the environmental and related social aspects of new proposals should be considered early in the formulation of new proposals and should be included throughout the entire planning process. This means that to be an effective component of project planning, EIA must be integrated with engineering and economic assessments, not simply added once the other assessments have been completed.

Warner and Preston (1974) state that an EIA must deal with four problem areas:

- Impact identification
- Impact measurement
- Impact interpretation
- Impact communication to information users

To address these problem areas, Lang and Armour (1977) suggest that an EIA should contain, as a minimum, the following seven components:

1. Project Description
2. Environmental Inventory
3. Environmental Effects
4. Evaluation of Effects
5. Mitigating Actions
6. Alternatives
7. Presentation

Note that Lang and Armour and other authors (Munn 1979; Dooley 1979) distinguish between environmental "effect" and environmental "impact". Environmental effect is defined as a man-induced environmental change and environmental impact is defined as a change in environmental quality, with usage of word "impact" implying that a value judgment has been made on the importance of an environmental effect or change to people (Munn 1979).

### 3.1.2 Weaknesses in the Traditional Approaches to EIA

The quality of EIA studies has been regularly criticized since the start of the formal EIA review processes. In reference to the general approach used for EIA in Canada, Beanlands and Duinker (1983) state that "the so-called 'shotgun' approach has prevailed, with comprehensive but
superficial coverage of all elements of the environment, regardless of their relevance to project decisions". Based on a review of more than 30 EIA's from across Canada, Beanlands and Duinker concluded that "predictions were commonly vague, of questionable value both for decision-making and for studies to test them". The criticism that EIA reports are excessively lengthy and filled with irrelevant detail has also been made by other authors (Schindler 1976; Caldwell 1978; Ward 1978; Cole 1979).

Rosenberg et al. (1981) also conducted a detailed review of recent EIA studies. In conclusion, they listed what they felt to be the main weaknesses of EIA based on a review of more than 40 documents for EIA's conducted around the world (note that all but two involve locations in North America). These are: "tokenism"; unrealistic time constraints; uncertainty of program or development schedules; difficult access to EIA literature; questionable ethics; lack of coordination amongst studies; poor research design.

3.1.3 Current Theories for an Improved Approach to EIA

The EIA literature stresses the need for the following features to improve the quality of analyses:

- the early conceptualization of interaction between a project and the environment;
- the identification of important resources at risk;
- the application of scientific and ecological principles;
- the development of clear criteria for interpreting impact significance; and,
- the recognition that impact assessment is an on-going and adaptive process.

These concepts are briefly discussed below.

3.1.3.1 The Early Conceptualization of Interaction Between a Proposed Project and the Environment.

Preparation of a conceptual framework that shows how the components of a proposed project are expected to interact with components of the surrounding environment has been recommended as an early step in the design of EIA studies (Holling 1978; Munn 1979; Beanlands and Duinker 1983). The
exercise can be made simple or complex, depending on the amount of information available and on the wishes of the assessor. Regardless of the degree of complexity, at least some information will be required with respect to both the proposed project and the environment. Beanlands and Duinker (1983) feel the early use of such a conceptual framework would have the following advantages for the design of ensuing studies:

"a) a separation of the project into manageable parts;  
b) a focus on the nature and the source of the perturbation;  
c) the early establishment of time and space boundaries;  
d) a recognition of the valued ecosystem components within the assessments;  
e) logical progression from physical-chemical components to biotic components;  
f) the consideration of functional relationships wherever possible; and  
g) a recognizable format within which to present the study results."

When sufficient information is available, the conceptual models that are produced can be refined so that selected impact scenarios can be analyzed by use of computer simulations (Holling 1978; Munn 1979).

3.1.3.2 Identification of Important Resources at Risk

A given environment consists of a large number of species or components that could be studied, but only a small number of species or components are likely to be considered of direct value to society. Dooley (1979) suggests that the extensiveness or scope of assessments will be specified by regulation or review process, and that the concerns and attitudes of special interest groups and the general public might be useful for the eventual identification and interpretation of impacts. The identification (or "social scoping") of socially important components of the environment is felt to be a necessary step early in the assessment process in order to focus study effort (Beanlands and Duinker 1983). Simply stated, information on environmental components that are felt to have the greatest social value, and whose loss or impairment are of greatest concern to society, will have
greater relevance for the decision maker and public-at-large that information on other components (Munn 1979; Beanlands and Duinker 1983). In the United States, "scoping" has become a formal requirement of the NEPA "Regulations for Implementing the Procedural Provisions" (Council on Environmental Quality 1979).

Beanlands and Duinker (1983) distinguish between "social" scoping and "ecological" scoping. Whereas social scoping, described above, identifies those environmental components that are socially valuable and should receive intensive study, ecological scoping indicates how the components might be best studied.

3.1.3.3 Application of Scientific and Ecological Principles

A major criticism that has been made about the traditional approach to EIA is the poor scientific quality of EIA studies and general absence of a scientific framework by which to conduct EIA research. In order to improve the scientific quality and predictive capability of impact assessments, the present approach whereby subjective judgment is applied to large amounts of descriptive field data must be replaced by an approach that uses explicit hypotheses to put forward quantitative, testable predictions (Ward 1978; Beanlands and Duinker 1983). However, Holling (1978) cautions that a good scientific study does not necessarily contribute to better decision-making if the proper variables or processes are not measured. This means that although scientific principles ought to be applied, the research necessary for impact assessment must also reflect policy concerns (e.g. the selection of environmental components of value to society, as discussed above). Also, one might argue that, in some cases rigorous scientific methods are not appropriate, because they will impose unnecessary cost and time burdens, for example, on small projects in environmentally insensitive areas. In these cases, the professional judgment of one or more specialists might suffice as a means of predicting the likely impact.
A difficulty with any impact prediction is the type and degree of uncertainty which limits its accuracy. Munn (1979) describes four kinds of uncertainty that are generally encountered in EIA:

"1) the natural variability of the environment, particularly the occurrence of rare events such as floods and earthquakes;  
2) inadequate understanding of the behaviour of the environment;  
3) inadequate data for the region or country being assessed;  
4) socio-economic uncertainties (inadequate understanding and inadequate data)"

Some of the uncertainty can be removed by field data collection, some can be removed by studies to define the "variability" of the system under study, and some can be removed by studies to identify structural and functional relationships, but uncertainty cannot be eliminated (Ward 1978; Holling 1978). Although the uncertainty surrounding predictions can be reduced through the use of hypothesis-testing experiments (Ward 1978), Holling (1978) suggests that the continued presence of uncertainty should be acknowledged and that the environmental impact assessments should anticipate that unexpected events are inevitable.

Holling (1978) outlines four properties of ecological systems that influence how impacts on the systems should be assessed and how the kinds of uncertainty outlined in the preceding subsection might be tractable:

"- The parts of an ecological system are connected to each other in a selective way that has implications for what should be measured. 
- Events are not uniform over space, which has implications for how intense impacts will be and where they will occur. 
- Sharp shifts in behaviour are natural for many ecosystems. Traditional methods of assessment can misinterpret these and make them seem unexpected or perverse. 
- Variability, not constancy, is a feature of ecological systems that contributes to their persistence and to their self-monitoring and self-correcting capacities."

3.1.3.4 The Development of Clear Criteria for Interpreting Impact Significance

Eventually, the predicted changes in valued ecosystem components caused by a proposed project must be interpreted in terms of their significance or importance. Unambiguous definition of the criteria to be used for
determining significance provides both a focus for the operational needs of the EIA study and reduces the likelihood of misunderstanding when impact interpretation is presented to the decision-maker and the public (Beanlands and Duinker 1983). General and undefined usage of the term "significance" can have different meaning depending on the background of the audience.

3.1.3.5 The Recognition that Impact Assessment is an On-going and Adaptive Process

EIA should not be regarded as complete once the formal pre-operation project review has been completed (Holling 1978; Munn 1979; Beanlands and Duinker 1983). Although this concept is rather straightforward, implementation of a satisfactory monitoring program will depend on the adequacy of pre-operational studies. Specifically, the earlier studies must define the natural variability in environmental features of concern so that data gathered during the monitoring studies will indicate, firstly, that a change has occurred and, secondly, that the change was induced by the project (Gore et al. 1979; Skalski and MacKenzie 1982). Holling (1978) indicates the project proponents should expect the unexpected and should design their projects so that features can be changed if problems are evident during the monitoring and on-going assessment program. Therefore, the proponents should anticipate that not only will EIA continue into the operating phase of the project but also that changes in project design will likely be required.

3.2 Analytical Features that Could be Included in Pre-development Studies Undertaken by Mine Proponents.

The analytical features one might expect in the Stage I and Stage II reports (described in Chapter 2.0) prepared by metal mine proponents are summarized in this section. The basic analytical steps that could be followed throughout the EIA are listed in Figure 3-1. In terms of the existing three-stage metal mine review process, a Stage I report might be
Figure 3.1 The basic EIA steps that could be followed by metal mine proponents.

**Initial Activities**

The mine proponent makes an initial determination of the extent and value of the orebody through field exploration and economic analysis, then decides to seek approval for development.

**STEP 1**


**STEP 2**

Identification of Important Environmental Resources.

**STEP 3**

Identification of Sources of Effect.

**STEP 4**

Development of Preliminary Measures to Protect Important Resources

**STEP 5**

Development of Scientific Objectives and Implementation of Research Studies, and Assessments of Risk.

**STEP 6**

Refinement of Predictions of Effect and Mitigative Measures (If Necessary)

**STEP 7**

Implementation of an On-going Assessment Program.
expected to contain the Steps 1 through 4, though Step 1 would be more appropriate as a preliminary activity prior to commencing Stage I studies. Step 5, to some extent, would be required to define baseline conditions that could be examined during Step 7, whether or not a mine had to proceed to Stage II. A Stage II study, if necessary, would be a more thorough undertaking of Step 5 and, in addition, Step 6. Step 7 corresponds to Stage III and would apply to both Stage I and Stage II mines. Reflecting the step-by-step sequence described for the "theoretical" EIA model, the derived criteria are listed below under the appropriate heading for each step.

STEP 1: Development of a Preliminary Conceptual Understanding of Interaction Between the Mine and the Surrounding Environment

1. A conceptual understanding of mine-environment interaction is presented in the EIA report as a basis for the EIA study strategy and objectives.

2. The conceptual model is used to identify the general activities associated with each phase of mine development that might have an effect on the aquatic environment.

3. The conceptual model provides a general indication of the basic ecological structure of the aquatic environment near the minesite and what ecological features might be affected by the mine.

4. The conceptual model is used as a basis for initial discussion with the Metal Mines Steering Committee, regarding environmental factors to be considered, the types of alternatives, locations and design features that should be considered and the overall study strategy for the EIA.

5. The conceptual model is used to indicate to engineering design personnel the general types of mine features for which alternatives should be examined.

STEP 2: Identification of Important Environmental Resources

1. STEP 2a: Background preparation

a) The background preparation of the EIA study is based on a general strategy and objectives outlined in the early stages of the study (whether or not a conceptual model is presented).
b) The background preparation includes:
   i. a review of environmental literature for the study area.
   ii. a review of environmental information obtained through
discussion with government resource agencies.
   iii. a field reconnaissance to identify the location of important
resources.

2. STEP 2b: Establishment of study limits

   a) Geographical limits of the study area
   The limits of the study area are clearly indicated in the report
and include definition of: the project boundaries (including
alternative locations for some mine-related activities such as
hydroelectric reservoirs and transmission lines, waste rock
disposal sites, etc.); jurisdictional boundaries, if appropriate;
ecological boundaries; and technical boundaries for EIA analysis.

   b) "Scoping" of environmental factors to be considered
   i. The method for choosing the valued ecosystem components,
for which specific effects are to be predicted and impacts
interpreted, is clearly outlined.
   ii. For each valued ecosystem component identified, the
critical times and locations of important activities are
specified.
   iii. Similarly, the environmental indicators chosen for study in
order to draw conclusions about impacts on valued ecosystem
components are clearly explained.
   iv. Government agency personnel or members of the public have
assisted in the "scoping" of environmental components to be
studied, or reasons are given to indicate why they were not
included.

3. STEP 2c: Field studies

   Based on the weaknesses identified in available information, field
studies are conducted to determine the critical locations and
timings of important resource features.

STEP 3: Identification of Sources of Effect

1. Where information obtained from the background review permits,
structural and functional relationships are shown in the
conceptual model (both for components of the environment and for
mine-environment interaction).

2. Identification of sources and types of impact is based on methods
that:
   a) are comprehensive, providing a systematic assessment of each mine
activity
   b) consider both direct and indirect effects
   c) consider both short term effects and long term effects
   d) consider all phases of mining activity (e.g. exploration,
development, closure)

3. Explicit criteria are developed for determining the significance
or importance of predictions that will be made concerning the
effects of mine development on the important resource features.
STEP 4: **Development of Preliminary Measures to Protect Important Resources**

1. **Preliminary predictions of effects and interpretations of impacts**

   a) For each source and type of possible impact that has been identified (STEP 3), either a prediction is put forward or reasons why a prediction cannot be made is stated.

   b) The predictions of effect indicate:
      i. magnitude
      ii. periodicity and duration
      iii. geographic extent
      iv. likelihood of occurrence

   c) The uncertainties related to the predictions of effect are clearly stated.

   d) Where general terms such as small, medium etc. are used to describe effects, they are defined.

   e) Cumulative effects are predicted.

   f) Predictions distinguish between expected environmental conditions "with" the project and "without" the project.

   g) Predictions consider the possible recovery of environmental features once the source of disturbance is removed.

   h) The significance criteria developed earlier are consistently applied to the predicted effects for interpreting impact.

   i) The groups in society that will be affected by the impacts caused by the mine are identified.

2. **Development of impact management strategies**

   The preliminary impact assessment studies are used to:

   a) develop preliminary mitigative measures

   b) outline the expected effects after mitigation

   c) recommend that further studies be conducted to better identify the location and amount of resources at risk

   d) recommend that further studies be conducted to resolve uncertainties about the cause-effect relationship between selected mining activities and environmental features

   e) develop a monitoring and follow-up assessment strategy

   f) develop contingency plans to deal with unexpected emergencies

   g) develop an adaptive or fall-back strategy in case the monitoring and follow-up studies (Step 6) show that the mitigative measures chosen initially are not working

   h) draw conclusions about the overall environmental acceptability of the mining project.

STEP 5: **Development of Scientific Objectives and Implementation of Experimental Research Studies, and Assessments of Risk**

1. Explicit scientific objectives are stated so that the results of baseline and experimental research will yield quantitative results, that can be tested during studies after mine production begins.

2. Studies are conducted (where necessary) to identify functional
relationships between environmental components and/or the cause-effect relationships between the proposed mine and selected environmental components.

3. Where sources of serious potential damage to an environmental component or components has been identified, studies are conducted to assess the risk or probability of occurrence.

4. Where scientific objectives are put forward, the methods used to achieve each objective are described (ie. laboratory studies, field "in-situ" studies, desk analysis (eg. systems simulation modelling) and the limitations for interpreting the results clearly identified.

STEP 6: Refinement of Predictions of Effect and Mitigative Measures (If Necessary)

1. Based on the results of additional scientific studies (if necessary), predictions of effect are stated in quantitative terms that can be examined for correctness once the mine begins operations.

2. Predictions are put forward for all alternative mine-design and mitigative features that are financially and technically practicable, and the preferred features (for environmental protection) identified.

3. Outstanding uncertainties are clearly identified.

4. Reasons why the outstanding uncertainties are not considered important are stated, or recommendations to elucidate the uncertainties by further study are given.

5. The risk associated with each prediction is identified in terms of probability of occurrence, or reasons why quantification is not necessary is given.

6. The assumption and procedures of additional methods of impact analysis are clearly stated.

7. Predictions that are based on professional judgement are clearly separated from quantitative predictions.

8. The significance or importance of predicted effects are identified using consistent application of the defined criteria (STEP 3).

9. Based on the predictions of effect and chosen mine design and mitigative measures, a contingency plan and on-going assessment program are put forward.

10. The report indicates what flexibility, in terms of mine operating features or mitigative measures, exists to allow adaptation to a range of possible findings by the on-going assessment program.

STEP 7: Implementation of an On-going Assessment Program
After the mine begins operation, the effects are assessed on an on-going basis and, where effects become apparent, alternate operating practices or mitigative measures developed in Steps 3 to 6 are implemented.
CHAPTER 4.0 THE EFFECTIVENESS OF PRE-DEVELOPMENT IMPACT ASSESSMENTS

The purpose of this chapter is, firstly, to examine aquatic resource impact management problems at metal mines for which impact assessment reports were submitted to the provincial government, and, secondly, to evaluate the effectiveness of the reports for anticipating the eventual problems.

The literature describing the effects that metal mines can have on aquatic resources was reviewed, to provide background on the general sources and types of problem that can occur. The review is summarized in Appendix I.

4.1. Study Methods

4.1.1 Analysis of Recent Aquatic Resource Impact Management Problems.

Fifteen mines were selected using the following criteria:

i. the mine proponent submitted a formal Stage I or Stage II report to the MDRP for review; and,

ii. the mine began production after submitting the Stage I or Stage II reports.

The mines were identified in periodic lists that are produced by the B.C. Ministry of Energy, Mines and Petroleum Resources and summarize the status of mines that have entered the Mines Development Review Process (eg. Crook 1984). The mines selected, the year that reports were submitted, the year in which each mine began operation, and the current (March 1986) operating status of each mine are shown in Table 4-1. One mine (Equity Silver) submitted pre-development reports to the provincial in 1976, three years before the formal process for reviewing metal mine development was in place. The authors of the Equity Silver reports used the 1976 "Guidelines for Coal Development" for guidance. The reports for most of the other mines were submitted shortly after issuance of the 1979 "Procedures for obtaining approval of metal mine development" (Ministry
Table 4.1 Mines for which impact management problems were examined.

<table>
<thead>
<tr>
<th>Mine Type</th>
<th>Mine Name</th>
<th>Reports Submitted Type</th>
<th>Year Production Began</th>
<th>Status (March 1986)</th>
</tr>
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<tbody>
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<tr>
<td></td>
<td>Banbury</td>
<td>Stage I</td>
<td>1982</td>
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<td>Stage I Addendum</td>
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<td>Stage I</td>
<td>1980</td>
<td>1981</td>
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<td>1982</td>
<td>1982</td>
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<td>1982</td>
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<td></td>
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<td>1981</td>
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<td>Stage I Supplement</td>
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<tr>
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<td>Equity Silver</td>
<td>Stage I</td>
<td>1976</td>
<td>1980</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stage II</td>
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<td>1983</td>
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<td></td>
<td></td>
<td>Stage II Supplement</td>
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</table>
of Energy, Mines and Petroleum Resources 1979). General descriptions and operating status of each mine are summarized in Appendix II.

For each mine selected for review, the type and severity of impacts and problems associated with facilities or strategies to control the impacts were discussed with representatives of:

i. the mine company;
ii. the federal Environmental Protection Service and/or
iii. the provincial Waste Management Branch; and,
iv. the federal Department of Justice.

Additional information was obtained from reports prepared by government agencies or by consultants on behalf of mine proponents. Problems were then analyzed in terms of the sources of problems, the effects on the aquatic environment, and the legal and financial consequences to mine operators.

4.1.2 Review of Pre-development (Stage I/Stage II) Impact Assessments

The Stage I/Stage II reports prepared for each mine that encountered an environmental problem were reviewed to determine:

i. if the source or cause of the problem had been identified; and, if so,

ii. if the potential effects of the problem on the aquatic environment were described;

iii. what mitigative measures had been proposed to manage the possible consequences of those problems identified; and,

iv. what conclusions were drawn concerning the expected impacts of the problem, whether or not mitigative measures were to be implemented.

4.2 Results

The impact management problems that have occurred at each of the 15 mines are described in subsection 4.2.1, and the number and types of problem anticipated in the pre-development reports are described in subsection 4.2.2.
4.2.1 Impact Management Problems at 15 Mines

Impact management problems were reported for eight of the thirteen Stage I mines and both of the Stage II mines. The problems identified at each mine are presented in Appendix III, and are summarized separately below for Stage I mines (subsection 4.2.1.1) and Stage II mines (subsection 4.2.1.2).

To assist the analysis, problems are categorized according to the general types of mining activity discussed in Appendix I: On-going Exploration; Mine Development and Operation; Mill Construction and Operation; and, Other Activities.

4.2.1.1 Stage I Mines

Nineteen problems were reported. Seventeen problems are incidents that occurred during the development or operation of the mine and/or mill, and two were requests by regulatory agencies for construction of additional treatment ponds prior to operation (Table Mountain and Venus). The latter were precautionary measures and are not addressed further. The sources of problems, the effects on the aquatic environment, and the legal and financial consequences to mine operators are summarized below.

a) The Sources of Problems

The source or cause of each problem is listed in Table 4-2. Most problems (approximately 60%) were in relation to Mill Construction and Operation Activities. No problems occurred in relation to On-going Exploration Activities. The types of problem are categorized and the number of mines in each category are shown in Table 4-3. These data indicate that problems relating to the treatment or containment of tailings and process waste-water have been the most common. In fact these problems have occurred at least once at all mines or mills that reported a problem. In particular, difficulties have related to the permitted discharge of cyanide and associated metals, breaks in tailings lines, and the construction and
Table 4.2  The source or cause of problems at Stage I mines.

