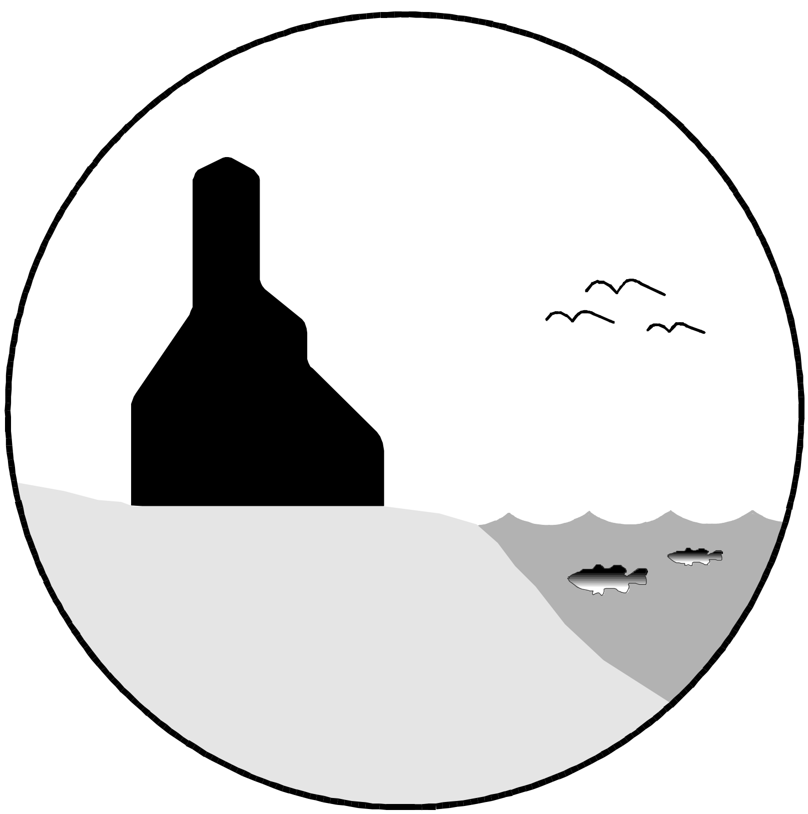
Assessment of the Aquatic Effects of Mining in Canada:

AQUAMIN

Final Report



Assessment of the Aquatic Effects of Mining in Canada: AQUAMIN

Final Report

Prepared for:
AQUAMIN Steering Group

By:
AQUAMIN Working Groups 7 and 8

April 30, 1996

Aussi disponible en français

We are pleased to present the Final Report of the multistakeholder Assessment of the Aquatic Effects of Mining in Canada (AQUAMIN). This document contains recommendations from AQUAMIN that will be presented to Environment Canada for consideration in the regulatory review process for the *Metal Mining Liquid Effluent Regulations* (MMLER) under the *Fisheries Act*.

This document is based on the work of AQUAMIN Working Groups, which prepared two Supporting Documents containing background information, including case studies reporting on the effects of mining on aquatic environments. The Final Report was prepared by two Working Groups and reviewed by the members of other AQUAMIN Working Groups as well as the AQUAMIN Steering Group. A list of all persons and stakeholder groups who participated in AQUAMIN is presented in Appendix 2 of the Final Report.

Members of the Working Groups communicated with their stakeholder groups and presented the views of their groups in their discussions. During the deliberations, members were cognizant of their responsibilities to balance complex issues and search for common ground between legitimate, but sometimes conflicting, viewpoints. Members in the Working Groups responsible for the preparation of the Final Report agree that implementation of all the recommendations contained in the Final Report would result in a significant improvement over the current federal system of environmental monitoring. The Government of Canada is strongly urged to consider all of the recommendations, and to move towards implementation.

On behalf of the AQUAMIN Steering Group:

Harlan Meade
Co-Chair, AQUAMIN Steering Group
Chair, Aquatic Effects Subcommittee
Mining Association of Canada
Environment Committee

Connie MacDonald
Co-Chair, AQUAMIN Steering Group
Environmental Conservation Service
Environment Canada

Members of the AQUAMIN Steering Group:

Co-Chairs
Connie MacDonald, Evaluation and Interpretation Branch, Environment Canada
Harlan Meade, Westmin Resources

Federal Government
Bill Blakeman, Industrial Sectors Branch, Environment Canada
Tom Hynes, CANMET, Natural Resources Canada
David Milburn, Department of Indian Affairs and Northern Development
David Robinson, Habitat Management, Department of Fisheries and Oceans

Provincial Governments
Leslie Cooper, Ontario Ministry of Northern Development and Mines
John Hawley, Ontario Ministry of the Environment and Energy
Neville Ward, Ontario Ministry of Natural Resources
Joseph LeJeune, New Brunswick Environment
Larry Strachan, Manitoba Environment
Gordon Ford, British Columbia Ministry of the Environment, Lands and Parks
David Sutherland, British Columbia Ministry of the Environment, Lands and Parks

Mining Industry
Elizabeth Gardiner, Ontario Mining Association/Mining Association of Canada
Robert Prairie, Noranda Technology Centre

Inuit Tapirisat of Canada
Angela Stadel

Environmental Nongovernmental Organizations
Irené Novaczek, Environmental Coalition of Prince Edward Island
Judy Parkman, Recycling Organization Against Rubbish

Contents

Page

Notice to Readers

Background

This report, the Final Report of the Assessment of the Aquatic Effects of Mining in Canada, was prepared by AQUAMIN Working Groups 7 and 8. Four drafts of the report were prepared and circulated for review. After circulation of the third draft, which was reviewed by members of Working Groups 7 and 8 and the Steering Group, members of the Working Groups met from February 26 to 28, 1996 to review the comments on the third draft and to reach agreement on the content of the Final Report. After these meetings, a fourth draft of the report was prepared and circulated for comment to all participants in AQUAMIN Working Groups 1 to 8, the Steering Group, participants in the AQUAMIN Part III Initiation Workshop, members of the Technical Committees of the Aquatic Effects Technology Evaluation (AETE), and members of the Environmental Protection Committee of the Canadian Council of Ministers of the Environment (CCME).