<table>
<thead>
<tr>
<th>Mine Name</th>
<th>Mine Development and Operation</th>
<th>Mill Construction and Operation</th>
<th>Other Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baker</td>
<td>1. mine drainage water</td>
<td>1. discharge from tailings pond</td>
<td>1. fuel spill at airfield</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. break in tailings line</td>
<td>2. sewage discharge</td>
</tr>
<tr>
<td>Free Gold</td>
<td>-</td>
<td>1. leakage from tailings pond</td>
<td>-</td>
</tr>
<tr>
<td>HB Mill¹</td>
<td>-</td>
<td>1. break in tailings line</td>
<td>-</td>
</tr>
<tr>
<td>Ladner Creek</td>
<td>1. general development activity²</td>
<td>1. effluent discharge</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2. mine water settling ponds</td>
<td>2. drainage water in mill building</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>3. uncontrolled runoff during operation</td>
<td>3. tailing pond storage</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. tailings dam reconstruction</td>
<td>-</td>
</tr>
<tr>
<td>Silence Lake</td>
<td>1. rockslide at mine rock stockpile</td>
<td>1. overflow of tailings berm</td>
<td>-</td>
</tr>
<tr>
<td>Summit Lake</td>
<td>-</td>
<td>1. mill-process discharge</td>
<td>-</td>
</tr>
<tr>
<td>Number of Problems:</td>
<td>5</td>
<td>10</td>
<td>2</td>
</tr>
</tbody>
</table>

¹ Note that no mining activity occurred at this operation.

² Changes in downstream water quality and biota were attributed jointly to mine-water settling ponds and to general site development and construction. Changes were again attributed to the mine-water settling ponds once production began.
Table 4.3  The number of Stage I mines having each type of problem.

<table>
<thead>
<tr>
<th>Category of Mining Activity</th>
<th>Type of Problem</th>
<th>Number of Mines having Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine development and operation</td>
<td>1. rock/land slide at ore stockpile</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2. drainage water from mine</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3. general development activity</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>4. mine-water settling ponds</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>5. uncontrolled runoff during operation</td>
<td>1</td>
</tr>
<tr>
<td>Mill construction and operation</td>
<td>1. tailings/mill effluent discharge</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2. drainage from mill building</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3. breaks in tailings lines</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>4. unexpected overflow or leakage of tailings ponds</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>5. tailings dam construction</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>6. tailings pond storage</td>
<td>1</td>
</tr>
<tr>
<td>Other Activities</td>
<td>1. fuel spill near airstrip</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2. water quality and biotic changes from sewage discharge</td>
<td>1</td>
</tr>
</tbody>
</table>
overflow or leakage of tailings ponds.

b) **Effects on the Aquatic Environment**

Four of the 17 problems (27%) caused no evident change to the aquatic environment. These are:

- the fuel spill at the airfield near Baker
- the small leakage of the tailings pond at Free Gold
- the small overflow of the tailings berm at Silence Lake
- the tailings pond storage at Ladner Creek (high runoff to the pond required a shutdown of the mill to prevent overflow)

In the first three cases, contaminants were released, but did not reach nearby surface water bodies. Also, the amount of pollutant discharged was described by Waste Management Branch and/or mine personnel as small. In the fourth case, material was not actually discharged.

The remaining 13 problems caused solid or dissolved substances to enter the receiving environment. The amount of observed or expected change in receiving water conditions varies considerably. One problem was detected at the source but was not detected a short distance downstream from the source (i.e. high sulphate levels in the mine water at Baker). The observed changes resulting from the other 12 problems are listed in Table 4-4.

In two cases the problem sources were felt by regional Ministry of Environment personnel to be producing a beneficial change in the receiving environment. These are the introduction of nitrogen compounds at Baker (from the sewage discharge) and at Ladner Creek (the mine-water settling ponds contained nitrogen compounds from explosives usage). At both locations the waters were felt to be nutrient poor and the nitrogen compounds appeared to be increasing biological productivity. In one case (the rockslide at Silence Lake), the problem is felt to be minor because the amount of material released was small, the time frame was brief and the release occurred in an area inaccessible to fish.

Ten problems involved the release of potentially toxic substances and/or relatively high levels of suspended solids. These occurred at four
### Table 4.4
Changes observed in the aquatic environment near Stage I mines.

<table>
<thead>
<tr>
<th>Mine Name</th>
<th>Problem Source</th>
<th>Observed Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baker</td>
<td>1. tailings pond discharge</td>
<td>- high cyanide and copper levels recorded below tailings pond in both groundwater and surface water</td>
</tr>
<tr>
<td></td>
<td>2. break in tailings line</td>
<td>- patches of sediment observed in stream; high cyanide levels recorded in tailings at time of break but no measurements made in receiving water</td>
</tr>
<tr>
<td></td>
<td>3. sewage discharge</td>
<td>- high levels of nitrogen and phosphorous recorded in surface water downstream; algal mats and changes in invertebrate community observed</td>
</tr>
<tr>
<td>HB Mill</td>
<td>1. break in tailings line</td>
<td>- tailings sediment distributed a short distance along the stream bottom; no toxic substances in tailings at the time of spill</td>
</tr>
<tr>
<td>Ladner Creek</td>
<td>1. general minesite development</td>
<td>- high levels of suspended solids, alkalinity, hardness and dissolved elements were recorded downstream; algal growth and sedimentation and changes in invertebrate community observed</td>
</tr>
<tr>
<td></td>
<td>2. mine-water settling ponds</td>
<td>- high levels of suspended solids and nitrogen compounds recorded in water below minesite; solids deposited on substrate immediately below the minesite but not further downstream where salmonids are found; nitrogen compounds felt to be cause of algal growth observed downstream</td>
</tr>
</tbody>
</table>
Table 4.4 Cont'd.

<table>
<thead>
<tr>
<th>Mine Name</th>
<th>Problem Source</th>
<th>Observed Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3. uncontrolled runoff during mine operation</td>
<td>high level of suspended solids recorded</td>
</tr>
<tr>
<td></td>
<td>4. tailings dam reconstruction</td>
<td>high levels of suspended solids recorded</td>
</tr>
<tr>
<td></td>
<td>5. mill-process discharge</td>
<td>high cyanide and copper levels recorded downstream; dead trout observed downstream at time of one peak discharge and bioassays suggested lethal levels immediately below minesite and stress levels where fish are found; macro-invertebrates downstream had high copper levels in tissue and showed reduction in numbers of taxa and individuals</td>
</tr>
<tr>
<td></td>
<td>6. mill-building drainage</td>
<td>high cyanide levels were recorded in the drainage but the relative contribution to receiving waters is difficult to identify given the other sources (point 5 above)</td>
</tr>
<tr>
<td>Silence Lake</td>
<td>1. rockslide at ore stockpile</td>
<td>several boulders and sediment were deposited in a nearby creek</td>
</tr>
<tr>
<td>Summit Lake</td>
<td>1. mill-process discharge</td>
<td>high cyanide and copper levels recorded in receiving water; bioassays showed lethal levels at minesite; periodic high levels recorded downstream could not be attributed to the mine activity</td>
</tr>
</tbody>
</table>

1 as indicated in Appendix III, the cause of death and the bioassay results have been disputed during legal proceedings.
operations (Baker, HB Mill, Ladner Creek and Summit Lake) and can be grouped into seven problem categories:

- cyanide and copper in mill effluent
- breaks in tailing lines
- minesite development activity
- mine-water settling ponds effluent
- uncontrolled runoff during mine operation
- runoff during tailings dam construction
- mill-building drainage

As shown in Table 4-4, these problems involved mainly changes in water quality and in several cases changes in the stream invertebrate communities. The potential effects of the relevant dissolved and solid substances on fish are described in Appendix IB. The probable effects on fisheries resources near each mine are discussed separately below.

**Baker Mine.** The discharge of cyanide and dissolved copper do not appear to have had an impact on fisheries resources. A study of fish resources in the nearby waters indicated that fish are not present in the watershed near the minesite and fish access is blocked by a waterfall located 35 km downstream (Beak 1982). Regional Waste Management personnel do not feel toxic concentrations of cyanide or copper persisted to that point. A study of aquatic invertebrates conducted over one year after the high levels of cyanide and copper were first recorded, and four months after the break in the tailings line, did not indicate signs of damage below the minesite (IEC Beak 1983). The study suggests that the benthic community showed signs of enhancement resulting from the high nutrient levels from the sewage discharge and this could have masked negative effects from the cyanide and copper discharge.

**HB Mill.** The spill of tailings material from the broken tailings are not felt by Regional Ministry of Environment personnel to have had a serious effect on fish in the affected stream. This is because fish do not utilize the segment of stream near the spill at the time of year the break occurred, and the amount of material released was small and was not felt to contain
toxic material.

**Ladner Creek.** Effects on fisheries resources might have occurred in two ways. Firstly, the sedimentation and changes in the benthic community observed during minesite development occurred in areas utilized by salmonid species. The reported changes could impact salmonids indirectly by affecting both spawning habitat and food production.

Secondly, when the high levels of cyanide and copper were recorded, dead steelhead trout were observed downstream. However, the cause of the mortalities was disputed during legal proceedings. Steelhead smolts from a hatchery had been placed in the river at the time high cyanide and copper levels were discharged and handling methods during the stocking were felt to be a possible cause of death. Although cyanide could not be proven as the cause of death in these fish, trout bioassays conducted shortly afterward showed that surface water at the minesite was lethal and approximately 8 Km downstream caused stress. The bioassay procedures were also disputed during legal proceedings.

**Summit Lake.** Fish bioassays indicated that the mine effluent, containing cyanide and metals, was lethally toxic but fish are not normally found in the lake into which mine effluent is discharged. Below the lake, in areas where fish are found, fish mortalities were not observed and bioassays were not conducted when high cyanide levels were recorded in the downstream areas. The downstream levels are felt to have been sufficient to have sublethal effects on young salmonids, but the absence of pre-operational water quality data at the downstream locations prevents attributing the high cyanide levels to the mine operation.

c) **Legal and Financial Consequences**

Three of the 13 Stage I mines have been convicted under either provincial or federal legislation relating to the protection of aquatic resources. The operators of three Stage I mines have been convicted under
the provincial Waste Management Act (Baker, HB Mill, Ladner Creek) and one mine operator has been convicted under the federal Fisheries Act (Ladner Creek). In addition, water samples for legal purposes were taken after the break in the tailings line at Baker, but charges were not laid. The operators of the Ladner Creek mine are appealing their conviction under the Federal Fisheries Act, but are also facing a separate civil action by the Steelhead Society of B.C. for damages to conservation efforts along the Coquihalla River.

The financial costs borne by operating companies to deal with the relatively serious impact management problems are shown in Table 4-5. In addition to fines, other costs described by mine operators are:

- additional legal costs, including lawyer's fees, and preparation time for consultants and senior executives;
- additional pollution control and/or environmental studies;
- immediate repair costs to fix broken equipment;
- installation of additional pollution control equipment;
- shut-down time causing a loss in production;
- increases in monitoring frequency and/or the number of factors monitored.

The costs shown in Table 4-5 must be regarded as approximations; repeatedly, the mining company representatives with whom these costs were discussed, emphasized that exact figures could not be quoted. This is mainly because financial records did not treat some factors (such as emergency repairs, court-appearance costs or the construction of waste treatment facilities within a larger mill complex) as separate expenditures. Therefore many of the costs are simply the educated guesses by the individuals with whom the costs were discussed. Nonetheless, the figures do provide a general indication of the relative costs borne by the mining companies to deal with the different kinds of problems that developed.

The data in Table 4-5 indicate that some mines expended amounts which were approximately 0.3% - 4% of total pre-production costs, to deal with eventual impact management problems.
Table 4.5  The financial costs borne by mining operations in relation to serious impact management problems.

<table>
<thead>
<tr>
<th>Mine Name</th>
<th>Problem Source</th>
<th>Fines and Other Costs($) Involved</th>
<th>Pre-Production Costs ($)</th>
<th>% of Pre-Production Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage I Mines</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baker</td>
<td>discharge of cyanide and metals</td>
<td>Fine 2,000, other 110,000</td>
<td>13.5 million&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>break in tailings line repairs</td>
<td>5,000 to 10,000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HB Mill</td>
<td>break in tailings line</td>
<td>Fine 1,500, Court costs 5,000, repairs 85,000</td>
<td>91,500</td>
<td>&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ladner Creek</td>
<td>discharge of cyanide and metals</td>
<td>Fine 5,000, Fine 135,000, Other (unable to estimate) 50 million&lt;sup&gt;3&lt;/sup&gt;</td>
<td>140,000 plus</td>
<td>at least 0.3</td>
</tr>
<tr>
<td>Summit Lake</td>
<td>discharge of cyanide and metals</td>
<td>Fine 0, Other 850,000&lt;sup&gt;4&lt;/sup&gt;</td>
<td>850,000</td>
<td>4</td>
</tr>
<tr>
<td><strong>Stage II Mines</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equity Silver</td>
<td>acid generation in waste rock</td>
<td>Fine 12,000, Other 1,300,000</td>
<td>(capital costs)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>3,000,000&lt;sup&gt;5&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> B.C. and Yukon Chamber of Mines 1982
<sup>2</sup> Pre-production costs include purchase of mill and refurbishing for new production
<sup>3</sup> Northern Miner Press Limited 1984
<sup>4</sup> Excluding lost production during a 3-4 day shutdown after problem identified
<sup>5</sup> Capital costs for initial collection and treatment facilities to deal with problem were estimated to be $1.2-1.4 million; legal costs, on-going studies and treatment measures were expected to bring total costs to at least $3 million.
4.2.1.2 Stage II Mines

The sources of problems, the effects on the aquatic environment, and the legal and financial consequences to mine operators are summarized below.

a) The Sources of Problems

The source or cause of each problem is listed in Table 4-6. Seven impact management problems have occurred. One problem (acid generation in waste rock) involves more than one source at a minesite (Equity Silver) because waste rock was used as material for construction purposes.

Five (71%) of the problems were in relation to Mill Construction and Operation Activities. The types of problem are categorized and the number of mines in each category are shown in Table 4-7. Note that three problems relate to the management of tailings material (i.e., the break in the tailings line and breakdown of tailings and seepage pumps).

b) Effects on the Aquatic Environment

One problem (failure of the tailings pump at Goldstream) involved the release of tailings material, but contaminants did not reach a nearby stream. Two problems (the crushed culvert at Equity Silver and the broken tailings pipe at Goldstream) caused small amounts of material to be released to streams, but the releases were too small and/or too brief to have had an observable effect on the receiving environment. The tailings pipe at Goldstream had been drained just prior to the break. The crushed culvert at Equity Silver caused pooling of low pH drainage water, but the low pH levels were a result of the larger acid generation problem.

In addition, the overflow from the seepage pond at Equity Silver (because a seepage pump failed) had a very low pH, but the overflow took place over a short period and the downstream values were not recorded.

The changes observed in the aquatic environment for three remaining problems, all at Equity Silver, are summarized in Table 4-8. Two problems
Table 4.6  The source or cause of problems at Stage II mines.

<table>
<thead>
<tr>
<th>Mine Name</th>
<th>Category of Mining Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mine Development and Operation</td>
</tr>
<tr>
<td>Equity Silver</td>
<td>1. acid generation in waste rock$^1$</td>
</tr>
<tr>
<td></td>
<td>2. acid generation in waste rock used for millsite construction$^1$</td>
</tr>
<tr>
<td></td>
<td>4. high suspended solids in millsite runoff</td>
</tr>
<tr>
<td>Goldstream</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2. tailings pumps fail</td>
</tr>
</tbody>
</table>

Number of Problems: 1 6 2

$^1$ waste rock from the mine was used for construction of the tailings pond, mill foundations and access roads. Although the problem is listed in three separate categories, it is actually one source and is therefore counted in the text once under Mine Development and Ore Extraction.
Table 4.7  The number of Stage II mines having each type of problem.

<table>
<thead>
<tr>
<th>Category of Mining Activity</th>
<th>Type of Problem</th>
<th>Number of Mines having Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine development and ore extraction</td>
<td>1. acid generation in waste rock</td>
<td>1</td>
</tr>
<tr>
<td>Mill site construction and operation</td>
<td>1. accidental spill of process chemical (sulphuric acid)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2. break in tailings line</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3. failure of tailings/seepage pumps</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>4. millsite runoff</td>
<td>1</td>
</tr>
<tr>
<td>Other activities</td>
<td>1. crushed culvert on haul road</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 4.8  Changes observed in the aquatic environment near Equity Silver.

<table>
<thead>
<tr>
<th>Problem Source</th>
<th>Observed Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. acid generation in waste rock</td>
<td>- reduced pH levels and increased levels of sulphate and metals (copper, zinc and iron) were recorded downstream; the size of the benthic invertebrate community was reduced</td>
</tr>
<tr>
<td>2. process chemical spill (sulphuric acid)</td>
<td>- high levels of suspended solids were recorded downstream</td>
</tr>
<tr>
<td>3. plantsite runoff</td>
<td>- high levels of suspended solids were recorded downstream; the size of the benthic invertebrate community was reduced</td>
</tr>
</tbody>
</table>
(the acid generation in waste rock and sulphuric acid spill) involved the release of potentially toxic substances. In one case (the sulphuric acid spill), the problem was accidental and the material was released rapidly; in the other case, the problem involved the chronic release of the substance over a larger geographical area. The suspended solids produced by the third problem (runoff from the plant site) enter the same receiving water and all three problems likely contributed to the reported decline in downstream invertebrate numbers. Waste Management personnel expressed serious concern over the long-term solution of the acid generation problem.

The potential effects of these substances on fish are discussed in Appendix IB. Although potentially harmful substances were released from the problem-sources at Equity Silver, negative changes in downstream fish populations have not been identified. Osborne and Hallam (1982) and Hatfield Consultants Ltd. (1983) reviewed available information and concluded that the data suggested downstream fisheries resources were not affected. Approximately four kilometers below the mine, the stream in which water quality problems were observed flows into a lower stream (Buck Creek) reported to have a rainbow trout population. The acidic and high metal conditions in the tributary were not observed a short distance below the junction of the two streams, nor were metals recorded in fish tissues or bottom sediments.

c) The Legal and Financial Consequences to Mine Operators

The operators of the one Stage II mine (Equity Silver) were convicted under the federal Fisheries Act.

The financial costs borne by the Equity Silver mine to deal with its impact management problem is shown in Table 4-5. As with the costs for Stage I mines, these costs must be regarded as approximations. The mine expended approximately 3% of its total pre-production costs to correct the acid generation problem.
4.2.1.3 Summary

Seventeen impact management problems were identified at six out of 13 Stage I mines. Changes in the receiving environment were observed in relation to most (12) of the problems. In two cases the changes appeared to be beneficial and in 11 cases the changes appeared to be negative (one problem source appears to have produced both positive and negative changes). In 10 cases (approximately 60%) potentially serious toxicants or high levels of suspended solids were released. These problems occurred at four of the 13 Stage I mines reviewed. Negative changes to a downstream invertebrate community and possibly the fish community were recorded at one mine (or 8% of all Stage I mines). Three of the Stage I mines were convicted under environmental legislation and costs to correct impact management problems were up to 4% of the total pre-production costs.

Nine impact management problems were identified at two Stage II mines. Changes in the aquatic receiving environment were observed in relation to three of the problems. In each case, potentially serious toxicants or high levels of suspended solids were released. Another problem involved the discharge of low pH effluent but a change in water quality was not recorded downstream at the time. Problems producing changes in receiving waters occurred at 1 of the 2 Stage II mines. Negative changes to the downstream invertebrate community were recorded, but effects on fisheries resources are not evident. One of the Stage II mines was convicted under environmental legislation and costs to correct impact management problems were up to 3% of the total pre-production costs.

4.2.2 Problems Anticipated in Stage I/Stage II Reports

4.2.2.1 Stage I Mines

The impact management problems identified in Stage I reports are shown
in Table 4-9. Of the 17 problems that occurred, the source or cause of 12 problems were identified in the appropriate Stage I report or Stage I addendum. These include four relatively major problems discussed in the previous subsection (i.e. the problems with cyanide treatment at the Baker, Ladner Creek and Summit Lake mines and the break in the tailings line at HB Mill). Problem sources that were not identified are:

- the broken tailings line at Baker
- the fuel spill at Baker
- the mine water settling ponds at Ladner Creek
- the leak in the tailings dam at Free Gold
- the berm overflow at Silence Lake

One problem (the mine water settling pond at Ladner Creek) relates mainly to a routine discharge source (though the problem was attributed to two sources, the other being runoff from general minesite development activity), while the other problems relate mainly to the failure of equipment or structures.

Specific mitigative measures were described for all of the identified sources of possible impact except the leakage of the tailings dam at Free Gold. However, the Free Gold report indicated further studies were to be conducted for designing the tailings facility.

In cases where problem-sources are identified, the reports indicate what general aquatic resource features (e.g. water quality, fish) might be affected by each problem source or the effects can be inferred. However, no report attempts to define the amount of change for the resource feature that could occur.

Table 4-10 shows what conclusions were drawn in relation to the problem-sources identified. No conclusions were drawn for any of the sources identified in one report (Ladner Creek) and for only some of the sources identified in another (Baker). Otherwise, the conclusions are very explicit that problems would not occur. Since in all cases mitigative
Table 4.9 Impact management problems identified in Stage I reports.

<table>
<thead>
<tr>
<th>Mine Name</th>
<th>Problem that Developed</th>
<th>Source/Cause Identified</th>
<th>Mitigative Measures</th>
<th>Further Studies Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baker</td>
<td>1. discharge of cyanide and metals</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>2. break in tailings line</td>
<td>No</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>3. fuel spill at airfield</td>
<td>No</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>4. acid mine drainage</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>5. sewage discharge</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Ladner Creek</td>
<td>1. run-off during mine development activity</td>
<td>Yes&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>2. mine water settling ponds</td>
<td>No</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>3. uncontrolled runoff during operation</td>
<td>Yes</td>
<td>Yes&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>4. discharge of cyanide and metals</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>5. mill drainage</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>6. tailings dam construction</td>
<td>Yes</td>
<td>Yes&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>7. tailings pond storage</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>HB Mill</td>
<td>1. break in tailings line</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Free Gold</td>
<td>1. leak in tailings dam</td>
<td>No</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Silence Lake</td>
<td>1. rockslide</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>2. berm overflow</td>
<td>No</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Summit Lake</td>
<td>1. discharge of cyanide and metals</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

<sup>1</sup> indicated in the Stage I addendum but not in the Stage I report.
### Table 4.10 Conclusions drawn for each problem identified in Stage I reports.

<table>
<thead>
<tr>
<th>Mine Name</th>
<th>Problem Source</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baker</td>
<td>1. discharge of cyanide and metals</td>
<td>&quot;Tailings effluent will be non-toxic to fish by a properly controlled alkaline chlorination process.&quot;</td>
</tr>
<tr>
<td></td>
<td>2. acid mine drainage</td>
<td>no conclusion presented</td>
</tr>
<tr>
<td></td>
<td>3. sewage discharge</td>
<td>no conclusion presented</td>
</tr>
<tr>
<td>HB Mill</td>
<td>1. broken tailings line</td>
<td>&quot;A sagging and leaking flume sometimes allowed tailings to spill into Sheep Creek during the previous operation. Installation of the plastic pipe eliminates this problem.&quot;</td>
</tr>
<tr>
<td></td>
<td>1. uncontrolled runoff</td>
<td>no conclusion presented</td>
</tr>
<tr>
<td></td>
<td>2. discharge of cyanide and metals</td>
<td>no conclusion presented</td>
</tr>
<tr>
<td></td>
<td>3. cyanide in mill drainage</td>
<td>no conclusion presented</td>
</tr>
<tr>
<td></td>
<td>4. tailings dam construction</td>
<td>no conclusion presented</td>
</tr>
<tr>
<td>Ladner Creek</td>
<td>1. uncontrolled runoff</td>
<td>no conclusion presented</td>
</tr>
<tr>
<td></td>
<td>2. discharge of cyanide and metals</td>
<td>no conclusion presented</td>
</tr>
<tr>
<td></td>
<td>3. cyanide in mill drainage</td>
<td>no conclusion presented</td>
</tr>
<tr>
<td></td>
<td>4. tailings dam construction</td>
<td>no conclusion presented</td>
</tr>
<tr>
<td>Silence Lake</td>
<td>1. rockslide</td>
<td>&quot;No mined or sloughed material will escape into Maxwell Creek.&quot;</td>
</tr>
<tr>
<td>Summit Lake</td>
<td>1. discharge of cyanide and metals</td>
<td>&quot;Process water containing cyanide and heavy metals is to be treated, prior to discharge, by alkaline chlorination, thus eliminating concern over toxicity.&quot; &quot;Cyanides and heavy metals will be innocuous due to their treatment within the mill prior to discharge.&quot;</td>
</tr>
</tbody>
</table>
measures were described, these conclusions imply that mitigation would be absolute.

4.2.2.2 Stage II Mines

As indicated in Table 4-11, the source or cause of four of the seven problems was identified in the pre-development reports. The most serious problem (acid-generation at Equity) was amongst those identified. Problem-sources that were not identified are:

- the break in the tailings line at Goldstream
- the breakdown of tailings pumps at Goldstream
- the process chemical spill at Equity Silver

General mitigative measures and on-going studies were outlined for the acid generation problem at Equity Silver. Similarly, mitigative measures were outlined for the placement of road culverts and for drainage from the mill site.

As with the Stage I reports, the potentially affected aquatic resource features were indicated or were evident. However, again, in most cases the amount of potential change in a particular resource feature was not indicated. An exception is a reference in the Equity Silver report to increased sedimentation resulting from activity in the mill and mine areas.

Table 4-12 shows conclusions drawn in relation to the problem-sources identified. The conclusions presented in the Equity Silver report indicate that the acid generation problem was not considered likely. However, a precautionary monitoring program was outlined because uncertainty existed.

4.3 Discussion

The effectiveness of the pre-development assessments is discussed below (in subsection 4.3.1) in relation to the anticipation of different types of problem, to the occurrence of problems at different mine types, to the relative seriousness of effects on aquatic resources, and to the consequences for mine operators. Analytical weaknesses that might have
Table 4.11  Impact management problems identified in Stage II reports.

<table>
<thead>
<tr>
<th>Mine Name</th>
<th>Problem that Developed</th>
<th>Source/Cause Identified</th>
<th>Mitigative Measures</th>
<th>Further Studies Proposed</th>
<th>Potential Effects Described</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equity Silver</td>
<td>1. acid generation in waste rock</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes³</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>2. process chemical spill (sulphuric acid)</td>
<td>No</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>3. crushed culvert</td>
<td>Yes¹</td>
<td>Yes</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>4. millsite runoff</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>Yes³</td>
</tr>
<tr>
<td></td>
<td>5. breakdown of tailings seepage pump</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Goldstream</td>
<td>1. break in tailings line</td>
<td>No</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2. breakdown of tailings pump</td>
<td>No</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

1 The impact analysts did not specifically refer to "crushed culverts". Nonetheless, these might have been considered, given the wording used. The crushed culvert occurred at the minesite. Discussion of culvert design and maintenance was in direct reference to the mine access road, not roads at the minesite.
2 An on-going monitoring program to detect development of an acid generation problem is recommended.
3 Increased sediment load is referred to.
4 Based on preliminary (Stage I) assessment.
Table 4.12  Conclusions drawn for each problem identified in the Equity Silver Stage II report.

<table>
<thead>
<tr>
<th>Problem Source</th>
<th>Conclusions</th>
</tr>
</thead>
</table>
| 1. acid generation in waste rock| "The tests subsequently indicated that the potential for acid generation does exist."
|                                 | "After considering the relevant factors which are required for acid mine waters to constitute a pollution problem, it is anticipated that the impact on the environment will be negligible provided that the monitoring programme for water seeping from the waste dumps is correctly implemented." |
| 2. millsite runoff              | "The plant and mine areas could impact the Buck Creek system. However, any increased sediment load may not impact environmental effects beyond Goosly Lake..." |
| 3. crushed culvert              | In reference to possible erosion along the mine access road, "However, with careful road construction techniques emphasizing road location, placement and maintenance of culverts being employed by the contractor, it is anticipated that these potential negative impacts will be at least transitory if non-existant." |
contributed to the relatively serious problems are discussed in subsection 4.3.2, and the adequacy of the review process is discussed in subsection 4.3.3.

4.3.1 Effectiveness of Pre-development Assessments

4.3.1.1 Types of problem

Most problems (60%-70%) at both Stage I and Stage II mines were in relation to mill construction and operation activities (including tailings ponds), as opposed to development and operation of the mine itself, on-going exploration and other activities. The sources of eight of the 24 eventual problems were not identified in pre-development studies. The sources 16 problems were identified, but, clearly, were not prevented. The occurrence of these problems appears to be because either inappropriate mitigative measures were chosen or the measures were poorly implemented. Most problems not identified were related to equipment failure and/or operator error. This indicates that, in addition to the development of impact management strategies before mine operation begins, effective supervision and enforcement activities are required as part of the overall management effort. The absence of more serious effects related to several of these problems might be due more to good fortune than good design (e.g., draining of the tailings line at Goldstream just prior to the break in the line).

The sources of problems can be placed in three general categories. The categories and the numbers and percentages of problems in each are:

- routine effluent discharge: 8 (33%)
- general site runoff: 5 (21%)
- equipment or structural failures: 11 (46%)

The problems associated with routine effluent discharge include mill and tailings discharges, mine and mill settling pond discharge and sewage discharge. The problems associated with general site runoff include runoff from mine and mill areas, runoff during tailings pond construction and runoff from waste rock material. The problems associated with equipment or
structural failure include broken tailings lines and pumps, breaches in tailings dams, a collapsed roadway culvert, spills of a process chemical spill, a rockslide at an ore stockpile and a fuel spill.

In terms of problems that were anticipated in the associated Stage I and Stage II impact assessments, the number and percentage of problem-sources identified in the different categories are:

- routine effluent discharge: 7 (88%)
- general site runoff: 5 (100%)
- equipment or structural failure: 6 (55%)

These data suggest that the pre-development assessments were in general more effective for identifying the sources of potential routine discharge problems and site runoff problems, than for identifying equipment or structural failures. However, these data should be interpreted with caution given the relatively small sample sizes involved.

4.3.1.2 Types of Mine having Serious Problems

a) Stage I Mines

The types and numbers of Stage I mines and mills examined for this thesis are:

a) underground gold or gold/silver, producing 30-300 tonnes/day: 8 mines  
b) gold-molybdenum, producing 100 tonnes/day: 1 mill  
c) underground gold/silver plus lead and zinc (mine in Yukon and mill in B.C.), producing 100 tonnes/day: 1 mine  
d) underground gold mine producing 1000 tonnes/day: 1 mine  
e) open pit magnesite (mine in B.C. and mill in Alberta) producing 100 tonnes/day: 1 mine  
f) open pit tungsten producing 100 tonnes/day: 1 mine

The three Stage I mines that had relatively serious problems are all underground gold mines. Two of the mines are relatively small (Baker and Summit Lake) falling in category a) above, and one is larger (Ladner Creek) and is the mine shown in category d). The Stage I mill (the HB Mill) that had a relatively serious problem was intended for processing gold and molybdenum (i.e. the mill identified in category b above), but was processing custom deliveries of lead-zinc-silver when the problem occurred.
With respect to gold mines, Ripley et al. 1978 indicate that there is a large variation in processing activities amongst lode-gold operations but summarize the following effects:

"i residual cyanide, from the cyanidation process, in waste waters;  
ii hydrospheric emissions of arsenic and heavy metals;  
iii suspended particulates in waste waters; and
iv atmospheric emissions of arsenic, sulphur, and tellerium compounds mainly associated with arsenopyrite ores.""

In comparison, the sources and types of effect identified in the present study are:

i. cyanide and metals in wastewater;  
ii. suspended solids and dissolved solids from broken tailings lines;  
   tailings dam construction; mine development activity; mine-water settling ponds; and uncontrolled minesite runoff.  
iii. nutrients from sewage discharge.

Clearly, cyanide, metals and suspended solids are a common impact management problem at gold mines and should not be unexpected. However, these problems have occurred at operations in British Columbia, even those that have prepared an impact assessment and have been subject to governmental review prior to proceeding. For cyanide treatment, the three gold mines initially used the same treatment method (alkaline chlorination) and converted to a new method (INCO-SO2/Air) after cyanide discharge problems developed.

b) Stage II Mines

The Stage II mines are an open-pit silver, gold, and copper mine producing 5000 tonnes/day (Equity Silver) and a combined open-pit/underground copper and zinc mine producing 1400 tonnes/day (Goldstream). Both mines are described as sulphide ore mines because the metals are extracted from ores having a high sulphide content. Ripley et al. 1978 provide the following summary of sources and types of effect from sulphide ore mines:

"The emission of heavy metal particulates, sulphur oxide, and acid mine drainage to the hydrosphere cause changes in water chemical composition, sediment, and quality, particularly at the local scale. In addition, water movement,
both at the surface and underground, is affected."
The relatively serious problems identified at the Equity Silver mine are:

i. acid produced in and draining from mine waste-rock;
ii. acid resulting from the spill of a process chemical (sulphuric acid); and,
iii. suspended solids in minesite runoff.

Elevated heavy metal levels accompanied the acidic conditions.

Acid mine drainage is clearly identified in the literature as a common impact management problem with sulphide ore mines and therefore should not be unexpected. However, acid generation in the rock material of mines is a highly complex problem and is usually the result of the combined activity of oxygen, water and a bacterium, *Thiobacillus ferroxidans* (Marshall 1982; Clarke 1974). The impact analysts for the Equity Silver mine concluded that the likelihood of an acid generation problem was low given conditions at the site.

4.3.1.3 Actual Effects on Aquatic Resources

The results indicate that changes in water quality and benthic communities were observed at four Stage I mines and one Stage II mine. The results further show that fish were observed to be directly affected at only one of the 13 Stage I mines and neither Stage II mine. These data suggest that fisheries resources have not been affected at most of the mines examined. Nonetheless, the review of possible effects on fisheries resources in Appendix IB indicates that the potential for more serious effects existed at several other mines and were perhaps not detected. Clearly, the ability to detect effects on fish or other resources is dependent on the types of monitoring and reporting procedures in place. The possibility that a problem occurred but was not detected and the possibility that a problem was detected but not reported are discussed briefly below.

a) The possibility that a problem occurred but was not detected

The type of data obtained during monitoring and problem-specific
studies is described in Appendix IV. During a monitoring program, routine sampling is undertaken by the mine and, in addition, both routine and irregular visits are conducted by Waste Management Branch personnel or personnel from other provincial or federal resource agencies (eg. Environmental Protection Service). In cases where the visits by government personnel take place infrequently (eg. once per year), great reliance must be placed on the sampling and monitoring program undertaken by the mine operator. Even routine visits of once a month might not be suitable for observing the effects of emergency spills or other catastrophic events that could occur. Based on the sampling and reporting procedures that are used, problems that result in a chronic release of toxicants, measurable over several months, and problems producing visible physical damage are more likely to be detected. In contrast, problems that result in sporadic but excessive releases in toxicants and are not related to visible physical damage appear to have a low likelihood of being detected.

b) Possibility that a problem was detected but not reported

This possibility is difficult to assess. Reporting of emergency events, such as chemical spills, where physical damage has not occurred and where the period of detection is brief, are dependent on the understanding and integrity of the mine operator. Where visits by resource agency personnel are frequent (eg. large, accessible mines), these events are probably reported without hesitation. However, where visits by resource agency personnel are not frequent, (eg. small, remote mines) there is perhaps greater possibility these events are not reported. The possibility that the problem will be detected by a second party, particularly resource agency personnel, might influence the decision of a mine operator to report. Nonetheless, for this thesis, mine operators generally exhibited an openness and willingness to identify impact management difficulties that had arisen.
4.3.1.4 Consequences to Mine Operators

As indicated in the results section (section 4.2), three of the 13 Stage I mines and one Stage II mine had impact management problems that resulted in convictions and/or relatively large financial expenditures. A fourth Stage I mine (Summit Lake) made a large expenditure to deal with a problem, but was not charged. The circumstances of the problems vary greatly and generalizations cannot be made, other than stating that three problems involved the release of cyanide. In one case direct effects on fisheries resources are felt to have occurred. In a second but similar case (involving the release of cyanide), direct effects are not felt to have occurred yet a conviction resulted because the terms of the discharge permit were not complied with. In a third case, which again involved the release of cyanide, neither direct effects appear to have occurred nor were charges laid, but, nonetheless, the mine operator incurred a relatively high cost to correct the problem.

4.3.2 Analytical Weaknesses Related to the Occurrence of Serious Problems

Where problem sources were referred to in reports, mitigative measures were generally described but the types and amount of potential effects prior to mitigation either were not described or were described very briefly. Consequently, report authors did not attempt to use the amount of possible effect for defining the amount of mitigation to be achieved.

In the case of serious problems that developed, the main weaknesses in the impact analyses are:

- the unchallenged assumption that a chosen mitigative measure would work (alkaline chlorination for cyanide removal at Stage I gold mines); and,
- the incorrect conclusion about the possible seriousness of an impact problem (acid generation at the Stage II Equity Silver mine), followed by failure to heed statements by the analyst that the conclusion was subject to uncertainty.

4.3.3 Adequacy of the Impact Assessment Process

The results indicate that, amongst the mines studied, a Stage I mine
entering the MDRP and entering production had a 1 in 3 likelihood of developing a relatively serious aquatic resource impact management problem. The mines studied had entered the review process shortly after its adoption in 1979. In fact, high metal prices at that time resulted in a relatively large number of report submissions over the 1979-1982 period (shown in Figure 4-1). Since that period, the review procedures have been modified (as discussed in Chapter 3.0), and allow closer examination of mines entering the review process. The one Stage II that developed a relatively serious problem actually submitted pre-development reports to the provincial government before the formal review process for metal mines was in place.

Other factors that must be considered when interpreting the numbers of problem that have occurred include:

i. the fact that three mines (Banbury Brussilof, and Free Gold) operated at "pilot-scale" levels of production;
ii. the Venus mine operated for only two weeks before shutting down; and
iii. five Stage I mines (Silence Lake, Skomac, HB, Table Mountain, Vollaug) and one Stage II mine (Goldstream) operated at a lower level of production than expected and/or for only one season.

This means that of the Stage I mines, four (Baker, Ladner Creek, Summit Lake and Taurus) operated at near-capacity production levels for more than one season. Under these operating conditions, 3 out of 4 Stage I mines had relatively serious impact management problems. Whether this proportion accurately indicates the proportion of mines that would have had problems, had they all been at full levels of production, is questionable, given the relatively small number of mines studied. Intuitively, one would expect that, for a particular mine, the likelihood of problems developing would increase the longer the mine remained in operation.

4.4 Conclusions

1. Amount and Occurrence of Problems. Twenty-four problems occurred amongst the 13 Stage I mines and two Stage II mines that submitted pre-development impact assessments to the provincial government. Six of the
Figure 4.1 The number of Stage I reports (for Stage I mines) submitted to the Mine Development Review Process, 1979-1985.

Note that three reports were submitted as drafts in 1982 and then as final reports in 1983. These are counted as 1983 reports only.
Stage I mines and both Stage II mines had at least one problem. The sources of eight of the eventual problems were not identified in the pre-development assessments.

Four Stage I mines and one Stage II mine had a relatively serious problem. The possibility of these problems occurring had been foreseen in the pre-development studies. Some of the mines studied had operated at a reduced, pilot scale and/or very briefly. If pilot-scale mines and mines that operated for less than one season are not counted then three out of four Stage I mines had a relatively serious problem.

2. Types of Problem. The most serious problems appear to be those relating to the discharge of cyanide and metals above permitted levels at Stage I gold mines and to the generation of acid in waste rock at one Stage II sulphide ore mine.

The most common problems have been associated with equipment and structural failures, mainly tailings facilities (i.e. lines, pumps, and dams).

The pre-development assessments appear to have been relatively more effective for identifying routine discharge problems and general site runoff problems, than for identifying problems related to equipment or structural failures. Since the sources of routine discharge problems were anticipated in the pre-development studies, the reason that the problems occurred appears related to the choice and/or implementation of mitigative measures.

3. Effects on Aquatic Resources. Effects on fisheries resources were observed at only one Stage I mine and none of the Stage II mines. However, in general, effects on aquatic resources are recorded in terms of water quality and benthic invertebrates, not in terms of fish populations. The types of chemical and solid material released during problems at most mines indicate that the potential for more serious effects existed at other mines. It is possible that the effects of some problems were not detected given the
monitoring procedures in use.

Although most problems (46%) have been related to the failure of equipment or structures, especially tailings lines, pumps, and dams, environmental effects often have not been recorded.

The effects of mine development on the aquatic environment are not always negative. Nutrients from sewage and explosives appear to have had positive effects.

4. Consequences to Mine Operators. The study results suggest that mine operators can expect to spend up to 4% of their total pre-production costs to correct a serious problem after production begins. These costs could be incurred even if environmental effects are not clearly identified and court action does not occur.

Similarly, serious environmental effects do not necessarily have to be shown for a mine operator to be convicted of an offence.

5. Apparent Weaknesses in the Pre-development Studies. In the case of serious problems that developed, the main weaknesses in the impact analyses are:

- the unchallenged assumption that a chosen mitigative measure would work (ie. alkaline chlorination for cyanide removal)
- the incorrect conclusion about the possible seriousness of an impact problem (ie. acid generation), followed by failure to heed statements by the impact analyst that the conclusion was subject to uncertainty.

6. Adequacy of the Review Process. The results suggest that a Stage I mine entering the provincial review process between 1979 and 1982, and operating at full production for more than one operating season, had a 3 in 4 likelihood of having a relatively serious impact management problem. Two out of four such mines were convicted under environmental legislation and at least one mine incurred problem-related expenses of up to 4% of the total mine pre-operational costs.
The purpose of this chapter is to evaluate the analytical methods used for Stage I assessments, in order to identify possible weaknesses and opportunities for improvement.