It was agreed by the Steering Group and Working Groups 7 and 8 that the content of the Final Report, as agreed to at the February meetings, would not change substantively in response to the comments received on the fourth draft. Rather, the objective of the review of the fourth draft of the Final Report was to obtain additional stakeholder input on the content of the Final Report. It was agreed by the Steering Group that all substantive comments on the fourth draft would be summarized by the AQUAMIN Secretariat. This summary, as well as the full text of all comments received, is available upon request from the AQUAMIN Secretariat.

Persons who participated in the preparation of this report were:

Working Group 7:

Al Colodey, Environment Canada, Pacific and Yukon Region
Ron Connell, Dome Mine, Placer Dome Canada
Bill Duncan, Trail Operations, Cominco Limited
Jack Klaverkamp, Freshwater Institute, Department of Fisheries and Oceans
Bob Michelutti, Falconbridge Limited
Irené Novaczek, Environmental Coalition of Prince Edward Island
Roy Parker, Environment Canada, Atlantic Region
Judy Parkman, Recycling Organization Against Rubbish
Alan Penn, Cree Regional Authority
Gerry Whitley, Department of Indian Affairs and Northern Development
Maxine Wiber, Rio Algom Limited

Working Group 8:

Brian Bell, Sudbury Operations, Inco Limited
Bill Blakeman, Industrial Sectors Branch, Environment Canada
Wayne Knapp, Department of Fisheries and Oceans, Pacific Region
Brennain Lloyd, Northwatch
Bernie Matlock, Nova Scotia Department of Environment
Angela Stadel, Inuit Tapirisat of Canada
Leonard Surges, Brunswick Mining and Smelting

AQUAMIN Secretariat:

Charles Dumaresq, Evaluation and Interpretation Branch, Environment Canada
Lise Trudel, Evaluation and Interpretation Branch, Environment Canada

Other AQUAMIN Documents

This document is accompanied by the following working documents:

Supporting Document I
Section I: Geology and Ore Deposits of Canada
Section II: Metal Mining and Milling Processes
Section III: The Regulatory Regime

Supporting Document II

Appalachian Region

- Regional Synthesis
- Case Studies
- Report Review Compilation

Eastern Canadian Shield: Québec

- Synthèse régionale
- Études de cas (French only)
- Compilation de l'examen détaillé (French only)

Eastern Canadian Shield: Ontario

- Regional Synthesis
- Case Studies
- Report Review Compilation

Western Canadian Shield

- Regional Synthesis
- Case Studies
- Report Review Compilation

Western Cordillera

- Regional Synthesis
- Case Studies
- Report Review Compilation

In addition, several supplementary documents were prepared:

- Criteria to Evaluate Information for the Assessment of Aquatic Effects of Mining in Canada (AQUAMIN)
- Framework for the Examination of Aquatic Effects of Metal Mining Activities
- Guidelines for the Revision of Supporting Document II
- Proceedings of the AQUAMIN Part III Initiation Workshop, May 1995

Copies of these documents are available upon request from:

AQUAMIN
Evaluation and Interpretation Branch
Environment Canada
Ottawa, Ontario
K1A 0H3

Copies of the the Summary of Reviewer's Comments, and the Regional Syntheses from Supporting Document II are available in French.

Acknowledgements

The AQUAMIN Steering Group extends its thanks to the following groups and individuals that have contributed to the completion of this program. First, many thanks to the members of all of the Working Groups for their hard work and dedication. To Working Group 1, for their accomplishments in the task of developing criteria for screening information for use in AQUAMIN. To Working Group 2, for the preparation of Supporting Document I. Many thanks to the members of Working Groups 3, 4, 5, and 6 for the preparation of Supporting Document II, for their patience with the process, and for showing the way. And many thanks also to the members of Working Groups 7 and 8, who worked through successive drafts of the Final Report on very tight time frames, culminating in a week of intense, but very successful, meetings. Their willingness to work together was essential to the preparation of this report, and their readiness to give and take and to seek solutions led to consensus on all recommendations contained in this report. Many thanks to the members of the AQUAMIN Secretariat, particularly Lise Trudel and Charles Dumaresq, for their hard work and dedication throughout the process, especially the last hectic days of it.

Thanks are also extended to those who participated in AQUAMIN in other ways. In particular, to those who participated in the Part III Initiation Workshop held in Ottawa in May 1995. And many thanks for the thoughtful and insightful comments of all those who reviewed the drafts of various documents prepared during AQUAMIN. Your input was vital.

Thank you also to those organizations that helped fund AQUAMIN: Evaluation and Interpretation Branch, Environment Canada; Industrial Sectors Branch, Environment Canada; CANMET, Natural Resources Canada; Habitat Management Branch, Department of Fisheries and Oceans; Natural Resources and Environment Branch, Department of Indian Affairs and Northern Development; and the Mining Association of Canada. Also essential was the in-kind support offered by government and industry in the form of time away from regular duties, travel expenses, and logistical and administrative support.