The following factors were examined: the apparent influence of government guidelines and procedures; the theoretical weaknesses, based on analytical approaches and methods described in the literature (these are reviewed in Chapter 3.0); and, the improvements to analytical methods suggested in recent government Terms of Reference (TOR's). In addition, the types of information and methods used in monitoring and follow-up studies were examined for comparison with the pre-development studies. The thesis study methods are described below (subsection 5.1), and the results, discussion, and conclusions are presented in the subsequent subsections.

5.1 Study Methods

Five Stage I reports and two recent site specific TOR's were examined. These are listed in Table 5-1. As described in Chapter 2.0, the review process has been evolving since the early 1970's. Given the evolutionary nature of the review process, reports submitted at different times over the 1979-1983 period were examined. One report was submitted in 1979, two reports were submitted in 1980, one was submitted in 1981, and one was submitted in 1983. The TOR's were produced more recently, in 1984 and 1985. The Stage I reports include:

i. three "Stage I" mines identified in Chapter 4.0 as having relatively major problems with impact management systems (Baker, Ladner Creek, Summit Lake);

ii. one additional "Stage I" mine (Free Gold) that was amongst the other "Stage I" mines reviewed in Chapter 4.0. This mine did not have a major problem. And,
Table 5.1 Mines for which Stage I reports and terms of reference were reviewed.

<table>
<thead>
<tr>
<th>Mine Name</th>
<th>Date Report Submitted</th>
<th>Mine Entered Production</th>
<th>Relatively Serious Problem Developed</th>
<th>Conviction Resulted</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STAGE 1 REPORTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baker</td>
<td>March, 1980</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Blackdome</td>
<td>January, 1983</td>
<td>No</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Free Gold</td>
<td>April, 1981</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Ladner Creek</td>
<td>July, 1979</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Summit Lake</td>
<td>February, 1980</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>TERMS OF REFERENCE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quesnel Fluorospar</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nickel Plate</td>
<td>3</td>
<td>-</td>
<td>-</td>
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</table>

1 An addendum was submitted in December, 1979.

2 Prepared in 1984

3 Prepared in 1985
iii. one "Stage I" mine that has not yet entered production (ie. Blackdome) and was therefore not reviewed in Chapter 4.0. The Stage I report for this mine was reviewed as a draft submission in 1982 and was submitted as a final report in 1983.

The contents of the reports and TOR's were reviewed, firstly, to determine to what extent analytical methods were influenced by government review guidelines and, secondly, to identify specific analytical weaknesses. The general contents of the Stage I reports and TOR's are outlined in Appendix V.

5.1.1 **Influence of Provincial Review Guidelines**

The procedural guidelines prepared in 1979 to assist mine proponents (Ministry of Energy, Mines and Petroleum Resources 1979) were reviewed to identify what analytical methods are recommended for use in pre-development studies. A memorandum (MacDonald 1984) issued by the MEMPR in September, 1984, and describing the revised MDRP, was also reviewed.

The contents of each Stage I report and TOR were compared to the topics and analytical methods recommended in the government guidelines.

5.1.2 **Identification of Analytical Weaknesses in Pre-development Studies**

The information and methods used in each report described above was examined in greater detail and were compared to theoretical concepts and methods in the EIA literature (reviewed in Chapter 3.0). The literature review was used to identify analytical features that could be included in the MDRP Stage I reports.

In addition, the types of information and methods used in studies conducted after metal mines begin operation were reviewed, and were compared with the types of information and methods used in the pre-development reports. Monitoring requirements and problem-specific studies for six Stage I mines and two Stage II mines were reviewed. The Stage I mines include three for which Stage I reports were examined (ie. Baker, Ladner Creek, and Summit Lake). The results of the review are summarized in Appendix IV.
The information requirements outlined in the two TOR's were compared to the type of information used both in previous Stage I reports and in post-start-up studies. These data were used to identify recent improvements to the previous analytical methods. The contents of the TOR's are summarized in Appendix VB.

5.2 Results

The influence of the provincial review guidelines is examined in subsection 5.2.1, and the weaknesses in analytical methods are examined in subsection 5.2.2.

5.2.1 Influence of the Provincial Review Guidelines

The analytical requirements outlined in the government guidelines are described in subsection 5.2.1.1. The conformity of the Stage I reports and TOR's to these requirements are examined, respectively, in subsection 5.2.1.2 and subsection 5.2.1.3. A summary of findings is presented in subsection 5.2.1.4.

5.2.1.1 The Analytical Requirements Outlined in the Government Guidelines

The types of information and analyses recommended for use by mine proponents in the former 1979 "Procedures" and outlined in the 1984 Memorandum describing the revised review process are summarized separately below.

a) The 1979 "Procedures"

i. Stage I Report

"The Stage I report should provide sufficient detail to inform regulatory and non-regulatory agencies about the current status of the project. The report should contain:

- a description of the existing environmental and social conditions that could be affected by the proposed development.
- a detailed project description including options that have been considered.
- a preliminary environmental and social impact assessment.
- an outline of proposed further studies."

...
The "Procedures" provide a recommended outline for the Stage I report, in which they state that the section on Environmental and Social Impacts "should address itself to significant impacts or an identification of environmental concerns which will be assessed in submissions for permit applications." The recommended outline acts as a checklist of topics to be covered and is shown in Appendix VI. No guidance is provided on how "significant" impacts or concerns should be determined.

ii. Stage II Report

"The format of the Stage II report remains flexible to accommodate the specific requirements of each proposed development. The content and format is left to the discretion of the proponent and consultant. It may be in the proponent's best interest to consider two reports, one covering the minesite and another, housing. Whatever the format, the Stage II report must contain a description of the final project design including:

- project description including options considered
- proposed housing for employees
- environmental and social impact assessment
- management of impacts"

Again, no guidance is provided on how impacts should be analyzed.

b) The Revised Procedures

The 1984 Memorandum issued by the MEMPR indicates that new guidelines are presently being prepared. The guidelines are to contain technical appendices outlining government information requirements. The memorandum indicates that these might include: biophysical/technical information; reclamation guidelines; tailings impoundment guidelines; sediment control guidelines; and pollution control objectives. In addition a checklist of potential topics required in proponent submissions might be included.

5.2.1.2 Conformity of the Five Stage I Reports With the 1979 Procedures

The contents of each report are summarized in Appendix VA. Information contained in each report is compared below to the contents and format recommended in the 1979 "Procedures" (Appendix VI). The information is examined in terms of the major topics addressed, the relative emphasis on
major topics, the subtopics addressed, and the apparent analytical framework.

a) Major Topics Addressed

Although titles of major sections vary, all reports contain the following major sections: "Introduction"; "Description of Existing Environmental and Social Conditions"; "Project Description"; "Environmental and Social Impacts". Two reports (Baker and Summit Lake) do not present a section outlining "Proposed Further Studies". Also, discussion of impact management measures differs amongst the reports. The Baker, Ladner Creek and Summit Lake reports present separate sections describing "Potential Impacts" and "Mitigative Measures". The Free Gold and Blackdome reports do not separate potential impacts and mitigation, but provide a general discussion of both, segregating the discussions under resource categories. All reports contain appendices, though the type of information presented varies considerably.

b) Relative Emphasis on Major Topics

The Blackdome, Ladner Creek and Summit Lake reports are substantially longer than the 100 page report-length suggested in the 1979 Procedures. Those reports range from 137 pages for the Summit Lake report to 182 pages for the Blackdome reports.

The proportion of reports used to describe existing environmental and social conditions (including relevant appendices, tables and figures) is generally greater than the suggested amounts (ie. 30%) in all reports. The environmental sections of all reports except the Free Gold report contain the results of environmental field studies. Note that the proponent for Ladner Creek was required to submit an addendum describing the tailings dam and water management measures.

The proportion of reports used for the analysis and description of impact varies, but in three reports (Ladner Creek, Summit Lake and Free
Gold) is less than the amount recommended (i.e. less than 10% of the total report). Similarly, the proportion used to describe further studies is low or absent in all cases.

c) **Subtopics Addressed**

Compared to the subtopics recommended in the 1979 Procedures for describing existing environmental conditions, all reports present information on: "Hydrology", "Fisheries", and "Water Quality". Groundwater is not addressed in the three reports submitted before 1981 (Baker, Ladner Creek, Summit Lake). Note that the serious problem at Baker (described in Chapter 4.0) involved the groundwater transport of chemicals from the tailings impoundment to a nearby stream. The Baker and Ladner Creek reports include a subtopic (aquatic invertebrates) not suggested in the 1979 Procedures.

With respect to the project description, the subtopics recommended in the 1979 Procedures but not included in some Stage I reports are: drainage control and monitoring and effluent control and monitoring. Reports for two out of the three mines (Ladner Creek and Summit Lake) at which major problems developed did not address these subtopics. Drainage control at Ladner Creek was subsequently addressed in an addendum. All reports except the Free Gold report include the results of acid generation tests, though this is not a recommended topic in the 1979 Procedures.

d) **Apparent Analytical Framework**

The manner in which information is presented in the reports suggests two basic approaches to the impact analyses. These are outlined in Figure 5-1. The analytical framework that would be used if analysts followed the Stage I format suggested in the 1979 Procedures (Appendix VI) most closely resembles that for the two reports submitted in 1981/1983 (Free Gold and Blackdome).

Three reports, (Baker, Ladner Creek, Summit Lake) position the
Figure 5.1 Apparent analytical frameworks in five Stage I reports.

PROJECT DESCRIPTION
(Alternative Sites)
(Mitigation)
(Monitoring)

IMPORTANT RESOURCES

IMPACT ANALYSIS
(Identify potential impacts)

IMPACT ANALYSIS
(For separate resource categories, source of effect and mitigation discussed)

FUTURE STUDIES

PROPOSE FURTHER STUDIES
(Location and design of tailings dam)

NO FURTHER STUDIES

ADDENDUM

1. LADNER CREEK
1. BAKER
2. SUMMIT LAKE

1. FREE GOLD
2. BLACKDOME

water quality and quantity monitoring
"Environmental Description" section behind the "Project Description" section. These reports are for mines that eventually had serious problems. Placing the description of environmental features section behind the section describing features of the project might simply be "house-keeping" during report preparation, but represents an interesting shift in the flow of logic for analyzing impacts. Since discussion of mitigative measures is presented in the project description section, this sequence implies that mitigative measures are developed prior to and independently from the analyses of existing environmental and social conditions. Clearly, such measures would not be developed for specific important resources identified downstream and would apply regardless of the mine location. The 1979 Procedures direct mine proponents to include mitigative measures in the "Project Description" Section, but after preparing a description of the surrounding environment.

5.2.1.3 Conformity of the Recent Terms of Reference

A list of the topics and subtopics contained in each TOR is presented in Appendix VB. Basically, the major aquatic-resource topics are the same as those prescribed in the 1979 Procedures (cf. Appendix VI) and found in recent Stage I reports (i.e. Surface Water Quantity and Quality, Groundwater Quantity and Quality and Fisheries).

Several subtopics described under the "Waste Management" topic are also indicated in the 1979 Procedures and are found in some previous Stage I reports (i.e. effluent discharge, drainage, tailings disposal). Subtopics not prescribed in the 1979 Procedures, but identified in the TOR's and often addressed in the previous Stage I reports are acid generation potential, toxicity and fish habitat assessment.

An analytical framework similar to that described above is not evident in the TOR's.

5.2.1.4 Summary

a) The government guidelines provide guidance on the type of descriptive
information to consider, but not on the methods to be used for impact analysis.

b) In general, the Stage I reports present the type of descriptive information suggested in the 1979 Procedures.

c) Later reports address several subtopics recommended in the 1979 Procedures but not included in earlier reports; for example, groundwater and the control and monitoring of effluent and drainage.


e) The Terms of Reference address the same major environmental topics recommended in the 1979 Procedures but also include some subtopics not previously recommended (e.g., acid generation potential).

5.2.2 Identification of Analytical Weaknesses

Based on the review of analytical approaches and methods in Chapter 3.0, the information and methods used in the Stage I reports and TOR's was examined using the following categories:

a) Conceptualization of interaction between the mine and fisheries resources

b) Identification and description of important fisheries resources

c) Identification of sources of effect

d) Development of measures to protect the important fisheries resources

e) Conclusions and interpretations of impact

For each topic, the information and methods found in the reports were compared to theoretical concepts and methods described in the EIA literature (Chapter 3.0). In addition, the information in the reports was compared to information used in post-start-up studies. The types of information collected in the post-start-up studies is summarized in Appendix IV.
The type of information and analytical methods used in the five pre-development assessments and in the two recent Terms of Reference are examined, respectively, in subsections 5.2.2.1 and 5.2.2.2.

5.2.2.1 Five Pre-development Assessments

a) Conceptualization of Mine-fisheries Interaction

No report presented a conceptual outline of the type of interaction expected between the mine and fisheries or other aquatic resources.

b) Identification and Description of Important Fisheries Resources

i. Factors Considered

The fisheries resource features considered in each report are summarized in Table 5-2. Related aquatic resource features such as hydrology and water quality were described in all reports, but in most cases were treated as separate resource features and were not discussed in relation to nearby fisheries resources.

In most reports, the important salmonids known to use the larger river systems and at least one type of related fishery (eg. sport) are identified and, in some cases, escapement figures are presented. For three reports (Ladner Creek, Summit Lake and Blackdome), field studies were conducted in tributaries near the minesite to identify what fish species were present and to provide details on the physical habitat features of nearby streams (for one report, Baker, aquatic field studies were conducted but fish data were not collected). Interestingly, even with this detail, the locations of critical habitat types (eg. spawning and rearing areas) and timing of fish use were generally not specified.

ii. Information Sources and Analytical Methods

The sources of information and analytical methods evident in the reports are examined in relation to the analytical features outlined in Step 2 of Chapter 3.0 (section 3.2). Four reports (Baker, Ladner Creek, Summit Lake, Blackdome) obtained information from provincial, federal and/or
Table 5.2  Fisheries resource features considered in each report.

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<td><strong>Main River Systems</strong></td>
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<td>Coquihalla River:</td>
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<td>- species present</td>
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<td>- steelhead importance and timing</td>
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<td>- recreational capability</td>
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<td>Finlay River:</td>
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<td>- species present</td>
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<td>Salmon River:</td>
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<td>- commercial and sport fisheries</td>
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<td>- anadromous and resident species</td>
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<td>- nearest expected spawning</td>
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<td>Bulkley River:</td>
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<td>Fraser River:</td>
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<td>- anadromous and resident species</td>
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<td>- salmon escapements</td>
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<td>- native food fishery</td>
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<td>- sport fish species and status</td>
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<td>- steelhead timing</td>
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<td><strong>Tributaries Near Minesite</strong></td>
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<td>- species identification</td>
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<td>- length, weight and condition factor, and general life history information</td>
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<tr>
<td>- water quality (physical habitat)</td>
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<td>- habitat types</td>
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<td>- water quality (aquatic invertebrate community)</td>
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<td>- possibility of fish usage (aquatic invertebrate community)</td>
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<td>- detailed habitat features and habitat types</td>
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<td>- salmon escapements</td>
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<td>- changes in hydrology</td>
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<td>- water quality</td>
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<td>- possible salmonid species</td>
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<td>- nearest expected spawning</td>
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<td>- water quality</td>
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1 field studies were conducted at all mines except Free Gold
2 this information is presented in report but is not discussed specifically in relation to fisheries resources
3 this information is presented separately in an appended subconsultant report
international resource agencies and from general or site-specific literature. The sources of information discussed in the Free Gold report are not indicated.

As indicated above, field studies were conducted for four reports. The type of data obtained during these studies is summarized in Table 5-3. The field studies generally included detailed habitat descriptions (based on methods used by the Ministry of Environment), fish collection, and water quality sampling. In several cases benthic invertebrates were sampled. In no case is it evident that field studies were undertaken to fill specific gaps in the information already available.

The scope of environmental factors chosen for description have been strongly influenced by the topics prescribed in the 1979 "Procedures". The reasons for choosing specific environmental factors (eg. "invertebrates" or "salmonids fishes" in Aquatic Resource or Fisheries Resource Sections) are not given in any report. Presumably, the analysts felt that the reasons for the choice of factors would be obvious.

The important aquatic resource features actually referred to in the report sections presenting impact analyses are listed in Table 5-4. Compared to the resource features described in the environmental section of each report, the features actually referred to in the analyses are very general. In fact, the relatively large sections describing resource features, particularly those incorporating the results of field studies, do not seem necessary for identifying the features considered in the analyses.

c) Identification of Sources of Effect

i. Sources Identified

The sources of possible effect identified in the "Impact Assessment" section of each report are summarized in Table 5-5. In terms of sources related to minesite activity: mine drainage water is referred to in three reports; development activities, acid generation and waste dumps are
Table 5.3  Field data obtained to describe fisheries resource features. 1

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<tbody>
<tr>
<td>Physical Habitat</td>
<td>-</td>
<td>RAB methodology 3</td>
<td>RAB methodology 3</td>
<td>not stated but evidently RAB methodology 3</td>
</tr>
<tr>
<td>Water Quality</td>
<td>collections on 2 occasions at 7 sites</td>
<td>collections on 3 occasions at 7 sites</td>
<td>collections on 1 occasion at 3 sites</td>
<td>collections on 4 occasions, but at different sites (a total of 10) and 2 sites were sampled twice</td>
</tr>
<tr>
<td>Fish</td>
<td>-</td>
<td>electroshocker surveys: pole seining: species identification; length, weight, condition factor</td>
<td>species identification and size</td>
<td>angling: species identification</td>
</tr>
<tr>
<td>Aquatic Invertebrates</td>
<td>taxonomic groups, relative abundance, and community diversity</td>
<td>taxonomic groups and relative abundance; authors indicate that samples retained for future calculations of diversity</td>
<td>taxonomic groups</td>
<td>-</td>
</tr>
</tbody>
</table>

1 field sampling by the proponent was not undertaken at Free Gold
2 presented in an appended subconsultant's report
3 RAB = Resource Analysis Branch, B.C. Ministry of Environment
Table 5.4  Fisheries resource features referred to in impact analyses.

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<tbody>
<tr>
<td>2. &quot;man, animals, fish&quot;</td>
<td>2. &quot;man, animals, fish&quot;</td>
<td>2. &quot;groundwater regime&quot;</td>
<td>2. &quot;hydrology of the area&quot;</td>
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Table 5.5  Sources of possible effect referred to in each impact analysis.

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<tbody>
<tr>
<td>Minesite</td>
<td>1. waste dump(^1)</td>
<td>1. waste dumps</td>
<td>1. mine water(^2)</td>
<td>1. exploration activities</td>
<td>1. development activities</td>
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<tr>
<td></td>
<td>2. mine drainage</td>
<td>2. acid generation in waste rock</td>
<td>2. development</td>
<td>2. closure</td>
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<td></td>
<td>3. mine abandonment</td>
<td>3. mine water</td>
<td>3. mine water</td>
<td>3. waste dump</td>
<td></td>
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<tr>
<td></td>
<td>4. acid generation</td>
<td></td>
<td></td>
<td>4. mine water</td>
<td></td>
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<tr>
<td>Millsite</td>
<td>1. general runoff</td>
<td>1. tailings effluent</td>
<td>1. mill discharge(^2)</td>
<td>1. mill construction</td>
<td>1. general runoff</td>
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<td></td>
<td>2. tailings pond construction, operation and abandonment(^1)</td>
<td>2. process chemicals</td>
<td>2. mill discharge chemical spills</td>
<td>2. tailings pond construction, discharge/operation and abandonment</td>
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<td></td>
<td>3. tailings pond runoff/washout</td>
<td>3. tailings discharge(^3)</td>
<td>3. tailings pond construction and abandonment</td>
<td>3. tailings pond seepage</td>
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<td></td>
<td>4. tailings seepage</td>
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<td>4. tailings pond seepage</td>
<td>3. water use/storage</td>
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<tr>
<td></td>
<td>5. tailings abandonment</td>
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<td>5. broken tailings lines</td>
<td>4. acid generation in ore material(^4)</td>
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<td></td>
<td>6. water use/storage</td>
<td>5. mill discharge</td>
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</table>

\(^1\) Refer to Table 5.4 for a detailed description of these mining activities.
Table 5.5 (Cont'd.)

<table>
<thead>
<tr>
<th>Category of Mining Activity</th>
<th>Report (Year)</th>
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<tbody>
<tr>
<td>Other</td>
<td>1. road construction</td>
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<tr>
<td></td>
<td>2. road construction</td>
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<tr>
<td></td>
<td>4. sewage</td>
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<td></td>
<td>6. fuel spills</td>
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1 acid generation tests indicated that ore waste rock and tailings material was not acid-producing - this information was not referred to in the impact analysis, but was presented elsewhere in the report.
2 referred to in appended subconsultant's report.
3 the mill was to be constructed within the underground mine.
4 discussed in relation to tailings discharge.
referred to in two reports; and, exploration activities, mine closure (i.e. due to subsidence), and explosives use are each referred to in one report.

In terms of sources related to millsite activity: mill and/or tailings discharge is referred to in all reports; tailings pond construction and abandonment is referred to in three reports; and, general site runoff, process chemical spills and water use/storage are referred to in two reports. Note that at the Summit Lake mine the mill was constructed within the underground mine. Problem sources identified in only one out of four reports are:

- mill construction activities
- tailings pond seepage
- broken tailings line
- acid generation in ore material (discussed in relation to tailings discharge)

In terms of other activities: road construction activities are identified in two reports; and, sewage, fuel spills and general equipment use during construction are each identified in one report.

ii. Analytical Methods Used

The analytical methods evident in the reports are compared to the methods outlined in Step 3 of Chapter 3.0. Descriptions of mining activities are presented in the "Project Description" sections of each report. However, invariably it is not clear that these have been systematically examined as possible sources of effect. Consequently, the manner in which the problem-sources were determined is not shown and reasons are not given to indicate why some mining activities are considered more important than others. In all cases, the reader is left with the uncomfortable feeling that the whole picture has not been considered. The method apparent in all reports can be described as "Ad Hoc", although the opportunity to use a "checklist" approach was available (Warner and Preston 1974; Munn 1979).

Separate examinations of the phases of mining activity (i.e.
exploration, construction/mine development, abandonment/closure) were presented in the Blackdome report and to a lesser extent in the Free Gold report. The phases of tailings dam activity were discussed in several reports (e.g. Ladner Creek).

c) Development of Measures to Protect Important Fisheries Resources

As discussed in subsection 5.2.1 (Influence of the Provincial Review Guidelines), the report sections that describe the types of effect and mitigative measures are generally small in relation to other report sections. Potential effects and expected effects are not clearly separated in most reports, and are usually discussed in general terms with the various sources of effect and mitigative measures. Potential effects, mitigative measures and expected effects have been identified where possible for each report and are discussed briefly below, in relation to theoretical features outlined in Step 4 of Chapter 3.0.

i. Descriptions of Potential Effects

The types of effect considered in each report are listed in Table 5-6. Usually important resource features were referred to in general terms (cf. Table 5-4) and the link between the resource feature affected and potential effect described is left to the judgement of the reader. The potential toxic effects to aquatic biota were discussed in four reports (Baker, Summit Lake, Free Gold and Blackdome) although the levels of detail varied. In the Blackdome study, actual fish bioassays had been conducted and the results were reported. For the Summit Lake report, bioassays had not been conducted but the potential lethal and sublethal effects and effects on different life history stages were discussed in an appended subconsultants report. In contrast, the Ladner Creek report referred to "contaminants" and "pollutants", but made no reference to toxicity.

A variety of other factors were considered in discussions of fish or fish habitat. The direct removal or impairment of fish habitat was
Table 5.6 The types of possible change to fisheries resource features considered in each impact analysis.

<table>
<thead>
<tr>
<th>General Resource Feature</th>
<th>Report (Year)</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Fish</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- habitat removal</td>
<td></td>
<td>- toxicity to fish</td>
<td>- toxicity of process chemicals to fish: (lethal vs. sublethal; life history stage)</td>
<td>- toxicity (process reagents)</td>
</tr>
<tr>
<td>- physical and</td>
<td></td>
<td>- increased sport fishing effort</td>
<td>- degradation</td>
<td>- bioaccumulation</td>
</tr>
<tr>
<td>chemical pollutants</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- barriers to movement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- reduction in food</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Quality</td>
<td></td>
<td>- siltation</td>
<td>- process chemicals (from spills)</td>
<td>- general quality</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- suspended solids</td>
<td>- process chemicals (from spills)</td>
<td>- nitrogen (from explosives)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- fuels</td>
<td>- discharge chemicals</td>
<td>- discharge chemicals</td>
</tr>
<tr>
<td>Hydrology</td>
<td>- drainage</td>
<td>- alternative</td>
<td>- groundwater flows</td>
<td>- surface flows</td>
</tr>
</tbody>
</table>

1 discussed in appended subconsultant's report.
considered in two reports; the possible effects on food resources of fish, the possible bioaccumulation of metals and the possibility of increased sport-fishing activity resulting from the mine presence were each discussed in one report. The importance of indirect effects was not explicitly addressed in any report. Also, the effects of changes in specific water quality features were often not discussed in relation to fisheries resources or human user-groups. For example, all reports considered the possibility of increased suspended solids and discharged chemicals but did not indicate why this was a concern. Three reports (Baker, Ladner Creek and Summit Lake) considered the potential for spills of process chemicals and one report (Blackdome) considered the potential for nitrogen increases from explosives use. Possible changes in the amount of surface water flow were considered in three reports (Baker, Free Gold, Blackdome).

ii. Mitigative Measures

The problem-sources for which mitigative measures were developed are shown in Table 5-7. Except in the Blackdome report, specific mitigative measures were described only for water quality features. In the Blackdome report, measures were also described to minimize effects on surface flow regimes. In no case is mitigation developed to reduce a specified quantitative potential effect.

The Ladner Creek report presents a discussion on mitigative "opportunities" that should be considered but does not outline those that would be adopted. An addendum to the Ladner Creek report provides more information on tailings dam design and stability and on drainage structures to be constructed to control runoff.

iii. Expected Effects

The expected or predicted changes to aquatic resources are summarized in Table 5-8. The terms "effect" and "impact" were loosely applied in the impact analyses, and in some cases seemed to indicate a possible change
Table 5.7 Sources of effect for which mitigative measures are described in each impact analysis.

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Minesite</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. exploration activities</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>2. development activities</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3. waste dump runoff</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>4. mine water</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>5. explosives use</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>6. mine closure</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>7. acid generation in waste rock</td>
<td>-</td>
<td>3</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Millsite</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. mill construction</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>2. mill discharge</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>3. tailings pond:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) construction</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>b) discharge/operation</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>c) abandonment</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>d) seepage</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>e) tailings line</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>4. process chemical spills</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5. general runoff</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6. water use/storage</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. sewage</td>
<td>-</td>
<td>1</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2. road construction</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>3. equipment movement</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>4. fuel spills</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5. minesite personnel (fishing)</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

1 mitigative measures described
2 mitigation stated to be unnecessary
3 identified as a source but specific mitigative measures not presented
4 designed for exfiltration
Table 5.8  Expected changes to fisheries and other aquatic resources.

<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Fish</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>habitat</td>
<td>&quot;no need for streambed degradation&quot;</td>
<td>-</td>
<td>-</td>
<td>no &quot;adverse effect&quot;</td>
</tr>
<tr>
<td>populations</td>
<td>&quot;minor increase in fishing pressure&quot;</td>
<td>effects &quot;extremely unlikely&quot;</td>
<td>&quot;no impacts on these species (16 kilometers downstream)&quot;</td>
<td>no &quot;direct effect&quot; (on Fraser River populations)</td>
</tr>
<tr>
<td><strong>Water Quality</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>siltation</td>
<td>&quot;problems are not expected to develop&quot;</td>
<td>&quot;small in relation to natural levels&quot;</td>
<td>-</td>
<td>&quot;unavoidable impacts short-lived&quot;</td>
</tr>
<tr>
<td>discharged chemicals</td>
<td>&quot;non-toxic&quot;</td>
<td>&quot;innocuous&quot;</td>
<td></td>
<td>no &quot;significant amounts&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>no &quot;adverse effects&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>no degradation of &quot;receiving waters&quot;</td>
</tr>
<tr>
<td><strong>Surface Hydrology</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;drainage alteration will be minor&quot;</td>
<td></td>
<td>&quot;minimal adverse effects&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Groundwater</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&quot;little effect&quot;</td>
</tr>
</tbody>
</table>
in the condition of the environment and in others to indicate the significance of the change.

Descriptions of expected change in aquatic systems were presented in all reports except the Ladner Creek report. In the Ladner Creek report, areas of concern were identified but preliminary predictions were not put forward. For those reports in which predictions were made, the descriptions were usually brief, general comments on the type of chemical and/or biological change that might be expected. In all cases no serious changes were expected in the receiving environment.

Quantitative predictions of the magnitude of the possible effects were not made, though undefined terms such as "little", "small" and "minimal" were used. Three reports made predictions in terms of the nearest known or suspected areas utilized by fish (ie. Summit Lake, Free Gold, Blackdome). Some statements indicate that predictions are based on the likelihood or risk of problems occurring, but uncertainty about the type and magnitude of predictions is not explicitly addressed and used as a basis for further study. However, the Free Gold report indicates that a mine-water sedimentation pond would be constructed if water quality monitoring indicated a need. Note that for the cyanide problems at Baker and Summit Lake (described in Chapter 4.0), statements in the respective reports indicated firmly that cyanide would not become a problem after treatment with alkaline chlorination.

In all reports, neither cumulative effects nor the kind of recovery that impacted factors in the surrounding environment would display, once the sources of impact were removed, were discussed. Similarly, except in the Summit Lake report, the predictions did not distinguish what the environment might be like "with" the project from what it might be like "without" the project. In the Summit Lake report, possible sediment production caused by mining activity is discussed in relation to the high levels of sediment that
occur naturally in downstream waters. However the natural levels are not defined.

The methods or body of knowledge (i.e. professional experience, general literature etc.) by which predictions were derived were not described and in general appear to be the professional judgement of the analysts.

iv. Further Studies

As indicated earlier, two reports (Baker and Summit Lake) do not outline further studies to be conducted. Two reports (Free Gold and Blackdome) indicate that baseline water quality conditions are to be the subject of further study and two reports (Free Gold and Ladner Creek) indicate further studies would be conducted to locate and design tailings ponds. The three reports at which relatively major problems developed (Baker, Ladner Creek, and Summit Lake) did not propose that water quality be the subject of further study. Even those reports that do indicate that baseline and on-going water quality studies are to be conducted provide no details concerning the substances to be sampled nor the location and frequency of sampling.

e) Conclusions and Interpretations of Impact

Conclusions concerning the expected severity of impacts on fisheries and general resources are summarized in Table 5-9. As indicated above, in most cases it is not clear whether analysts are describing changes in resource features or assessing the value of those changes. However the statements in Table 5-9 are the only summary conclusions of impact provided in the respective reports. As with the identification of expected change in resource features, the determination of the significance of impacts appears to be largely the professional judgment of the analyst and where conclusions about significance are made criteria are not presented.

f) Comparison with Post-start-up Studies

Once production begins, the effects of mining activity are examined by
Table 5.9  Interpretations of impact presented in each Stage I report.

<table>
<thead>
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<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Fish Resources</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&quot;extremely unlikely that this</td>
<td>&quot;there is a</td>
<td>&quot;expected to have</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[Salmon River] could be</td>
<td>potential for</td>
<td>no direct effect</td>
<td></td>
</tr>
<tr>
<td></td>
<td>affected&quot;</td>
<td>impact&quot;</td>
<td>on the Fraser</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;no impacts on</td>
<td>River fish</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>these [known</td>
<td>populations&quot;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>downstream]</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>&quot;species would be</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>expected&quot;</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>&quot;the residual</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>potential for</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>impacts is minimal&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>General</strong></td>
<td>&quot;major environmental impacts&quot;</td>
<td>&quot;environmental</td>
<td>&quot;insignificant</td>
<td>&quot;the impacts on</td>
</tr>
<tr>
<td></td>
<td>are not expected given &quot;due</td>
<td>impacts from the</td>
<td>environmental</td>
<td>the physical and</td>
</tr>
<tr>
<td></td>
<td>attention to mitigation</td>
<td>Scottie mine and</td>
<td>damage or land</td>
<td>biological</td>
</tr>
<tr>
<td></td>
<td>procedures&quot;</td>
<td>mill should be</td>
<td>conflict will</td>
<td>resources will</td>
</tr>
<tr>
<td></td>
<td></td>
<td>negligible&quot;</td>
<td>arise&quot;</td>
<td>be minimal&quot;</td>
</tr>
</tbody>
</table>


a routine monitoring and inspection program and, where the need arises, more intensive field studies. The types of information obtained during these investigations is briefly described in Appendix IV.

In general, sampling is more frequent for the monitoring programs, compared to data collected during pre-development field studies. For example, sampling frequency for tailings ponds and outflow, mine drainage and surface receiving waters varies from once per week to once every three months. As shown in Table IV-1 of Appendix IV, pre-development sampling in receiving waters is highly variable, ranging from no occasions at Free Gold to four occasions at Blackdome. Also, the monitoring programs include types of information usually not obtained during the pre-development studies (eg. bioassays and background levels of residuals, such as cyanide).

Besides the monitoring studies at operating mines, more intensive studies are undertaken when problems are suspected. Information obtained during the intensive studies, but not presented in pre-development assessments includes:

- metallothionein levels in fish livers
- metal concentrations in invertebrate tissue
- zooplankton (daphnia) bioassays
- periphyton studies
- metal content in sediments
- particle-sizes of suspended solids

Anticipation of post-start-up data requirements does not appear to improve in the later pre-development studies (1979/1983), compared to the earlier ones, though differences are evident. For example, fish bioassays are commonly undertaken in post-start-up studies. Pre-development bioassays are described in the Blackdome report but not in the earlier reports. In contrast, benthic invertebrate studies are also commonly undertaken in post-start-up studies and are presented in the 1979/1980 pre-development studies, but not in the Blackdome report (or the 1981 Free Gold report).
g) Summary

i. Conceptualization of mine-fisheries interaction. General conceptualizations of mine-fisheries interaction were not presented in the reports reviewed.

ii. Identification of important fisheries resources and of sources of effect. Important fish species are usually identified but descriptions of critical locations are vague. The other types of information and analytical methods vary considerably amongst the reports. For example, the 1983 Blackdome report includes some factors not found in earlier reports (e.g. explosives use; separate consideration of the phases of mining activity), but does not include other factors that are found in those reports (e.g. spills of process chemicals and fuels).

iii. Development of measures to protect important fisheries resources. The development of specific impact management strategies is difficult to assess because the sections presenting impact analyses are usually brief and very general. In fact, discussions of mitigative measures, expected effects, interpretations of impact significance, and further studies were not directed at specific resource features and would apply regardless of the environmental reviews and studies presented in previous report sections.

iv. Comparison with post-start-up studies. The types of data and sampling frequency used in the post-start-up studies differ from the data and sampling frequencies evident in the pre-development reports.

5.2.2.2 Two Recent Terms of Reference for Pre-development Assessments

The Ministry of Environment Terms of Reference (TOR) for the Quesnel Lake Fluorspar Project and the Nickel Plate Gold Project were reviewed. The general objectives and the information and analytical requirements for managing impacts on fisheries resources are outlined in Appendix VB. Below, the information and analytical requirements are compared to the analytical methods evident, firstly, in previous Stage I reports and, secondly, in
post-start-up studies.

a) **Comparison with the Previous Stage I Assessments**

Whereas the Stage I reports (and the 1979 Procedures) emphasize presentation of descriptive information, the TOR's emphasize "impact management planning". The type of information requested in the TOR's is compared below to the information actually presented in previous pre-development studies.

i. **Conceptualization of Mine-Fisheries Interaction**.

As with the Stage I reports, an explicit conceptualization of the interaction between the mine and fisheries or other aquatic resources is not presented; nor is one requested. In a sense the TOR's are themselves the conceptualization.

ii. **Identification of Important Resources**.

Information requested in the TOR's but usually not presented in previous Stage I reports includes:

- fish habitat utilization and capability
- studies of the seasonality of benthic invertebrates
- qualitative and quantitative sampling of the periphyton community
- determination of the metal content in fish muscle and of metallothionein levels in fish livers
- documentation of downstream water uses
- groundwater studies

iii. **Identification of Sources of Effect**

Information requested in the TOR's but not evident in the previous studies includes:

- breakdown products of processing reagents
- influence of blasting agents (except for the 1983 Blackdome report)
- mapping of sources of effluent and refuse during mine development
- pipeline ruptures
- reagent transport
- concentrate transport

iv. **Development of Measures to Protect Important Fisheries Resources**

Information requested in the TOR's but usually not presented in previous Stage I reports includes:
- **Potential effects/Supplementary studies.** Chemical analyses of pilot-scale or laboratory mill tailings; bioassays or studies of pond supernatant toxicity (except the 1983 Blackdome report); quantities of groundwater or leachate, if quality is poor; minerals in ore that might affect cyanide destruction; reagent addition rates and locations; modelling of particulate emissions; determination of effluent flow rates and quality before/after treatment. Also, studies of ore radioactivity, concentrate transport across a lake, and the effects of lake drawdown; these studies appear specific to the mines under review.

- **Mitigative measures.** Presentation of a draft surveillance and supervision plan; development of spill contingency plans for chemicals, oil products and concentrates; storage of runoff and drainage water and contingencies if storage is exceeded; long-range, post-operating controls for mine site drainage, tailings supernatant and seepage; equipment and methods for the transport of a process chemical (i.e. cyanide).

b) **Comparison with Post-start-up Studies**

Data collected during post-start-up studies are described in Appendix IV.

Data collected during post-start-up studies, outlined as pre-development requirements in the TOR's, and not collected during previous pre-development studies includes:

- metallothionein levels in fish livers, and
- characteristics of the periphyton community.

Data not outlined as a pre-development requirement in the TOR's and not collected during previous pre-development studies includes:

- metal concentrations in invertebrate tissue
- zooplankton (Daphnia) bioassays
- metal content of sediment
- particle-sizes of suspended solids.

c) **Summary**

The TOR's emphasize development of impact management plans. Also, the TOR's appear to represent the government conceptualization of mine-fisheries interaction. Compared to information presented in the previous Stage I reports, the TOR's request more information in each of the following categories:

- identification of important resources;
- identification of sources of effect; and,
- measures to protect important fisheries resources.
The TOR's do not request, as pre-development data, some types of information obtained during post-start-up studies.

5.3 Discussion

The types of variability amongst reports, the apparent influence of the government guidelines and procedures, and the analytical weaknesses and improvements in the pre-development studies and TOR's are discussed below.

5.3.1. Variability Amongst Stage I Reports

The Stage I impact analyses are subject to several types of variability, including:

- differences in the mine type and location
- differences in the capabilities of report authors
- changes in the requirements of the review process over time

Clearly, the type of mine and its location will influence the specific project and resource features examined at a particular site, but should not necessarily influence the basic analytical approach and methods. In contrast, the Stage I reports were prepared by a variety of authors and the analytical capabilities of each have likely influenced the quality of the respective impact analyses. The review process imposes no restriction on who might undertake the impact analyses and, consequently, must act as a screening process both for site-specific impact issues, and for analytical quality. As described in Chapter 2.0, the review process has itself been evolving. Amongst the reports reviewed, one (Ladner Creek) was submitted in the same year that the MDRP began (1979) and three were submitted shortly afterwards (Baker, Free Gold, and Summit Lake). The Blackdome report was submitted slightly later, in 1983.

5.3.2. Influence of the Governmental Review Guidelines

The 1979 Procedures emphasize presentation of descriptive information but provide little guidance on analytical requirements. In consequence analysts for Stage I reports have emphasized project and environmental descriptions and not actual analyses of impacts.
Since 1982, the provincial resource agencies have played a more active role undertaking reviews of draft Stage I reports and, more recently, preparing site-specific terms of reference for Stage I assessments (based on the submission of a development Prospectus). The recent Terms of Reference still request background information but emphasize development of impact management plans.

5.3.3 Analytical Weaknesses and Improvements

Analytical weaknesses and improvements are discussed below in terms of the conceptualization of mine-fisheries interaction (subsection 5.3.3.1), the identification of important resources at risk (subsection 5.3.3.2), the identification of sources of effect (subsection 5.3.3.3), and the development of mitigative measures (subsection 5.3.3.4).

5.3.3.1 Conceptualization of Mine-Fisheries Interaction

A conceptual framework for examining the type of interaction expected between mining activities and features of the aquatic environment is not explicit in either the Stage I reports or the TOR's. In both cases, report authors likely had their own image of what the interaction was, however these were unclear in both types of document. As indicated in subsection 5.2.2.2, the TOR's themselves are a type of conceptualization. However, as such, the TOR's tend to convey a somewhat disjointed picture of potential interaction, because information is categorized under topics which appear to reflect the separate branches within the Ministry of Environment (ie., Fisheries, Water Management, and Waste Management). The early and explicit development of a conceptual framework for describing the interaction between a mine and the nearby aquatic environment would assist in guiding the pre-development studies.

5.3.3.2 Identification of Resources at Risk

a) Defining Important Resource Features

The previous Stage I reports in general place a large emphasis on
describing the surrounding environment, in fact, often exceeding the amounts suggested in the 1979 Procedures. Important fish species and general habitat quality are usually identified. However, the locations of important habitat types and times of critical fish use are generally not presented. The recent MOE information requirements emphasize collection of the latter information and, furthermore, request information on habitat utilization and capability.

However, the information needs for identifying important resources and for defining baseline conditions to be measured during follow-up project assessments are not clearly separated. Some requested information appears superfluous for identifying the location of important resources and for refining impact management strategies; but important for monitoring changes after the mine enters production (e.g. benthic invertebrates).

b) Defining Baseline Conditions for Future Assessments

The type of information obtained during follow-up assessments has often not been the same as the type of information presented in the Stage I reports. A limited amount of water quality information is presented in some Stage I reports and water quality baseline studies are proposed for further study in others. However, as indicated in Appendix IV, water quality is only one of several factors examined during follow-up assessments.