Finally, many thanks to the operators of the mines that were used as case study sites for the preparation of Supporting Document II. It was essential to have their cooperation. Without their openness, and willingness to provide information and help in the process, the case studies, so vital to the success of AQUAMIN, could not have been prepared.

Executive Summary

In 1993, the Assessment of the Aquatic Effects of Mining in Canada (AQUAMIN) was initiated in response to an Environment Canada commitment to update and strengthen the *Metal Mining Liquid Effluent Regulations* (MMLER). The objective of AQUAMIN was to examine the effectiveness of the MMLER, by conducting an assessment of the environmental effects of mining, and to formulate, on the basis of this assessment, recommendations in three key areas: (1) amendments to the MMLER, (2) the design of a national environmental effects monitoring (EEM) program for metal mining, and (3) information gaps and research needs. Recommendations included in this Final Report are to be considered by Environment Canada and the Department of Fisheries and Oceans in the regulatory review process.

AQUAMIN was directed by a Steering Group which included representatives of all stakeholder groups. The Final Report and supporting documents were prepared by several multistakeholder Working Groups. The assessment of the effects of metal mining on aquatic ecosystems in Canada was based on existing information. Over 700 reports related to more than 95 Canadian mine sites were reviewed and detailed case studies were conducted for 18 sites.

The key recommendations contained in this report are:

➥ It is recommended that a cooperative national environmental protection framework be implemented. This framework should include three components: the MMLER, site-specific requirements, and environmental effects monitoring.

➥ It is recommended that the revised MMLER apply to all metal mines, including gold mines (but excluding placer operations).

➥ It is recommended that arsenic, copper, cyanide, lead, nickel, radium-226, the lower pH limit of effluent, total suspended matter, and zinc be regulated in the revised MMLER.

➥ It is recommended that the revised MMLER include a requirement that metal mine operators conduct and report periodic testing of effluent for acute lethality.

➥ It is recommended that, in establishing sampling and reporting requirements in the revised MMLER, efforts be made to simplify and streamline requirements to increase compatibility or eliminate duplication, identify data gaps, and ensure that compliance data are forwarded to regulatory agencies of the appropriate jurisdictions in an acceptable format, to reduce compliance costs.

➥ It is recommended that the revised MMLER include a requirement that mine operators develop, conduct, and report on a site-specific EEM program that:

- monitors key components of aquatic ecosystems (e.g., water, sediments, fish, benthic invertebrates)
- uses tools that are appropriate to site conditions

Methodologies, sampling frequency, and other details should be determined at the local level.

➥ It is recommended that an EEM coordination group be formed as an umbrella organization to oversee and monitor the progress of EEM, and to act as a clearing house for information. National in scope, it would include representation from affected stakeholders — government, industry, aboriginal groups, and environmental nongovernmental organizations.

➥ It is recommended that the Environmental Code of Practice for Mines be updated.

Key Findings

The main conclusion from this review of aquatic effects is that a variety of conditions (e.g., nature of mining operations and receiving environment) affected the magnitude and extent of effects observed. For example, older mine sites and/or those with acid mine drainage typically had more pronounced effects than newer sites. The case studies have identified sites where receiving environment conditions have improved over time as a consequence of improvements in effluent quality and wastewater management.

All of these studies were conducted in the absence of national monitoring requirements. As a result, monitoring of receiving environments varied among and within mine sites due to a lack of consistency in study objectives, approaches, and the methods used. Hence, monitoring at mine sites would benefit from a consistent, but flexible, national program.

Within this review, it was not possible to evaluate with confidence the effectiveness of concentration limits of MMLER parameters. However, it was concluded that the current MMLER may not be sufficient to protect fish, fish habitat, and the use of fisheries resources at all mine sites. Therefore, the MMLER and other elements of the national environmental protection framework should be strengthened.

Environmental Protection Framework

Currently, in the Canadian metal mining sector, the quality of liquid effluents is regulated by federal and provincial governments. Federal and provincial roles should be coordinated within a cooperative national environmental protection framework that includes three essential components. The first component, the revised MMLER, is a federal regulation that will ensure a consistent minimum level of effluent quality at all Canadian metal mines. The second component, site-specific requirements, will ensure that more stringent requirements could be established, if necessary, to protect local receiving environments. The third component, environmental effects monitoring, will serve as a feedback loop, providing information to decision-makers and the public regarding the effectiveness of the other two components. Properly informed public stakeholders should play key roles in the implementation of each of the components of this cooperative national environmental protection framework.

The Revised MMLER

AQUAMIN concluded that the revised MMLER should apply to all metal mines, including gold mines (except placer mines). The revised MMLER should begin to apply when average effluent flow rates exceed minimum levels, specified in the regulations, over a specified period of time and the regulations should cease to apply when the closure plan for an operation has been fully implemented to the satisfaction of the relevant regulatory agencies.

The revised MMLER should be based on current commercially available effluent treatment technologies and should include appropriate parameter limits, toxicity testing, and sampling, analytical, and reporting requirements. These changes, plus feedback based on the results of EEM, together with the need to identify causes of and respond to failed acute lethality tests, will encourage continuous improvement in environmental protection.

AQUAMIN considered effluent parameters, both regulated and not regulated by the MMLER, that were identified as having a potential for effects in receiving environments downstream from mine sites. To determine whether these parameters should be regulated under the revised MMLER or studied further, they were screened according to the level of concern, frequency of occurrence, and levels found in metal mining and milling effluents.