Recent MOE Terms of Reference request some information that is currently obtained during follow-up assessments (e.g. studies of benthic invertebrates, periphyton and the enzyme metallothionein in fish liver). However, the intent or purpose of this information is not distinguished from the intent or purpose of other information, such as that directed at identifying and describing the important fish populations or habitat.

Since the two types of information have, for the most part, different purposes this should be indicated and perhaps the information should be
presented differently in the Stage I assessment. All information to be measured during follow-up assessments could be segregated and presented as a comprehensive package of baseline information, perhaps entitled "Baseline Ecological Profile for Future Assessment". This subsection of the report would contain all primary sampling information, i.e. those factors to be measured, such as water quality, the relative abundance and diversity of benthic invertebrate species, and metal content in sediments, invertebrates and fish tissue etc., plus supplementary sampling information, i.e. those factors that might affect interpretation of the primary sampling information, such as stream flow and precipitation at the time of sampling. The baseline profile could be presented as part of the Stage I report or the studies for the baseline profile could be outlined in the Stage I report and the data submitted later as a separate report. In fact, perhaps these data should be submitted as a Stage III report, since they are required for both Stage I and Stage II mines.

5.3.3.3 Identification of Sources of Effect

Identification and description of the separate activities of a mining project are a common feature in Stage I reports. The review of general sources of impact presented in Appendix IA indicates that the types of problem associated with the different mining activities have been well studied. However, in the reports reviewed, the use of project description information as a basis for systematically examining sources of possible effect is generally not evident. The list of project topics outlined in the 1979 "Procedures" provides an opportunity to use a simple checklist approach for examining possible sources of effect, but this opportunity does not appear to have been used. Although some possible sources (e.g. access roads, sewage, tailings lines) were perhaps felt by analysts to be of no further concern, there is no indication in some Stage I reports that they were even considered. The TOR's act as a preassessment of sources of effect.
Apart from the lack of systematic examinations of possible sources of effect, the Stage I studies appear weak in three general areas. These are: the assessment of the likelihood that equipment or structures might fail (based on the results obtained in Chapter 4.0); relating problem-sources directly and indirectly to specific resources at risk; and explicit consideration of the different phases of mining activity. These topics are briefly discussed below.

a) Assessment of the Likelihood that Equipment or Structures might Fail

Emergency situations relating to equipment failure and/or human error appear to be common causes of problems (cf. Chapter 4.0), but are usually not well considered in pre-development assessments. Recent MOE information requirements emphasize the need for preventative measures and contingency plans for some activities (e.g. spills of process chemicals). Nonetheless, a need is apparent for a systematic appraisal of all mining activities as potential problem sources, including the risk of failure or breakdown of some features.

b) Relating Problem-sources to Resources at Risk

This would likely be improved by developing a conceptual model of the mine-fisheries interaction, as discussed above. Two additional analytical techniques could be used. An impact matrix (Munn 1979) could be used to examine possible indirect effects as long as the matrix is kept manageable and applied to a specified resource feature (e.g. salmonid fish). Similarly, "worst-case" scenarios could be developed to assess the possible severity of effects on the specified resource features.

c) Explicit Consideration of Different Phases of Mining Activity

In general, the literature describing possible effects of mining activity on the environment indicates that the separate phases of mining activity should be addressed. This has either not been done or done only to a limited extent in the reports reviewed. As described in Appendix I, the
various mining activities can be grouped according to the stages of development that will occur for the mine (e.g. Pre-production, Production, Post-production). Ripley et al. 1978 divided the activities associated with the development of a mine into six phases: exploration, development, extraction, beneficiation (i.e. milling) further processing (i.e. smelting and refining), and reclamation and abandonment. Ripley et al. and other authors (e.g. Marshall 1982) usually portray, graphically, these phases of mining activity as discrete components of a continuous process. Such a portrayal might be appropriate for presenting a description of ore treatment by a mine, but I feel it is inappropriate as a conceptual framework for interpreting sources of impact.

The phases of mining activity are not temporally discrete and substantial overlap can occur; a more realistic conceptualization is shown in Figure 5-2. This in turn can affect how one visualizes potential impacts. For example, "exploration" is not necessarily discontinued once "development" is started, and on-going exploration activities might not only provide direct sources of impact but, if new ore reserves are found, might extend the life of the mine and milling operations and thereby alter the time frame of the EIA. In fact this conceptualization shows that impact management planning should begin before "exploration", and not once development has begun.

5.3.3.4 Development of Mitigative Measures

In most Stage I reports, the actual analysis of impacts was brief and general. The analyses were not used as a focus to identify outstanding uncertainties that should be addressed through more intensive study. The identification of potential effects, choice of mitigative measures and management of emergencies are briefly discussed below.

a) Identification of Potential Effects

For understanding the potential effects and designing appropriate
The general phases of mining activity in relation to the stages of mine production.

<table>
<thead>
<tr>
<th>Time Axis</th>
<th>Stage of Production</th>
<th>Phases of Mining Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PRE-PRODUCTION</td>
<td>Exploration → Development (on-going) (removal of unwanted material)</td>
</tr>
<tr>
<td></td>
<td>PRODUCTION</td>
<td>Extraction Beneficiation Further Processing</td>
</tr>
<tr>
<td></td>
<td>POST-PRODUCTION</td>
<td>Abandonment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reclamation</td>
</tr>
</tbody>
</table>
mitigative measures, recent MOE Terms of Reference emphasize the need to determine acutely toxic effects to fish. These effects are generally easier to recognize and interpret than sublethal and chronic effects. However, some factors that likely will be assessed later during the "follow-up assessments", such as metal content in fish livers and invertebrates are likely to indicate the sublethal or chronic effects (e.g. bioaccumulation of metals). These differences in effect and their importance are not clearly explained in the MOE information requirements nor explicitly considered in previous Stage I reports. As discussed above in subsection 5.3.3.2 (Identification of Resources at Risk), this information should be clearly separated from information used to identify important resource features or to enhance predictions of effects.

b) Choice of Mitigative Measures

In the three Stage I reports where the impact analysts described a treatment method and assumed that the method would totally remove the problem (i.e. cyanide removal at Baker, Ladner Creek and Summit Lake), this assumption proved to be incorrect. If the analysts had assumed initially that the chosen method might not work, they possibly would have assessed alternative treatment methods or developed an adaptive approach to improving or replacing the treatment method. The use of adaptive strategies for EIA is discussed in Chapter 3.0.

Compared to most Stage I reports examined, an experimental approach to development of mitigative measures is evident in both a recent Stage I report (Blackdome) and the TOR's. For the Stage I report, mill-effluent discharge was simulated and the need for further treatment assessed. The 1984 MOE Terms of Reference for the Quesnel Lake mine, indicate that a similar approach be undertaken.

c) Management of Emergencies

Most impact management efforts appear directed at the easily
identifiable routine or chronic discharge sources. However, as shown by the results in Section 4.0, greater emphasis must be placed on managing "emergencies" due to structural or equipment failure. In particular, improved designs and/or operating procedures are required for tailings lines and pumps. The TOR's indicate a large improvement in contingency planning, requesting that contingency plans be prepared for possible ruptures in tailings lines, accidents, chemical and fuel spills, concentrate spills during transport, and overflows of stored runoff and drainage water. However the TOR's do not describe what is expected in the plans.

5.4 Conclusions

5.4.1 Influence of the Review Guidelines.

1. The analytical methods used in Stage I reports have been strongly influenced by the 1979 "Procedures" prepared by the B.C. Ministry of Energy, Mines and Petroleum Resources. However, the Procedures provided poor guidance on how impact analyses were to be used for developing impact management measures. Consequently, the Stage I reports are basically descriptions of the project activities and of the surrounding environment.

2. The review process imposes no restrictions on who might undertake the impact analyses and, consequently, must act as a screening process both for site-specific impact issues, and for analytical quality.

The review agencies evidently feel Stage I reports prepared using the 1979 "Procedures" have not been adequate, and that draft reviews and/or site specific terms of reference are necessary. This direct participation in the analytical process suggests a shift in at least some of the cost of analyses from the mine proponent to the public.

5.4.2 Analytical Weaknesses and Recent Improvements

1. Development of Mitigative Measures

Stage I Reports. Problems at minesites and weaknesses in Stage I reports have been mainly related to the assumption that mitigative measures
will work and to the failure of equipment or structures. Analytical weaknesses include:

- the absence of a critical appraisal of impact management measures in order to develop a contingency or fall-back strategy;

- no assessment of the likelihood that equipment or structures might fail and development of contingency plans to deal with these emergencies.

Terms of Reference. The TOR's appear to address the problems of equipment and structural failure, by recommending in some instances the preparation of contingency plans. However, the TOR's do not indicate what factors should be included in the contingency plans. Also, the TOR's do not emphasize the basic assumption that mitigative measures might not work, so that fall-back mitigative strategies might be developed in case the chosen measure is eventually found to be inadequate.

2. Identification of Sources of Effect.

Stage I reports. The main analytical weaknesses include:

- the absence of a systematic assessment of project activities as sources of potential impact; and,

- an apparent bias in both pre-development and post-start-up studies towards examining routine sources as opposed to emergency sources.

Terms of Reference.

Systematic appraisals of potential sources of effect are not evident in the TOR's, but the types of sources that should be considered are described. The TOR's in a sense, act as pre-assessments of such potential sources.

3. Identification of Resources at Risk

Stage I reports. The main analytical weaknesses include:

- poor identification of specific resources at risk and types of effect expected; and,

- no indication of the amount of effect expected without mitigation and with mitigation.

Terms of Reference. The TOR's outline information requirements that should better define what resources are at risk, compared to information
presented in previous Stage I reports. However, a clear description of the linkages between the mines and important fisheries resources is presented in neither the Stage I reports nor the TOR's.

Impact management planning is clearly the intent of the MOE terms of reference but what impacts are being managed and why are not clear because the management strategies are identified for separate but related facets of the aquatic environment (i.e. "Waste", "Surface Water Quality", "Fish" etc). These categories appear to reflect the interests of branches within the Ministry of Environment and perhaps represent a somewhat disjointed approach to managing impacts on the aquatic environment.

Like the previous Stage I reports, the TOR's do not suggest defining the amount of effect that could occur without mitigation (i.e. the possible worst-case situation).

4. Definition of Baseline Conditions for Future Studies

Stage I reports. Analytical weaknesses include:

- poorly defined quantitative information that could be used as a baseline for future monitoring, or details of what information would be collected as baseline information; and,

- the collection of information during assessments after mines began operation that differed from data collected as baseline during pre-development assessments.

Terms of Reference. The TOR's suggest collection of more information (compared to previous Stage I reports) that likely can be used as baseline data for monitoring, and that has been collected recently during post start-up assessments. However, the TOR's still do not clearly state what information is intended as baseline and what is intended to simply describe important resource features.

5. Procedural Considerations

In general, information requested in the TOR's appears to be mainly factors that would be expected from any mine development and would be more appropriate as a "guidelines" document for distribution beforehand. Some
form of procedural guidelines are presently being prepared.
CHAPTER 6.0  RECOMMENDATIONS

Recommendations are presented below for possible improvements to the methods currently used for impact management planning in relation to metal mine development. Recommendations are made separately for analytical and procedural improvements.

6.1 Analytical Improvements

An analytical framework for examining the effects of mine development on aquatic resources is shown in Figure 6-1. The recommendations made below are for each component shown in the analytical framework.

1. Conceptualization of Interaction Between The Mine and The Aquatic Environment

Neither the Stage I reports nor the government terms of reference present clear descriptions of the linkages between mining activities and the important aquatic resources that might be affected. An early and explicit description of these linkages would help to facilitate discussions between government technical staff and the mine proponent, and to guide the ensuing studies.

2. Identification of Important Resources at Risk

a) Anticipation of Follow-up Studies

The TOR's do not clearly define what impacts are being managed and why because separate management strategies are recommended for the separate but related facets of the aquatic environment (ie. "Waste", "Surface Water Quality", "Fish" etc). These should be synthesized into a single impact management plan, so that the important resources felt to be impacted are clearly identified and the planning and monitoring of mitigative measures at the problem-source are linked to the resource at risk.

b) Definition of Baseline Conditions

Reports submitted by proponents should contain a new section, "Baseline
Figure 6.1 An analytical framework for undertaking impact management planning at new metal mine developments in British Columbia.

- **PRE-STAGE**: Conceptualization of Interaction
  - **STAGE I**: Identification of Important Resources
    - Identification of Sources and Types of Effect
    - Development of Mitigative Measures
  - **STAGE II**: Refinement, if Necessary
  - **STAGE III**: Define Baseline Conditions
    - Implement Measures
    - Verify Measures (Adapt, if Necessary)
Conditions", that clearly defines information that has been or will be collected for use during follow-up assessments, or this information should be submitted as a supplement. In fact, as shown in Figure 6-1, quantitative baseline data could be submitted as a separate Stage III report.

3. Identification of Sources of Effect

The use of a formal checklist or abbreviated matrices (ie. directed at specific resource features) would help both the analyst and reviewer determine whether all potential impact sources were examined.

4. Other Improvements to Report Format

Stage I reports should emphasize information required to develop management strategies and should reduce the amount of descriptive material. "Project" sections should summarize what sources of effect have been identified and "Environmental" sections should summarize what important resources are at risk.

5. Development of Mitigative Measures

a) Analysis of Alternate Management Strategies

As shown in Figure 6-1, impact management strategies might have to be altered, if a problem develops after production begins. Mitigative measures should not be assumed to work and alternate or "fall-back" measures should be assessed and put forward in the event that the chosen methods do not work. The development of "worst-case" scenarios might assist to identify the type and amount of mitigation necessary.

b) Emergency Contingency Planning

Based on the results shown in Chapter 4.0, increased emphasis should be placed on identifying and planning for problems relating to equipment and structural failure, including the development of contingency plans. The government terms of reference request some kinds of contingency planning, but do not describe what is expected in such plans. The contents of the contingency plans should be defined. Also, in some cases, risk-of-failure
studies and "what-if" scenarios could be used to examine the likelihood and implications of equipment or structural failures, particularly tailings lines and pumps.

6.2 Procedural Improvements

An opportunity is apparent for the mining industry to undertake a stronger role in the development of analytical standards for impact assessment, both to absorb some of the costs of developing assessment procedures and to increase understanding amongst proponents as to the kind of analytical and impact problems that exist. This could perhaps be undertaken by an existing organization such as the Mining Association of B.C. Possible activities are:

- the development of a screening or certification system so that impact analysts are known to have a specialist capability, both in impact assessment and in mine development problems;

- the undertaking of annual audits of problems so that improvements in mitigative measures, predictive analyses and monitoring methods can be developed; and,

- the development of a Code of Good Practice both for impact analysis and for use by mine operators during the development and operation of the mine.
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APPENDICES
APPENDIX I. An Overview of the General Sources and Types of Impact from Metal Mines

This appendix provides a brief description of the general sources and types of impact from metal mine development, particularly in relation to the mines examined in Chapter 4.0. The general sources of impact are reviewed in Section A and the types of effect that can occur in relation to fisheries resources are reviewed in Section B.

A. General Sources and Types of Impact from Metal Mines

To facilitate a comprehensive examination of the impacts produced by mining operations, Ripley et al. 1978 divided mining activity into six sequential phases:

"i exploration, which may consist of geochemical or geophysical techniques, followed by the drilling of promising targets and delineation of orebodies;

ii mine development, or preparing the mine for production by shaft sinking or pit excavation, building of access roads, and construction of surface facilities;

iii the ore-removal activities which take place at the minesite itself; namely extraction and primary comminution (or crushing);

iv that which takes place at a mill usually located not far from the mine site and where a large fraction of the gangue from the ore is removed; namely, beneficiation or concentration;

v further processing, which may be carried out at any distance from the mine and results in the production of the final desired element or compound. This phase may involve a number of stages and be carried out at a number of locations: for the purpose of this study, only that processing carried out, in Canada, near the mine or mill will be considered; and

vi since every orebody is finite, the final phases are those of reclamation and abandonment."

In terms of mine production, exploration and development can be considered pre-production activities; extraction, beneficiation and further processing (ie. smelting and refining) can be considered production activities; abandonment can be considered post-production activities. Reclamation can begin during pre-production activities and continue well into abandonment.

The general types of impact that can result during the various phases of mining activity are described below for each phase. The descriptions are based mainly on information provided in Ripley et al 1978 and Marshall 1982. Although "Further Processing" of ore during the smelting and refining stages can lead to important pollution problems, it is not usually a component of mine development proposals. In most cases, ore concentrates are shipped to established local smelters (eg. the Cominco smelter at Trail B.C.) or direct to overseas markets. However, one category of "Further Processing", hydrometallurgy, is briefly discussed because it often takes place at the minesite and one type of hydrometallurgy (cyanidation) is used at a number of mines reviewed in Section 3.0 of the text.
1.0 Exploration Phase

During mineral exploration, the major effects on the aquatic environment result from the disturbance to land caused by the development and use of access roads. In particular, road construction and operation can lead to the production of sediment from the erosion of cleared rights-of-way, stream crossings and borrow pits. Once produced, the sediments from these sources might enter nearby lakes and streams. If soil overburden is removed from underlying bedrock during the exploration phase, sediments might also be produced by the erosion of overburden stockpiles. In addition, drilling operations and the mechanical removal of overburden can produce variable amounts of oils and greases, suspended solids, heavy metals, and acidic waste waters.

2.0 Development Phase

Prior to the extraction of ore, the ore deposit must be exposed, either by penetrating layers of non-ore rock with shafts and tunnels, in the case of underground mining, or by the complete removal of non-ore bearing material (both soil overburden and non-ore rock) in the case of surface mining. The amount of disturbance caused by the two kinds of mine development can differ; in general, surface mining disturbs a larger land area and produces much more waste material than underground mining. Regardless of the kind of mine development, the possible sources of disturbance to aquatic systems include the drainage from waste rock stockpiles (the chemical composition of the waste rock can affect the chemistry of drainage water), the soil erosion from disturbed land surfaces and the waste material produced both by an increased work force (e.g. refuse, sewage) and by the use of heavy equipment (e.g. oils, greases and hydraulic fluids).

3.0 Extraction Phase

Once overburden and wasterock have been removed to provide access to ore bodies and the extraction of ore begins, the production of waste rock becomes a continual feature of the extraction process. As during the development phase, the amount of waste rock produced during the extraction phase by surface mining is generally greater than by underground mining (in fact, the amount is approximately 50 times greater; Ripley 1978). Basically, the sources of possible disturbance to aquatic systems are the same as those described for the development phase, except that during the extraction phase, the removal of drainage water found within the mine itself becomes a new, on-going source of potential disturbance. Compared to the development phase, the extraction phase is of longer duration (i.e. for the life of the mine) and, obviously, the possible effects of mining activity will occur over a longer time-frame, limited by the length of time the mine remains in operation.

4.0 Beneficiation Phase

After the metal ore is extracted it is usually treated near the minesite to remove unwanted rock material, and to separate metal types for shipment. During this phase, three general steps are followed:

- Comminution - crushing and/or grinding of the ore to prepare the ore material for further treatment by reducing the size of rock particles
- Concentration - the separation of target metal types from other metal types and from waste material (i.e. tailings)
- Dewatering - removal of water from the concentrate
prior to shipment

In relation to potential impacts on aquatic ecosystems, the latter two steps are generally more important than the first. The crushers and grinders used during comminution can produce quantities of dust but unless dust production is in sufficient amounts to affect the drainages of nearby waterbodies, the potential damage from dust will be small compared to effects from waste-water and the tailings discharged during the concentration and dewatering steps.

4.1 Waste-water Discharge

The water discharged from milling operations can contain a variety of dissolved and solid residuals. These can include processing reagents, thiosalts (sulphur based salts originating both from the sulphide-containing ores themselves and from reducing-sulphur compounds used in the floatation process), suspended solids and the ubiquitous dissolved metals (Scott and Bragg 1975). Also, as with water drained from the mine, the waste water from the mill can be acidic. To remove the various contaminants before either reuse in the mill or release to the environment, the discharge water is usually treated in holding ponds which might, in some cases, be the tailings pond. The amount of water reuse by the mills and type of wastewater treatment system used varies greatly between mines, and depends on local conditions (such as available water supplies, amount of precipitation) and treatment costs.

One type of hydrometallurgy, the cyanidation process, occurs at most of the gold and gold/silver mines reviewed in Chapter 4.0 of the text. In fact, the cyanidation process is associated with three of the major impact-management problems identified in that section.

Generally, hydrometallurgy uses chemical solutions to "leach" or separate metals from the ore concentrate. In the cyanidation process, sodium or calcium cyanide is used to dissolve the gold or silver, which is then precipitated from the solution using a zinc or aluminum dust. The precious metal is then separated from the precipitate using high temperatures (i.e. pyrometallurgical methods). After the metal has been removed as a precipitate, the original solution contains quantities of cyanide, a potentially serious toxicant, that usually must be reduced. The technology for removing large quantities of cyanide is still developing.