The current MMLER prescribe limits for arsenic, copper, lead, nickel, zinc, radium-226, and total suspended matter, as well as a lower limit for effluent pH. These parameters should continue to be regulated under the revised MMLER. It is recommended that cyanide also be regulated under the revised MMLER. Additional metals and other contaminants identified as being of potential concern at some mine sites included aluminum, cadmium, calcium, fluoride, iron, mercury, molybdenum, nitrogen compounds, and thiosalts. For various reasons, regulation of these parameters is not recommended. However, it is recommended that the revised MMLER require that the occurrence of these parameters in effluent be monitored by conducting periodic effluent characterization at all sites. Where necessary, these parameters could be addressed through site-specific requirements or future revisions to the MMLER.

To respond to concerns about cadmium and mercury, which are bioaccumulative and have been declared toxic under the *Canadian Environmental Protection Act*, it is recommended that cadmium in effluents be monitored and reported on a more frequent basis if concentrations exceed a specified level. Similarly, if periodic effluent characterization demonstrates a consistent presence of significant concentrations of mercury, a working group should be established to investigate possible control options.

To address concerns about ammonia, the Environmental Code of Practice for Mines should be updated to include pollution prevention measures to reduce the release of nitrogen-bearing compounds to receiving environments. Furthermore, it is recommended that current government/industry research programs to develop cost-effective pollution prevention and control technologies for nitrogen compounds continue. To address concerns about thiosalts, it is recommended that research be conducted to identify means of limiting thiosalt production, and that current research efforts to identify and develop control technologies for thiosalts continue.

The current MMLER do not include a requirement that effluent be non-acutely lethal, although the Guidelines for the Control of Liquid Effluents from Existing Mines specify this as an objective and suggest that mine operators should conduct acute lethality tests. AQUAMIN participants agreed on the overall objective that mining effluents be non-acutely lethal (acutely lethal, in respect of effluent, means that the effluent at 100 % concentration kills more than 50% of test organisms subjected to it for a specified period of time), but recognized that this goal might not be achievable at all sites at this time. Therefore, it is recommended that the revised MMLER include a requirement that mine operators conduct and report on periodic testing for the acute lethality of effluent. The frequency of testing would be reduced at sites where effluents are consistently non-acutely lethal. Similarly, failed tests would increase testing frequency. If tests are failed consistently, operators would be required to conduct toxicity identification evaluation/toxicity reduction evaluation studies to identify the cause of the failed tests. As soon as an adequate body of data on the results of acute lethality testing and toxicity identification evaluation/toxicity reduction evaluation becomes available, it is recommended that a review be conducted to determine whether the MMLER should be revised to require that mining effluent be non-acutely lethal.

In establishing sampling and reporting requirements in the revised MMLER, efforts should be made to simplify and streamline requirements to increase compatibility or eliminate duplication, identify data gaps, and ensure that data are forwarded to regulatory agencies in a format acceptable to the appropriate jurisdictions to reduce compliance costs.

Site-specific Requirements

Technology-based effluent regulations such as the MMLER may not adequately protect fish, fish habitat, and the use of fisheries resources at every site. Thus, there is a need for flexibility to apply more stringent site-specific requirements where necessary.

Under the *Fisheries Act*, if site-specific requirements are needed to protect a specific receiving environment, site-specific regulations can be established. As well, other federal, and provincial agencies frequently have the means to implement a wide variety of site-specific requirements and should be encouraged to do so. However, the federal government should retain and enhance its ability to establish site-specific requirements in cases where provincial, territorial, or aboriginal governments are not in a position to do so.

Environmental Effects Monitoring

An EEM program for mines as defined by AQUAMIN should be nationally consistent, site-specific, and nonprescriptive, and should assist practitioners in determining whether a mine effluent has affected its aquatic receiving environment. A well-designed EEM program should recognize two distinct phases in assessing the aquatic effects of mining.

1) *Site Characterization*: Collection of information to describe the operation and design the EEM program.

2) *Field Investigation and Monitoring*: Examination of aquatic effects and their potential causes.

Throughout site characterization and conducting EEM, information requested and obtained must be scientifically defensible. Questions and hypotheses may arise from many sources, including traditional knowledge, local knowledge, and input from the public, government or industry.

At any time during the EEM program, a need for corrective action may arise if the cause of an unacceptable effect is determined. Identification, evaluation, and implementation of mitigation measures, however, are outside the scope of EEM.

Implementation of Environmental Effects Monitoring

In formulating a recommendation for the implementation of EEM, the relative merits of regulatory and cooperative approaches to EEM were explored. It is recommended that the revised MMLER include a requirement that mine operators develop, conduct, and report on a site-specific EEM program. However, the methodology, sampling frequency, and other details associated with program design should be determined at the local level. It is recommended that an EEM coordination group be formed as a national, multistakeholder umbrella organization to oversee and monitor the progress of EEM, and to act as a clearing house for information. It is recommended that the results of the national EEM program be the subject of periodic and independent multistakeholder review. Furthermore, it is recommended that a central registry of information generated by site-specific EEM programs be established.

It is recommended that public liaison committees be established to obtain input from public stakeholders for local EEM programs. To provide meaningful input, public liaison committees should have timely access to compliance and monitoring records and to the results of EEM. It is important that the significance of effects, as they relate to human health or to fisheries resources, is made know to the community.

The definition of acceptable and unacceptable effects is an important issue. It is recommended that guidelines for the process of determining thresholds for unacceptable effects be developed by Environment Canada in consultation with the Department of Fisheries and Oceans and other stakeholders. It is expected that acceptable and unacceptable effects will have to be defined on a site-specific basis, and that criteria for their definition will need to be reviewed periodically to take into account developments in environmental sciences and social values. The threshold levels determined should be used in the design of EEM programs.

Environmental Code of Practice for Mines

It is recommended that the current code be updated, with a focus on water management, pollution prevention, and stakeholder involvement. Detailed recommendations should cover the preproduction phase, mine operation, site close out, and stakeholder involvement through the establishment of public liaison committees, and effective communication.

Information Gaps and Research Needs

There is a need for better information on the biological availability of metals, their bioaccumulation, and their ecological effects. The development of appropriate quality assurance/quality control procedures, and improvements in sampling methods and metal analysis and characterization are also needed. The bounds of natural variability of populations of fish and benthic invertebrates require improved definition for the purposes of EEM.

Summary of Recommendations

Environmental Protection Framework

- It is recommended that a cooperative national environmental protection framework be implemented. This framework should include three components:

  - ➢ MMLER: a federal regulation to ensure a consistent, minimum quality of effluent being discharged to aquatic ecosystems

  - ➢ Site-specific requirements: more stringent site-specific requirements may be necessary to ensure adequate protection of some aquatic ecosystems

  - ➢ Environmental effects monitoring: constitutes a feedback loop, providing information to decision-makers and the public regarding the effectiveness of both environmental protection measures and long-term regulatory strategies

- It is recommended that the costs of developing, implementing, and managing the environmental protection framework be assessed by the federal government and be understood by all stakeholders.

- It is recommended that Environment Canada, in consultation with other stakeholders, develop guidelines for the establishment of public liaison committees, including the reporting of information to public stakeholders.

The MMLER

- It is recommended that the MMLER be amended to improve the quality of effluent discharged to aquatic ecosystems.

- It is recommended that Environment Canada establish a process to review the MMLER in light of future environmental effects monitoring results. A mandatory review after a specified period could be incorporated into the revised MMLER to ensure that such a review does take place.

- It is recommended that the revised MMLER be a best available technology economically achievable (BATEA) based regulation, with feedback of results from EEM and toxicity identification evaluation/toxicity reduction evaluation to encourage continuous improvement in environmental protection.

Application

- It is recommended that the revised MMLER apply to all metal mines, including gold mines (excluding placer operations).

- It is recommended that there be a transition period to ensure that any mines that are not under regulation or not in compliance have a reasonable period to improve their control systems.

- It is recommended that the revised MMLER continue to address those sources of liquid effluents addressed in the current MMLER.

- It is recommended that the revised MMLER begin to apply when the average effluent flow rate exceeds a minimum level, specified in the regulation, over a specified period of time.

- It is recommended that the revised MMLER apply after commercial production ends, *during* the period when the closure plan for an operation is being implemented.

- It is recommended that the revised MMLER cease to apply when the closure plan for an operation has been fully implemented to the satisfaction of the relevant regulatory agencies.

Parameters

- It is recommended that a review of treatment technology be completed prior to revising the MMLER and that appropriate concentration limits for all regulated parameters be established on the basis of this review.

- It is recommended that arsenic, copper, cyanide (for operations that use cyanide as a process reagent), lead, nickel, radium-226, the lower pH limit of effluent, total suspended matter, and zinc be regulated in the revised MMLER.

- It is recommended that aluminum, calcium, fluoride, iron, mercury, molybdenum, and an upper limit for pH not be regulated in the revised MMLER.

- It is recommended that aluminum, ammonia, arsenic, cadmium, calcium, copper, cyanide, fluoride, iron, lead, mercury, molybdenum, nickel, pH, radium-226, total suspended matter, and zinc be included in the list of parameters to be measured in periodic effluent characterization.

- It is recommended that in cases of receiving water sensitivity, or consistently elevated aluminum or ammonia levels in effluent and the receiving environment, site-specific requirements should be implemented.

- It is recommended that if cadmium concentrations in an effluent exceed a specified level, they should be monitored and reported on a more frequent basis.

- It is recommended that if effluent characterization demonstrates a consistent presence of significant concentrations of mercury in effluent, a working group should be established to investigate possible control options.

- It is recommended that the updated Environmental Code of Practice for Mines include pollution prevention measures, particularly explosives management practices, to reduce releases of nitrogen-bearing compounds to the receiving environment.

- It is recommended that government/industry research programs to identify and develop effective and efficient pollution prevention and control technologies for total ammonia and nitrogen compounds continue.

- It is recommended that thiosalt impacts be monitored as part of EEM.

- It is recommended that research be conducted to identify means of limiting thiosalt production.

- It is recommended that current research efforts to identify and develop control technologies for thiosalts continue.

Toxicity

- It is recommended that the revised MMLER include a requirement that all metal mine operators conduct and report periodic testing of effluent for acute lethality using current standard test methods.

  ➢ It is recommended that, if effluents are consistently non-acutely lethal, the frequency of testing should be reduced.

  ➢ It is recommended that a failed test should trigger increased testing frequency.

  ➢ It is recommended that, if an effluent is consistently acutely lethal, the operator should be required to conduct toxicity identification evaluation/toxicity reduction evaluation in an attempt to determine the cause of toxicity and to report the results. Results should be considered in establishing site-specific requirements.

- It is recommended that as soon as an adequate body of data on the results of acute lethality testing and toxicity identification evaluation/toxicity reduction evaluation is available, a review be conducted to determine if the MMLER should be revised to require non-acutely lethal effluent.

Sampling, Analysis and Reporting

- It is recommended that, in establishing sampling and reporting requirements in the revised MMLER, efforts be made to simplify and streamline requirements to increase compatibility or eliminate duplication, identify data gaps, and ensure that compliance data are forwarded to regulatory agencies of the appropriate jurisdictions in an acceptable format, to reduce compliance costs.