Presently, alkaline chlorination is the most commonly used method, though a new process, described as the SO2/air process appears capable of removing larger quantities at lower cost (Devuyst et al. 1982). As shown in Chapter 4.0 of the text the alkaline chlorination process has not been adequate at a number of gold mines in B.C. The SO2/air process is a new method developed by International Nickel Company (which has filed applications to patent the process). The process uses SO2 and air to oxidize the cyanide and uses copper to catalyze the reaction and lime to make the reaction mixture slightly alkaline.

4.2 Tailings Disposal

Mill tailings are the fine rock material that remains after the chosen ore has been removed and concentrated. When discharged from the mill, the tailings are a slurry of water and small rock particles (approximately 0.05-1.0 mm in diameter), and usually have a low pH (or high acidity), relative to the surrounding water, and contain a variety of metals. Tailings are disposed of in one of two ways, either on land or in water, though land disposal, using earthen dams, is most common. Disposal underwater occurs in several locations in B.C., generally in areas having high precipitation (Poling 1977; Ellis 1982). In some cases the larger particle sizes in a tailings mixture are separated for use as backfill, in underground mines, or as construction material in the tailings dam.
4.3 Other Sources of Impact

The beneficiation phase requires sources of water and energy and a transportation facility for removing the ore concentrate. Local aquatic resources might be affected by the withdrawal of water, depending on the location of water removal facilities and on the amounts withdrawn, by the placement of a hydroelectric dam and/or transmission lines, if these are used to power the mill (and some equipment in the mine), and by spillage of ore concentrate, whether the ore is shipped by land (rail cars or trucks) or by water (barges or ships).

5.0 Abandonment and Reclamation

Reclamation of a minesite once extraction has ceased is usually directed at the rehabilitation of disturbed land surfaces, including tailings impoundments and waste piles (i.e., wasterock, soil overburden). The condition of these land surfaces and the adequacy of rehabilitation efforts will determine the kind, severity and persistence of effects to aquatic systems after the mine has been abandoned. Roots (1977) has claimed that the effects of mine development can be most serious after the mine ceases operation and is abandoned, but that in British Columbia, experiences of this kind are lacking, compared to parts of the world (such as Europe) where the mining industry has been established for a much longer time.

Ripley et al. 1978 indicate that, recently, the concept of reclamation has shifted from a "clean-up" activity once mining activity has ceased, to an activity incorporating an early detailed planning stage and an on-going implementation stage (including reclamation activity during the exploration and development phases). Impacts that might occur once reclamation measures have been implemented will depend on both the physical processes (e.g., wind and water erosion, mass wasting) and chemical processes (e.g., acid generation and leaching of toxic residuals) that continue to take place. Clearly, these processes and their effects must be anticipated as early in the planning stage as possible to prepare appropriate preventative measures.

B. Effects on Fisheries Resources

The effects of mine development on aquatic resources at the mines examined in Chapter 4.0 generally involved changes in water quality and, in some cases, changes in the benthic community. In most cases, effects on nearby fisheries resources were not directly observed and assessment of such effects is based on the interpretation of changes in water quality and/or the benthic community. The main factors that might have affected the fisheries resources near each mine are:
- cyanides and dissolved metals
- suspended solids and associated materials
- nutrients from sewage and explosives
- increased acidity

These are briefly discussed below.

1.0 Cyanide and dissolved metals

Discharges of high levels of cyanide and copper were the cause of major problems identified at Baker, Ladner Creek and Summit Lake. Both cyanide and copper can be toxic to aquatic organisms. However, interpretation of the direct and indirect effects of cyanide and metals is complex. The chemical form and toxicity of cyanide is affected by pH, temperature, dissolved oxygen, salinity, dissolved metals and other dissolved substances (Committee on Water Quality Criteria 1972; Clarke 1974; McNeely et al 1979). Some chemical forms of cyanide can become more toxic with exposure to sunlight (Committee on Water Quality Criteria 1972; Clarke 1974). Metals (e.g., copper and zinc) can also occur in a variety of chemical forms and
toxicity is determined by the chemical species and other factors such as temperature, hardness and turbidity. Cyanide and copper can affect fish directly, either lethally or sublethally, or indirectly by affecting food organisms such as benthic invertebrates. Also, metals can concentrate in tissues and consequently be passed on through the food chain and accumulate at higher trophic levels.

2.0 Suspended solids and associated material

Suspended solids were released from the broken tailings lines at Baker and the HB Mill, during the development of the Ladner Creek minesite, by a rockslide at Silence Lake and by the runoff from the Equity Silver millsite. At the time of the Baker incident high levels of cyanide were recorded in the tailings. Factors affecting interpretation of the effects of cyanide are discussed above. Also, at the time samples were taken at the Ladner Creek minesite elevated levels of other factors (alkalinity, hardness, and dissolved substances) was also recorded. The European Inland Fisheries Commission, EIFAC(1965) cited in the Commission on Water Quality 1972, indicate that suspended solids can be harmful to fisheries by:

"- acting directly on fish swimming in water in which solids are suspended either killing them or reducing their growth rate and resistance to disease;
- preventing the successful development of fish eggs and larvae;
- modifying natural movements and migrations of fish;
- reducing the food available to fish;
- affecting efficiency in catching fish"

3.0 Nutrients from sewage and explosives

Nitrogen compounds in the aquatic environment are usually produced or altered by a natural process (the Nitrogen Cycle) and include ammonia, nitrate, nitrite and organically-bound nitrogen. Under natural conditions, these compounds do not usually reach toxic levels, but if additional compounds are introduced, for example from sewage, toxic levels can occur (McNeely et al 1979). Ammonia and nitrite have the greatest toxic potential while organically-bound nitrogen is not of direct concern (McNeely 1979). Phosphorus is usually not toxic, but when nitrogen compounds are present can promote the growth of plant material. The overall effect of nutrients at the two mines (Baker, Ladner Creek) where increases were observed appears to have been positive.

4.0 Increased acidity

Increased acidity has been observed on a large scale at the Equity Silver mine. An increase in acidity can be directly toxic to aquatic organisms, can increase the toxicity of some substances (eg. zinc and cyanide) and can increase the solubility of other, potentially toxic substances such as trace metals (Clarke 1974;Committee on Water Quality 1972). The toxic potential of pH in turn can be influenced by hardness (Clarke 1974).
APPENDIX II. Descriptions of Mines Examined
Appendix  General description and operating status of mines for which impact management problems were reviewed. (Crook 1984; B.C. and Yukon Chamber of Mines 1982; Northern Miner Press 1984)

Table II.1

<table>
<thead>
<tr>
<th>Mine Name</th>
<th>Operating Company</th>
<th>Location</th>
<th>Type</th>
<th>Principle Metals</th>
<th>Capacity</th>
<th>Start Production</th>
<th>History/Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage I Mines</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baker</td>
<td>Dupont of Canada Exploration Ltd.</td>
<td>north central</td>
<td>u.g.</td>
<td>gold</td>
<td>100</td>
<td>1981</td>
<td>production in 1982 and 1983; ceased in late 1983</td>
</tr>
<tr>
<td></td>
<td>Banbury Gold Mines Ltd.</td>
<td>near Hedley</td>
<td>u.g.</td>
<td>gold</td>
<td>100-300</td>
<td>1983</td>
<td>pilot-scale production</td>
</tr>
<tr>
<td></td>
<td>BayMag Mines Co. Ltd.</td>
<td>southeast</td>
<td>o.p.</td>
<td>magnesite</td>
<td>100</td>
<td>1981</td>
<td>mill in Alberta; pilot-scale 1982 and 1983</td>
</tr>
<tr>
<td>Free Gold</td>
<td>Reako Explorations near Smithers</td>
<td>u.g.</td>
<td>gold</td>
<td>50-100</td>
<td>1981</td>
<td></td>
<td>pilot-scale 1982 and 1983</td>
</tr>
<tr>
<td></td>
<td>Ltd./Panther Mines Ltd.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HB Mill</td>
<td>David Minerals Ltd. (mill only)</td>
<td>near Salmo</td>
<td>u.g.</td>
<td>gold, silver, molybdenum</td>
<td>1000</td>
<td>1982</td>
<td>mill obtained from Cominco and refurbished; no operation 1983</td>
</tr>
<tr>
<td></td>
<td>Ladner Creek</td>
<td>near Hope</td>
<td>u.g.</td>
<td>gold</td>
<td>1500</td>
<td>1982</td>
<td>operated 1983</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Mine Name</th>
<th>Operating Company</th>
<th>Location</th>
<th>Type¹</th>
<th>Principle Metals</th>
<th>Capacity</th>
<th>Start Production</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silence Lake</td>
<td>Dumac Resources Corp.</td>
<td>near Clearwater</td>
<td>o.p.</td>
<td>tungsten</td>
<td>100</td>
<td>1981</td>
<td>ceased operation, fall 1982</td>
</tr>
<tr>
<td>Skomac</td>
<td>Robert Mines Ltd.</td>
<td>near Greenwood</td>
<td>u.g.</td>
<td>gold</td>
<td>30</td>
<td>1975 (mine) 1981 (mill)</td>
<td>sporadic production; ceased operation 1983</td>
</tr>
<tr>
<td>Summit Lake</td>
<td>Scottie Gold Mines Ltd.</td>
<td>near Stewart</td>
<td>u.g.</td>
<td>gold</td>
<td>145</td>
<td>1981</td>
<td>ceased operations late 1984</td>
</tr>
<tr>
<td>Table Mountain</td>
<td>Cusac Industries Ltd.</td>
<td>near Cassiar</td>
<td>u.g.</td>
<td>gold</td>
<td>30</td>
<td>1981</td>
<td>ceased operations 1982</td>
</tr>
<tr>
<td>Taurus</td>
<td>Taurus Resources Ltd.</td>
<td>near Cassiar</td>
<td>u.g.</td>
<td>gold</td>
<td>100</td>
<td>1981</td>
<td>ceased operations 1983</td>
</tr>
<tr>
<td>Venus</td>
<td>United Keno Hill Mines Ltd.</td>
<td>northwest B.C.</td>
<td>u.g.</td>
<td>gold, silver, lead, zinc</td>
<td>100</td>
<td>1981</td>
<td>mill in B.C.; mine mine in Yukon. 2 weeks production only</td>
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<td>Vollaug</td>
<td>Erickson Gold Mines Ltd. (from Plaza Mining Corp.)</td>
<td>near Cassiar o.p.</td>
<td>gold</td>
<td>120</td>
<td>1981</td>
<td>1982</td>
<td>mining suspended 1982</td>
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</table>
## Appendix Table II.1 (Cont'd.)

<table>
<thead>
<tr>
<th>Mine Name</th>
<th>Operating Company</th>
<th>Location</th>
<th>Type</th>
<th>Principle Metals</th>
<th>Capacity</th>
<th>Start Production</th>
<th>Notes</th>
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</thead>
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<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Equity Silver</td>
<td>Equity Mining Corp./Placer Development Ltd.</td>
<td>near Houston</td>
<td>o.p.</td>
<td>copper, silver, gold</td>
<td>4500</td>
<td>1981</td>
<td>still producing</td>
</tr>
<tr>
<td>Goldstream</td>
<td>Noranda Mines Ltd.</td>
<td>near Revelstoke</td>
<td>o.p.</td>
<td>copper, zinc</td>
<td>1400</td>
<td>1983</td>
<td>ceased operation 1984</td>
</tr>
</tbody>
</table>

1 u.g. = under ground; o.p. = open pit
APPENDIX III. Impact Management Problems Identified at Thirteen Stage I Mines and Two Stage II Mines

A. Stage I Mines

No impact management problems were identified for:
1. Banbury Mine
2. Brussilof Mine
3. Skomac
4. Taurus
5. Vollaug Mine

Impact Management Problems were identified for the following mines:
1. Baker
2. Free Gold
3. H.B. Mill
4. Ladner Creek
5. Silence Lake
6. Summit Lake
7. Table Mountain
8. Venus

The impact management problems identified at each mine are summarized below.

1. Baker
   a) On-going Exploration
      No problems identified
   b) Mine Development and Operation
      i. 1982-1983: the mine drainage water contained high sulphate levels
         and possible acid drainage was a concern. However, pH levels
         remained neutral and elevated sulphate levels were not evident a
         short distance downstream.
   c) Mill Construction and Operation
      i. spring 1982 - high cyanide and dissolved copper levels were
         recorded in groundwater and in a stream below the tailings pond.
         Waste Management Branch charges were laid, the mine pleaded
         guilty and was fined $2000. The mine operators estimated costs
         to deal with the problem were $112,000 (including court costs).
      ii. May 1983 - the tailings line ruptured, spilling approximately 280
         tonnes of tailings into a nearby creek. No charges were laid,
         but legal samples were taken by Waste Management personnel.
   d) Other Activities
      i. summer 1983 - high levels of nitrogen and phosphorous from
         domestic sewage were recorded downstream, and resulted in
         enhanced production of algae and benthic invertebrates.
      ii. 1983 - a small spill of helicopter fuel occurred at an airfield
         built by the mining company, but no fuel entered a nearby stream.
         The fuel was owned and cleaned-up by a second party.

Notes:
1. A pre-operational study of water quality and benthic
   invertebrates was conducted in 1976 (Beak 1977).
2. A study of fisheries resources in streams near the mine (Beak
   1982) concluded that there is no fish life in the associated
   watershed until a point 35 Km downstream. Fish access is
   prevented by several waterfalls at that location.
3. A study of benthic invertebrates in streams near the mine (IEC
   Beak 1983) indicated that the effects of sewage discharge had
increased biological production and likely masked detrimental effects from cyanide and dissolved copper.

4. The original cyanide removal treatment method (alkaline chlorination) was replaced by the INCO-SO2/Air method.

Sources:
1. regional MOE personnel, Prince George, B.C.
2. management personnel of DuPont Explorations Ltd.

2. Free Gold
   a) On-going exploration
      No problems identified
   b) Mine Development and Operation
      No problems identified
   c) Mill Construction and Operation
      1982 - 1983: a small leak occurred in the tailings pond but the leaked material did not reach nearby waterbodies
   d) Other Activities
      No problems identified

Sources:
1. regional MOE personnel, Smithers, B.C.
2. management personnel of Reako Explorations Ltd.

3. HB Mill
   a) Mill Construction and Operation
      January 1982: the tailings line froze and an unknown quantity of tailings spilled into Sheep Creek, which flows into the Salmo River. The mill had been shut down several days before the break but the tailings line had not been flushed. Tailings were observed along the creek bottom below the tailings pipe. Salmonids utilize the segment of creek where the spill occurred. However, MOE personnel felt that given the time and location, effects on fish would not be serious. The operators were charged and convicted under the Waste Management Act, and were fined $1500. The problem was attributed to equipment failure and operator error. The operator estimates costs to repair the tailings line were approximately $85,000 (labour plus supply and services). Additional court and legal costs were approximately $5000.
   b) Other Activities
      No problems identified.

Sources:
1. regional MOE personnel, Nelson, B.C.
2. management personnel of David Minerals Ltd.

4. Ladner Creek
   a) On-going Exploration
      No problems identified.
   b) Mine Development and Operation
      i. September 1980: increases in suspended solids, alkalinity, hardness, turbidity and some metals (barium, manganese, aluminum, iron, silica, calcium, magnesium and sodium) were recorded below the minesite. The increases were attributed to filtration from mine water settling ponds and to general minesite development (construction). Increased sediment deposition and algal growth
and changes in the benthic invertebrate community were also identified. These effects were observed in downstream areas in which salmonids are known to occur.

ii. 1980 - 1984: the mine settling ponds periodically produced high levels of suspended solids and nitrogen compounds, including ammonia and nitrite. The high levels of nitrogen species are attributed to explosives usage. Ammonia and nitrite are apparently converted to nitrate downstream by natural aeration in the creek. The increased nitrates have promoted algal growth downstream.

iii. October 1983: increased suspended solids from uncontrolled runoff.

c) Mill Construction and Operation

i. September 1980: as for point i) (Mine Development and Operation)

ii. 1982 - 1984: mill effluent discharge was periodically of poor quality, particularly in relation to the levels of cyanide and copper discharged:

- early spring 1982: high levels of cyanide and copper were discharged to Ladner Creek. At that time, several hundred dead trout were observed downstream in the Coquihalla River. Many of these were identified as hatchery-produced steelhead smolts placed in the Coquihalla River over the period of discharge. Trout bioassays suggested that water immediately below minesite was lethal, but the Coquihalla River was not. The mine operators were charged and convicted under both the Pollution Control Act and Fisheries Act. Fines were $5000 for the Pollution Control Act conviction and $135,000 for the Fisheries Act conviction. The mine operators are appealing the Fisheries Act conviction. In a separate civil action the Steelhead Society of B.C. are suing the operators for damages. At the time, the mill shutdown operations for several weeks.

- late winter/early spring 1983: as full recycle operation of the mill was achieved, effluent quality had deteriorated by February 1983. Combined with the rapid filling of the tailings pond (point iv below) this resulted in a two-week shutdown of the mill.

- December 1983: a new cyanide treatment process (INCO/SO2 Air) was begun, resulting, initially, in reduced cyanide and copper.

- February 1984: high cyanide and copper levels were again recorded downstream.

- June 1984: a change in mill operation related to the amount of gold recovered resulted in a continuing decline in effluent quality causing part of the milling process and effluent discharge to be shutdown.

iii. October 1982: high cyanide levels were recorded in the drain tile discharge from the mill building. Mill clean-up procedures were altered to correct the problem.

iv. early spring 1983: the tailings pond filled rapidly during snowmelt and, combined with a deterioration in mill effluent quality, resulted in a two-week shutdown of the mill.

v. early spring 1983 - fall 1984: To allow greater storage the tailings dam was raised. On-going construction activity and surface disturbance contributed to periodically high suspended solids levels recorded downstream.

d) Related Activities

No problems identified.
Notes:
1. salmonid fish are found in Ladner Creek approximately 500m below the minesite.
2. from 1982-1984 cyanide and dissolved copper approached lethal levels to trout on several occasions immediately below the minesite (where trout are not found) and approached stress levels further downstream where trout are found.
3. copper levels in downstream macroinvertebrates was up to 10 times higher than in upstream macroinvertebrates. The numbers of macroinvertebrates and individuals showed a decline over 1982 and 1983, even in areas where trout normally are found.
4. additive toxic effects might have occurred when cyanide, copper and nitrites were present at the same time.
5. over the 1982-1984 periods suspended solids appeared to be settling over substrate immediately below the minesite but not further downstream where fish are found.
6. nitrogen compounds appeared to be promoting downstream algal growth and was felt to be enhancing biological productivity.

Sources:
1. regional MOE personnel, Surrey, B.C.
2. EPS personnel, Pacific Region, West Vancouver, B.C.
3. Management personnel of Carolin Mines Ltd.

5. Silence Lake

a) On-going Exploration
   No problems identified.

b) Mine Development and Operation
   1. in 1982 a small amount of erosion of the waste rock dump and a small rockslide occurred at the rock storage site causing boulders and a small amount of sediment to enter a nearby stream. Regional Waste Management personnel did not feel the incident was serious because the incident was brief and involved a relatively small amount of material. The location to the slide is not accessible to salmonids and Waste Management personnel did not feel that fisheries resources were affected.

c) Mill Construction
   1. in 1982 a small overflow of the tailings berm occurred when operations first began, but effluent did not enter a nearby stream.

d) Other Activities
   No problems identified.

Notes:
1. The mine ceased operation late in 1982 and the operators were in receivership. No water quality data was forwarded by the mine to the Waste Management Branch and the Waste Management Branch had not collected their own.

Sources: 1 regional MOE personnel, Kamloops, B.C.

6. Summit Lake

a) On-going Exploration
   No problems identified.

b) Mine Development and Operation
No problems identified.

c) Mill Construction and Operation
1981 - 1984: in October 1981, high levels of cyanide and copper were recorded in the discharge to Summit Lake and in the lake itself. Fish kills were observed in bioassays and the mine operation was required to shutdown for 3-4 days in July 1982. Periodically high levels of cyanide and copper were recorded below the ice barrier forming the lake, but could not be attributed to the mine. The mine operators were not charged, but incurred expenses of approximately $850,000 improving the effluent treatment process. The initial alkaline chlorination process was replaced with the INCO-S02/Air process.

d) Other Activities
No problems identified.

Note:
The mill is located within the mine (underground) and tailings material is discharged to the bed of Summit Lake. Summit Lake is formed by an ice dam that drains when high water levels cause the ice dam to rise.

Sources:
1. regional MOE personnel, Smithers, B.C.
2. management personnel of Scottie Gold Mines
3. EPS personnel, Pacific Region, W. Vancouver, B.C.

7. Table Mountain
a) On-going Exploration
No problems identified.
b) Mine Development and Operation
No problems identified.
c) Mill Construction and Operation
An additional treatment pond was constructed at the request of the Waste Management Branch
d) Other activities
No problems identified.

Sources:
1. regional MOE personnel, Smithers, B.C.
2. management personnel of Cusac Industries Ltd.

8. Venus
a) On-going Exploration
No problems identified.
b) Mine Development and Operation
Two "large underground holding treatment sumps" constructed at the request of regulatory agencies.
c) Mill Construction and Operation
Two additional tailings ponds constructed at the request of regulatory agencies.
d) Other Activities
No problems identified.