- It is recommended that a review of the current analytical procedures for the measurement of parameters (e.g., total or dissolved metals, nitrogen, or cyanide species) to be monitored and reported be completed prior to revising the MMLER.

- It is recommended that, if a parameter is consistently measured at concentrations significantly lower than the regulated limit at a particular site, the monitoring frequency for that parameter should be reduced (similar to Schedule 2 in the current MMLER).

- It is recommended that standard minimum quality assurance/quality control requirements for sample collection, handling, and analysis be developed and revised accordingly as technology improves.

- It is recommended that effluent flow be monitored.

- It is recommended that, in cases where other jurisdictions have legally enforceable requirements, the federal government reach delivery agreements with the other jurisdictions to establish single reporting mechanisms.

- It is recommended that Environment Canada continue to publish periodic reports on the status of the metal mining industry's compliance with the MMLER.

Site-specific Requirements

- It is recommended that site-specific requirements be developed and implemented as appropriate by provincial, territorial, or aboriginal governments or other federal regulators where necessary to ensure protection of fish, fish habitat, and the use of fisheries resources.

- It is recommended that the federal government retain and enhance the ability to establish site-specific requirements in cases where a provincial, territorial, or aboriginal government is not in a position to do so.

- It is recommended that provincial, territorial, or aboriginal agencies be encouraged to develop and implement the site-specific requirements necessary to protect aquatic resources and other designated water uses.

  ➢ It is recommended that the federal government continue to assist provincial, territorial, or aboriginal agencies by providing scientific and technical advice.

- It is recommended that, in the event that neither a company nor a provincial, territorial, or aboriginal agency are in a position to implement more stringent environmental protection measures to adequately protect a particular receiving environment, the federal government should have the ability to implement site-specific requirements, using a simpler mechanism than that which currently exists, while ensuring that social and economic impacts are still considered.

- It is recommended that, to foster a nationally consistent approach to the development of site-specific requirements, the federal government continue to provide leadership in developing environmental quality guidelines.

Environmental Effects Monitoring

- It is recommended that an environmental effects monitoring program be developed for all metal mines in Canada.

- It is recommended that the most important components of an EEM program are fish, fish habitat, and the use of fisheries resources as defined under the *Fisheries Act*.

- It is recommended that an EEM program take a progressive, phased approach to determine any effects in the aquatic environment in accordance with standard scientific methods.

- It is recommended that an EEM program address site-specific questions, and that practitioners (stakeholders) be encouraged to design the most appropriate study for each site.

- It is recommended that, at any time in an EEM process, if the cause of an unacceptable effect is known, recommendations for corrective action can be put forward.

Design Strategy

- It is recommended that the EEM program be effective and efficient, that all information collected have a clearly identifiable purpose, and that maximum use be made of historical data and relevant regional data.

Program Design and Components

- It is recommended that the objective of site characterization be to obtain sufficient understanding of the mine's effluent and aquatic receiving environment to develop an effects monitoring program that is scientifically sound and meets the needs of all stakeholders.

- It is recommended that the objective of the assessment of current conditions be to determine whether the aquatic environment has been negatively affected by the mine effluent. Only if the assessment finds an unacceptable effect should studies proceed to a more detailed assessment.

Study Design

- It is recommended that the EEM program ensure that study designs are scientifically defensible and that quality assurance is given high priority. Study designs must be placed in the context of multiple samplings before (where possible) and after development, and at both exposed and reference locations.

Implementation of EEM

- It is recommended that the revised MMLER include a requirement that mine operators develop, conduct, and report on a site-specific EEM program that:

    ➢ monitors key components of aquatic ecosystems (e.g., water, sediments, fish, benthic invertebrates)

    ➢ uses tools that are appropriate to site conditions

    ➢ follows the approach to EEM recommended in Section 6 of this report

  Methodologies, sampling frequency, and other details should be determined at the local level.

- It is recommended that guidelines for the process of determining what is to be considered an acceptable or unacceptable effect should be developed by Environment Canada in consultation with the Department of Fisheries and Oceans and other stakeholders.

- It is recommended that Environment Canada establish a central registry of reports and data generated through EEM in the mining industry.

- It is recommended that Environment Canada institute an independent and periodic peer review of the EEM program to provide recommendations on revisions to the environmental protection framework.

- It is recommended that an informal resource group of individuals from government, industry, and academia be established to review and make recommendations regarding site-specific EEM programs.

- It is recommended that an EEM coordination group be formed as an umbrella organization to oversee and monitor the progress of EEM, and to act as a clearing house for information. National in scope, it would include representation from affected stakeholders — government, industry, aboriginal groups, and environmental nongovernmental organizations.

Environmental Code of Practice for Mines

- It is recommended that the current Environmental Code of Practice for Mines be revised in two ways:

    ➢ update material in the current code

    ➢ add additional sections to address other aspects of environmental management and monitoring

- It is recommended that the updated Environmental Code of Practice for Mines continue to have a significant focus on issues related to water management and water pollution prevention.

- It is recommended that the updated Environmental Code of Practice for Mines also address other issues, such as stakeholder involvement.

1 Introduction

1.1 Origin of AQUAMIN

In 1990, Environment Canada and the Department of Fisheries and Oceans committed to re-examine the *Metal Mining Liquid Effluent Regulations* (MMLER).[1] In 1992, Environment Canada sponsored a workshop to discuss the MMLER revision process and to seek guidance on this process from representatives of all groups with a stake in mining and the environment. Stakeholders represented were the federal government, the mining industry, provincial governments, aboriginal peoples, and environmental organizations. The key recommendations of participants at this workshop were:[2]

1) "before any amendments were made to the MMLER, an aquatic effects assessment should be undertaken"

2) "the assessment should be comprehensive, reviewing chronic, acute, and cumulative effects, with multi-stakeholder participation"

3) "public communication and consultation should be incorporated into the review process"

On the basis of these recommendations, the Assessment of the Aquatic Effects of Mining in Canada (AQUAMIN) was initiated by Environment Canada. The process formally began in June 1993 at a multistakeholder meeting to outline the objectives and scope of AQUAMIN.

1.2 Background: *Metal Mining Liquid Effluent Regulations* and Guidelines

1.2.1 *Metal Mining Liquid Effluent Regulations*

Canada's *Metal Mining Liquid Effluent Regulations*[3] were promulgated in 1977 under the

---

[1] Government of Canada. 1990. Canada's Green Plan. Cat. No. En21-94/1990E.

[2] Pat Delbridge Associates. 1992. Report of the Workshop Proceedings on *Metal Mining Liquid Effluent Regulations*. November 26–27, 1992, Toronto, Ontario. Unpublished document.

[3] Environment Canada. 1977. *Metal Mining Liquid Effluent Regulations* and Guidelines. Report EPS 1-WP-77-1.

authority of the *Fisheries Act*.[4] The objective of the MMLER was to limit the discharge of deleterious substances from new, expanded, and reopened (since 1977) base metal, uranium, and iron ore mines. The regulations are permissive in that they set authorized concentration limits for deleterious substances in effluents discharged into waters frequented by fish. Concentration limits are presented in Table 1. The concentration limits are "technology based," with the best practicable technology (BPT) being achieved through recognition and utilization of the constant physical and chemical properties of the metals arsenic, copper, lead, nickel, zinc, and radium-226.

For the purposes of the regulations, effluent includes mine water effluent, mill process effluent, effluent from tailings, treatment pond effluent or treatment facility effluent, as well as seepage and surface drainage from the site. Operators are required to measure or estimate the volume of effluent discharged.

Table 1: Authorized concentration limits of deleterious substances prescribed in the MMLER.

A: Authorized concentration limits of substances.

Substance	Maximum Monthly Arithmetic Mean (mg/L)	Maximum in a Composite Sample (mg/L)	Maximum in a Grab Sample (mg/L)
Arsenic	0.5	0.75	1.0
Copper	0.3	0.45	0.6
Lead	0.2	0.3	0.4
Nickel	0.5	0.75	1.0
Zinc	0.5	0.75	1.0
Total suspended matter (TSM)	25.0	37.5	50.0
Radium-226 (pCi/L)	10.0	20.0	30.0

Note: Concentrations are given as total values with the exception of radium-226, which is a dissolved value after filtration of the sample through a 3 micron filter.

[4] Department of Fisheries and Oceans. 1992. Extracts from the *Fisheries Act*. R.S.C., 1985, c. F-14. Amendment List, June 18, 1992.

B: Authorized pH levels.

Minimum Monthly Arithmetic Mean	Minimum in a Composite Sample	Minimum in a Grab Sample
6.0	5.5	5.0

Accompanying the MMLER is the Environmental Code of Practice for Mines, which is not legally enforceable. The intent of the code is to guide professionals in meeting their environmental control responsibilities. It also emphasizes pollution control practices that should be considered at all stages of mine–mill development, from initial planning through to abandonment.

1.2.2 MMLER and Gold Mines

The regulations do not apply to gold mines, which are defined as mines where the gold produced is recovered at the site by cyanidation and accounts for more than 50% of the value of the mine's output. In the mid-1970s, there were few treatment methods in general use for controlling cyanide-bearing liquid and solid wastes from gold mines. Untreated cyanide-bearing gold mine effluents are generally very toxic to fish.[5] In 1977, Environment Canada decided to exempt gold mines using cyanidation from the MMLER. However, a gold mining working group was set up as part of a task force to encourage and promote the development of technologies to control cyanide concentrations in effluent. During the 1980s, Canada became a world leader in developing and implementing several technologies related to the control of cyanide, including alkaline chlorination, the Inco SO_2/air oxidation process, hydrogen peroxide oxidation, cyanide regeneration, and optimization of natural degradation in tailings impoundments. Commercially proven cyanide treatment technologies are now in place at all gold mines in Canada.

1.2.3 Metal Mining Liquid Effluent Guidelines

The Guidelines for the Control of Liquid Effluents from Existing Mines, hereafter referred to as MMLEG, were published at the same time as the MMLER to establish effluent quality

[5] T.W. Higgs Associates Ltd. 1992. Technical Guide for the Environmental Management of Cyanide in Mining. Prepared for the Cyanide Subcommittee of the British Columbia Technical and Research Committee on Reclamation.

objectives for existing metal mines, other than gold mines using cyanide, that commenced operation before February 25, 1977. Acceptable levels for substances in the guidelines are the same as authorized levels for substances prescribed in the MMLER (Table 1).

Effluent quality objectives are not legally enforceable for these mines, but their operations are subject to the general provisions of the *Fisheries Act*. Compliance with the guidelines is considered to meet the spirit of the law, but discharging an effluent that is acutely lethal to fish may be an offence under Subsection 36(3)[6] of the *Fisheries Act*. A mine may be legally obligated to meet the guidelines if a federal, territorial, or provincial government agency imposes these limits in a regulation, permit, or licence issued under its legislation.