Note:
1. The mine is located in the Yukon Territory and the mill is located in British Columbia.
2. In late 1983, Waste Management Branch personnel had taken samples of seepage waters but results were not available.

Sources:
1. regional MOE personnel, Smithers, B.C.
B. Stage II Mines
Two mines were examined and impact management problems were identified at both:
1. Equity Silver Mines
2. Goldstream Mine

1. Equity Silver
   a) On-going Exploration
      No problems identified.
   b) Mine Development and Operation
      i. 1980 - 1984: mine drainage water and runoff from mine waste rock were found to be reducing pH levels and increasing levels of sulphate and metals (copper, zinc and iron) in receiving waters. Some waste rock was used for a variety of construction purposes (ie. tailings dam, plant-site, haul road) and consequently low pH problems developed throughout the minesite. A three phased workplan was developed to collect, treat and monitor waste-rock runoff. A company-government Technical Surveillance Committee was formed to deal with the problem.
   c) Mill Construction and Operation
      i. 1980 - 1982: low pH problems from plantsite drainage, related to acid generation in waste rock used for plantsite construction (as indicated above).
      ii. 1981: high silt levels occurred periodically in plantsite runoff.
      iii. November 1981: approximately 100 tonnes of sulphuric acid spilled from a storage tank and entered receiving waters. A reduction in pH was recorded downstream.
      iv. May 1982: a seepage pond at the foot of a tailings dam overflowed while a damaged pump (used to return seepage water to the tailings impoundment) was being repaired. An unknown quantity of effluent having a low pH(2.8) was released.
   d) Other Activities
      i) 1980 - 1982: low pH problems from roadway drainage, related to acid generation in waste rock used for road construction (as described above).
      ii) February 1982: culvert crushed on main haulroad, pools of low pH water had to be trucked to tailings pond.

Notes:
2. The mine is on a watershed divide; the tailings site is in the Foxy Creek drainage; the minesite, mill site and haulroad are in the Bessemer Creek drainage which is part of the Buck Creek system. Fish have not been found in Bessemer Creek but have been found in Buck Creek (approximately 3 Km below the minesite). Fish were not found in Foxy Creek for approximately 24 Km downstream.
3. Low pH and high metal levels were recorded in Bessemer Creek to its junction with Buck Creek. The benthic invertebrate population was
greatly reduced. Low pH and high heavy metal levels were recorded at the junction of Bessemer and Buck Creek, but were attenuated 2 Km downstream and increased heavy metals levels were not evident in fish tissue or bottom sediments. No direct evidence that fisheries resources were affected. Trout bioassays indicated that the water was not toxic.

4. In 1983 the mine was charged and convicted under the Fisheries Act. The fine was $12,000. The mine began a program to deal with the acid generation problem, including a capital expenditure of $1.1 million to contain, divert and treat waters. Additional costs include lawyers, consultants and executive fees and travel costs. Total eventual costs are expected to be approximately $3.0 million.

Sources:
1. regional MOE personnel, Smithers B.C.
2. management personnel of Equity Silver Mines Ltd.
3. EPS personnel, Pacific Region, W. Vancouver B.C.

2. Goldstream
   a) On-going Exploration
      No problems identified.
   b) Mine Development and Operation
      No problems identified.
   c) Mill Construction and Operation
      i. spring 1983: tailings pumps did not operate properly; several small spills occurred, with overflow going onto the ground but not to nearby streams. Afterwards, an additional "stand-by" pump was installed.
      ii. July 1983: a bridge supporting the tailings line washed out, breaking the tailings line. Little or no tailings material entered creek because the tailings line had been drained just prior to the mishap.
   d) Other Activities
      No problems identified.

Sources:
1. regional MOE personnel, Nelson, B.C.
2. management personnel of Noranda Mines Ltd.
APPENDIX IV. Information Collected During Post-start-up Studies

Once production begins, the effects of mining activity are examined by a routine monitoring and inspection program and, where the need arises, more intensive field studies. The types of information obtained during these investigations is briefly described below.

a) Routine Inspection and Monitoring
   i. Inspection by Provincial and Federal Personnel
      The frequency of routine inspection by Waste Management Branch personnel is determined in part by the size of the mine and in part by the sensitivity of the surrounding environment. Therefore a relatively small, remote mine such as Baker is usually visited routinely once a year, while a large, accessible mine near a salmon-bearing stream such as Goldstream is usually visited monthly. Irregular visits by Waste Management Branch personnel or personnel from other provincial or federal resource agencies (eg. Environmental Protection Service) might occur at any time depending on agency resources and priorities. Visits by government personnel can involve both visual inspection and collection of additional samples.
   ii. Sampling and Monitoring by Mine Operators
      The sampling programs prescribed in Waste Management permits for eight mines are summarized in Table IV-1. In general, sampling is more frequent for the monitoring programs, compared to data collected during pre-development field studies (cf. Table 5-3). Also, the monitoring programs include information usually not obtained during the pre-development studies (eg. bioassays; background levels of residuals, such as cyanide). Sampling frequency for tailings ponds and outflow, mine drainage and surface receiving waters varies from once per week to once every three months. Sampling frequency for groundwater varies from none to once every six months and bioassays (for tailings water only) varies from none to once every three months. However, apart from the sampling programs for the Summit Lake and Baker mines, the monitoring schedules appear intended to identify problems that might occur with chronic discharges but not with emergency or "catastrophic" problems. In most cases, one to three months will lapse between sample periods. The sample programs for the Summit Lake and Baker mines are based on a more frequent sampling regime with some samples taken on a weekly and even daily basis. (Note that the Baker permit was revised after serious problems occurred in 1982 and 1983). These sampling programs are more likely to indicate the occurrence of a catastrophic problem, but, even with weekly sampling, a problem such as a reagent spill might occur and be over before routine samples are collected.
   iii. Requirements for Reporting
      Reports on the results of the routine sampling are usually required every three months. In addition, the terms of the permits instruct mine operators to immediately notify the Director of the Waste Management Branch if an emergency condition arises and to immediately take remedial action. The latter procedures rely on the discretion of mine operator in identifying, reporting and dealing with an emergency.

b) Additional Intensive Studies
    The results of intensive studies are included in the descriptions of impact management problems outlined for four mines in Appendix III (Baker, Ladner Creek, Equity Silver, Summit Lake). The types of study undertaken are summarized below in relation to the type of aquatic feature examined (ie. fish, invertebrates, vegetation and other features) and are compared to the information presented in Stage I reports.
    i. Fish Studies
       Studies have included: species presence and detailed habitat assessment (ie. at Baker mine, where pre-production fish resource studies were not
Table IV.1  Sampling programs prescribed in Waste Management Permits for eight mines.

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<thead>
<tr>
<th>STAGE I MINES</th>
<th>STAGE II MINES</th>
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<tr>
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<tr>
<td><strong>Serious Problems Developed</strong></td>
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<td>Baker</td>
<td>Ladner Creek</td>
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<td><strong>Date</strong></td>
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<tr>
<td><strong>Supernatant/ Discharge</strong></td>
<td>weekly</td>
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<tr>
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<td>(pH daily;</td>
</tr>
<tr>
<td>ponds, out-</td>
<td>mine water</td>
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<tr>
<td>flow, treat-</td>
<td>quarterly)</td>
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<td>ment source)</td>
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<tr>
<td><strong>Receiving Streams</strong></td>
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<td></td>
<td>quarterly</td>
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<tr>
<td><strong>Groundwater</strong></td>
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</tr>
<tr>
<td><strong>Bioassays</strong></td>
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<tr>
<td>(tailings)</td>
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</table>
undertaken); additional problem-specific fish bioassays; and, collection and analysis of fish tissues for metal content and of fish livers for the enzyme metallothionein.

In the pre-development Stage I assessments, studies of species presence and habitat are relatively common, and a pre-production bioassay was undertaken for one mine (Blackdome). Metal content in tissues and metallothionein studies were not described in any of the Stage I reports reviewed. Fish condition factors (based on length-weight relationships) were reported in one Stage I report (Ladner Creek), but are not commonly calculated during follow-up assessments.

ii. Aquatic invertebrate studies

Studies have included: examination of population sizes and community structure; metal concentrations in invertebrate tissue; and, zooplankton (Daphnia) bioassays.

Studies of the benthic invertebrate community were undertaken for two Stage I reports (Baker and Ladner Creek) and observations of major taxa during assessments of fish habitat are presented in one report (Summit Lake). However, studies of metal concentrations in invertebrate tissue and zooplankton bioassays were not undertaken.

iii. Aquatic vegetation studies

At one mine (Baker) a preliminary study of periphyton growth was undertaken. In addition, for most mines unusual algal growth is usually noted during routine visual inspections. Periphyton studies were not presented in any Stage I report.

iv. Other Studies

Other studies have included the measurement of metal concentrations in sediments and measurements of particle sizes in suspended solids. In addition, sediment deposition and suspended solids levels are usually noted during routine inspections. In Stage I reports general substrate conditions are occasionally described in terms of fish habitat. However, no report presents information on the metal content in sediments or analyses of particle sizes of suspended solids.
APPENDIX V. General Contents of Five Stage I Reports and Ministry of Environment Terms of Reference

A Stage I Reports

1.a) Mine: Baker
   Author and Date: Ker, Priestman & Associates Ltd. March 1980.
   c) Report Contents:

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<th>No. of Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summary</td>
<td>2</td>
</tr>
<tr>
<td>Introduction and Acknowledgements</td>
<td>2</td>
</tr>
<tr>
<td>Project Description</td>
<td>13</td>
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2.a) Mine: Blackdome
   b) Report Title: Blackdome Explorations Ltd. Blackdome Project Stage I Submission Environmental Impact Assessment
   Author and Date: IEC Beak Consultants Ltd. January 1983.
   Mine Type, Size and Life: gold-silver, underground; 200 tons/day; 4.3 years
   d) Report Contents:

<table>
<thead>
<tr>
<th>Topics</th>
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<td>182 pages</td>
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</table>
3. a) Mine: Free Gold
   b) Report Title: Free Gold Project Smithers B.C. Stage One Report
      Author and Date: Reako Explorations Ltd. Panther Mines Ltd. April 1981.
      Mine Type, Size and Life: gold and metallic sulphides, underground with
      a portable mill; 50 ton/day: 2 years.
   c) Report Contents:
      Topics                      No. of Pages
      Summary                      2
      Introduction                 7
      Description of Existing     
      Environmental and Social
      Conditions                  30
      Project Description         25
      Environmental and Social
      Impacts                     6
      Proposed Further Studies     1
      Bibliography                2
      Appendix A. Report on Phase 1
      Geotechnical Investigations
      for a Tailings Impoundment
      Basin near Smithers, B.C.
      Appendix B. Mineral Inventory Map Sheet 93L  1
      Total Length:                96 pages

4. a) Mine Name: Ladner Creek
   b) Report Title: Ladner Creek Development Stage I Report. Project
      No.1-06-913 Submitted by Carolin Mines Limited.
      Author and Date: B.C. Research. July 1979.
      Mine Type, Size and Life: gold, underground; 1500 tons/day; 3-10 years
      Project Summary: Stage I report submitted; addendum requested and
      submitted December 1979; designated "simple" in April 1980; production
      commenced early 1982.
   c) Report Contents:
      Topics                      No. of Pages
      Summary                      2
      Introduction                 3
      Methods                      5
      Development Program          20
      Environmental Data           25
      Environmental Impacts        5
      Recommendations for Future Work
      References                   1
      Tables                       17
      Figures                      10
      Appendices(8)
         A. Report of Acid Production Potential on four samples from the
            Carolin Mine
         B. Soil Profile Descriptions
         C. Checklist of Mammals Possibly Occurring in the Ladner Creek
            Area
         D. Checklist of Birds whose Breeding Range coincides with the
            Ladner Creek Area
         E. Information Relevant to Land Tenure
F. Hydrology for Ker, Priestman & Associates Ltd.
H. Letter from Acting Regional Archaeologist

Maps 8
Total Length 156

d) Addendum
Report Title: Carolin Mines Ltd. Ladner Creek Project. Addendum to Stage I Report.
Author and Date: Ker, Priestman & Associates Ltd. 23p + 2 figures

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<td>Figures</td>
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5.a) Mine Name: Summit Lake
b) Report Title: Stage I Report. Scottie Gold Mines Ltd. Summit Lake, B.C.
   Author and Date: Ker, Priestman and Associates Ltd. February 1980.
   Mine Type, Size and Life; gold, underground; 200 tons/day; 3 years or more
   Project Summary: project designated "simple" in July 1980; production commenced September 1981.

c) Report Contents:

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<th>Topics</th>
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Appendix IV. Golder Associates
Ltd, Site Evaluation Summit
Lake.

Appendix III. Pollution Control
Objectives for the Mining,
Metallurgical and Related
Industries of B.C.

Total Length: 137 pages

B. MOE Terms of Reference
1. General Topics
   a) Mine Name: Quesnel Fluorspar
      Topics Addressed: A table of contents was not presented. However, the
      section headings are:
      1. Surface Water
         1.1 Surface Water Quality
            1.1.1 Hydrology
            1.1.2 Preliminary Water Management Plan
            1.1.3 Water Balance
         1.2 Surface Water Quality
            1.2.1 Acid Generation Potential
            1.2.2 Abnormal Effluent Quality
            1.2.3 Water Quality Monitoring
            1.2.5 Documentation of Water Uses
      2. Groundwater
         2.1 Groundwater Quantity
         2.2 Groundwater Quality
            2.2.1 Abnormal Drainage
            2.2.2 Groundwater Quality Monitoring
      3. Waste Management
         3.1 Preliminary Waste Management Plan
            3.1.1 Acid Generating Potential
            3.1.2 Effluent Discharges
            3.1.3 Tailings Disposal
            3.1.4 Pilot Plant
            3.1.5 Drainage
            3.1.6 Tailings Spills
            3.1.7 Emissions and Ambient Air Quality
            3.1.8 Climatological Information
            3.1.9 Facilities
      4. Fisheries
         4.1 Toxicity
         4.2 Fish Habitat
      5. Wildlife
      6. Terrain, Vegetation and Soils
      7. Recreational Resources

   b) Mine Name: Nickel Plate
      Topics Addressed: A table of contents was not presented. However, the
      section headings are:
      1. Surface Water Management
         1.1 Mine Water Uses
         1.2 Water Management Plan
         1.3 Surface Hydrology
1.4 Surface Water Quality

2. Groundwater Management
   2.1 Suggested Framework for Hydrological Study
   2.2 Requested Parameters for Groundwater Quality Assessment
   2.3 Mine Drainage

3. Waste Management
   3.1 Waste Management Plan
   3.2 Acid Generation Potential
   3.3 Air Emissions Management

4. Fisheries

5. Wildlife

6. Terrestrial Environment

7. Reclamation

2. Review of the Contents of Two Recent Terms of Reference for Pre-development Assessments

The Ministry of Environment Terms of Reference (TOR) for the Quesnel Lake Fluorspar Project and the Nickel Plate Gold Project were reviewed. The general objectives and the information and analytical requirements for managing impacts on fisheries resources are outlined briefly below.

a) General objectives

The Quesnel Lake TOR stresses the development of strategies or plans "to manage" possible impacts. The objectives of specific information requests are usually "to resolve any technical or policy concerns related to" the topic under consideration (e.g. surface water quality). These objectives are not stated in the Nickel Plate TOR but the development of impact management plans is emphasized.

b) Information and analytical requirements

In the Quesnel Lake TOR, the mine proponent is directed to consider fisheries concerns identified in other TOR sections, Surface Water Quality, Ground Water Quality and Waste Management (specifically, toxic leachates, effluents and acid generation), and to "present a strategy to manage any potential impacts on water quality and fisheries due to such sources." Possible accidental spills of concentrate to be moved across a lake by barge are also to be assessed.

In the Nickel Plate TOR, the mine proponent is not directed to consider the concerns identified in other Sections of the Terms of Reference, but is instructed to "present a statement of anticipated impacts during construction and operation of the project".

The type of information requested in each TOR for fisheries, surface water quality, groundwater quality and waste management is described briefly below.

i. Fisheries studies

Field information is requested for: identification of species present, distribution and relative abundance; habitat distribution and habitat utilization on a seasonal basis. In addition, the Quesnel Lake TOR requests information on present and potential capability of spawning and other habitat. The Nickel Plate TOR also requests: "a draft surveillance and supervision plan" to be used during construction and operation; four to five quantitative benthic invertebrate studies (prior to development) describing "taxonomy, density (productivity), and seasonality"; "some qualitative and quantitative sampling of the periphyton community"; determination of the
metal content in fish muscle and metallothionein level in fish liver. For the Nickel Plate project, the mine operators had proposed using a nearby lake for water storage and were therefore instructed to examine the effects of storage and drawdown on angling and biomass.

ii. Surface Water Quality
In the Quesnel Lake TOR, information is requested for: potential acid generation; bioassays and chemical analyses of pilot scale or laboratory mill tailings; ore radioactivity; pre-development water quality sampling at four locations (the frequency of pre-development sampling is not specified, but a list of factors to be "monitored" indicates monthly sampling of some variables, 3-4 samples per year for others and weekly sampling of suspended solids during freshet conditions); documentation of possible water uses (i.e. drinking water supply, aquatic life, recreation, irrigation, livestock watering and wildlife) including fish species present, numbers, importance, and locations of spawning, rearing and overwintering areas. The request for fisheries information is redundant and has been discussed above.

In the Nickel Plate TOR, information is requested for: water use; pre-development sampling at 4 locations with results from at least three sampling periods included in the Stage I report.

iii. Groundwater Quality
In the Quesnel Lake TOR, information is requested for: samples from adits, wells or springs and leached mine material; fish bioassays and estimated quantities of groundwater or leachate, if quality is poor; influence of blasting agents; quality sampling in spring and late summer; outline of an on-going monitoring program to "be conducted seasonally during the first year of operation and thereafter at least annually". In the Nickel Plate TOR, a detailed outline of factors to be addressed in a "hydrological study" is presented. This does not include bioassays.

iv. Waste Management
The Quesnel Lake TOR states: "The Stage I report should describe as completely as possible the nature of all anticipated emissions, effluents and refuse during the development and operation of this proposed project. Estimated flow rates, proposed method(s) of treatment, quality before and after treatment and points of discharge should all be included. The Stage I Report should outline provisions to prevent spills of any chemicals or oil products that may be used at the mine, or of concentrate during any part of the transportation system. Contingency plans to manage any spills that do result should also be included. Review of this preliminary waste management plan will greatly facilitate the Ministry's processing of Permit applications when they are submitted."

In addition, information is requested for: acid generation potential and the mineral composition of rock material; the addition rates for all reagents and their addition locations; modelling of particulate emissions; measurement of wind and precipitation; the location of proposed facilities (e.g. chemical storage, work camp).

The Nickel Plate TOR emphasizes "long range, post operating controls for mine site drainage, tailings supernatant and tailings seepage" including: mapped locations of "the concentrating plant, tailings ponds, waste rock piles, etc."; types and quantities of all processing reagents and their breakdown products; minerals in the ore that might affect cyanide destruction; analysis of chemical constituents in the mill tailings pond, supernatant and other discharges; toxicity of the pond supernatant; treatment and disposal of drainage; explosives use; contingency plans for
accidents, spills or pipeline ruptures; storage of runoff and drainage water and contingencies if storage is exceeded; equipment and methods for the transport of cyanide; acid generation potential.
APPENDIX VI Stage I Report Format Recommended in the "Procedures for Obtaining Approval of Metal Mine Development"
OUTLINE OF THE STAGE I REPORT

The following outline is suggested. The exact format need not be followed but should serve rather as a check-list. The entire Stage I Report, for most projects, should not exceed 100 pages.

TABLE OF CONTENTS

SUMMARY

ACKNOWLEDGEMENTS (authors and contributors to this report)

INTRODUCTION 5 pages

History
Location
Brief project description and schedule of development

DESCRIPTION OF EXISTING ENVIRONMENTAL AND SOCIAL CONDITIONS 30 pages

Physiography
Land tenure
Climate
Air Quality
Surface Water
  Drainages
  Water quality
  Hydrology
  Fisheries
Groundwater
  Quantity
  Quality
Soils and surficial geology
Vegetation
Wildlife
Land Capability and Use
  Agriculture, Forestry, Recreation, Trapping, Guiding
Histcric and Archaeological Sites
Existing Social Environment
  Population
  Employment
  Housing
  Education
  Commercial services
  continued:
PROJECT DESCRIPTION  
30 pages

Exploration
Description of Deposit
Options considered
Mine Development (pit, underground, waste disposal, reclamation, drainage control)
Mill (Process description, loading, storage, waste disposal, water supply, drainage control, reclamation)
Transportation
Sewage and Garbage disposal
Utilities
Employment
Housing
Detailed Development Schedule
Reclamation objectives, facilities and staff
Drainage control and monitoring
Effluent control and monitoring

ENVIRONMENTAL AND SOCIAL IMPACTS  
10 pages

- should address itself to significant impacts or an identification of environmental concerns which will be assessed in submissions for permit applications.

PROPOSED FURTHER STUDIES  
5 pages