1.2.4 Guidelines for the Measurement of Acute Lethality

The MMLER do not require acute lethality testing, and do not require that effluents be non-acutely lethal, but Environment Canada developed Guidelines for the Measurement of Acute Lethality in Liquid Effluents from Metal Mines, which accompany the MMLER. These guidelines specify a bioassay test procedure in which fish (rainbow trout) are exposed to undiluted effluent for 96 hours. If 50% of the fish survive, the effluent is considered to have passed the test. As stated above, mines are subject to the general provisions of the *Fisheries Act,* but discharging acutely lethal substances into waters frequented by fish may be considered a violation under the act.[7]

1.2.5 Industry's Compliance Performance

Compliance is assessed on the basis of monthly effluent quality data and standards. A mine is considered to be in compliance for a given month if all liquid effluent discharges meet prescribed standards for the eight effluent quality parameters in the MMLER for that month. Compliance for the year is based on the percentage of operational months a mine was in compliance. The compliance status of the industry is monitored by Environment Canada and

---

[6] Subsection 36(3): "no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish or in any place under any conditions where the deleterious substance or any other deleterious substance that results from the deposit of the deleterious substance may enter any such water."

[7] The current Environment Canada reference method for toxicity testing using rainbow trout is presented in:
Environment Canada. 1990. Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout. Conservation and Protection, Ottawa, Ontario. Report EPS 1/RM/13.

is periodically reported to the public.[8] Table 2 provides a summary of the level of compliance by the mines under regulation from 1982 to 1990.

Table 2: Summary of compliance by mines under the MMLER.

Year	No. of Mines	% Compliance
1982	20	95
1986	30	84
1990	49	87

Note: Data for 1982 are incomplete.

1.2.6 Comparison of the MMLER with Provincial Regulations

Requirements of the various provincial regulations and the MMLER are presented in Table 3.

[8] Status reports available and from which information in this section is derived:

Environment Canada. 1985. Status Report on Water Pollution Control in the Canadian Metal Mining Industry (1982). Conservation and Protection, Ottawa, Ontario. Report EPS 1/MM/2.

Environment Canada. 1988. Status Report on Water Pollution Control in the Canadian Metal Mining Industry (1986). Conservation and Protection, Ottawa, Ontario. Report EPS 1/MM/3.

Environment Canada. 1992. Status Report on Water Pollution Control in the Canadian Metal Mining Industry (1990 and 1991). Conservation and Protection, Ottawa, Ontario. Report EPS 1/MM/4.

Table 3: Authorized levels of parameters prescribed in various provincial regulations and the MMLER.

Parameter	Ont. Monthly Mean	Qué. Monthly Mean	B.C.* Range	Sask. Monthly Mean	Nfld.	MMLER**		
						Monthly Mean	Composite Sample	Grab Sample
Cadmium (mg/L)	0.001***		0.01 - 0.1		0.05			
Mercury (mg/L)	0.001***		Nil - 0.005		0.005			
Suspended solids (mg/L)	15	25	25.0	25 - 75	30	25.0	37.5	50.0
pH	6.0 - 9.5***	6.5 - 9.5	6.5 - 8.5 6.5 - 10	6.0 - 9.5	5.5 - 9.0	>6.0	>5.5	>5.0
Aluminum (mg/L)			0.5 - 1.0					
Arsenic, total (mg/L)	0.5***	0.50	0.10 - 1.0	0.5	0.5	0.5	0.75	1.0
Arsenic, trivalent (mg/L)			0.05 - 0.25					
Copper (mg/L)	0.3***	0.30	0.05 - 0.3	0.3	0.3	0.3	0.45	0.6
Nickel (mg/L)	0.5***	0.50	0.2 - 1.0	0.5	0.5	0.5	0.75	1.0
Lead (mg/L)	0.2***	0.20	0.05 - 0.2	0.2	0.2	0.2	0.3	0.4
Zinc (mg/L)	0.5***	0.50	0.2 - 1.0	0.5		0.5	0.75	1.0
Iron (mg/L)		3.00	0.3 - 1.0					
Antimony (mg/L)			0.25 - 1.0					
Chromium (mg/L)			0.05 - 0.3					
Cobalt (mg/L)			0.5 - 1.0					
Fluorine (mg/L)			2.5 - 10.0					
Manganese (mg/L)			0.1 - 1.0					
Molybdenum (mg/L)			0.5 - 5.0					
Selenium (mg/L)			0.05 - 0.5					
Silver (mg/L)			0.05 - 0.5					
Gross alpha (pCi/L)			10 - 100					
Uranium dioxide (mg/L)	0.001***		2.0 - 5.0					
Uranium (mg/L)				2.5				
Radium-226			‹10.0 pCi/L	0.37 Bq/L	0.37 Bq/L	10 pCi/L	20 pCi/L	30 pCi/L
Thorium-230 (Bq/L)				1.85				
Lead-210 (Bq/L)			0.92	1.84				

Table 3 (continued)

Parameter	Ont. Monthly Mean	Qué. Monthly Mean	B.C.* Range	Sask. Monthly Mean	Nfld.	MMLER**		
						Monthly Mean	Composite Sample	Grab Sample
Nitrite/nitrate as nitrogen (mg/L)			10.0 - 25.0					
Ammonia as nitrogen (mg/L)	10.0***							
Un-ionized ammonia (mg/L)				0.5				
Temperature (°C)					>32			
Strontium-90 (Bq/L)			0.3 - 1.0		0.37			
Oils (ether extract) (mg/L)			0.25 - 1.0		15			
Oil and grease (mg/L)			0.05 - 0.3		10.0 - 15.0			
Barium (mg/L)			-		5.0			
Boron (mg/L)			-		5.0			
Chlorine (mg/L)			0.5 - 1.0		1.0			
Phosphorus (mg/L)	1.0***							
Phosphate as phosphorus (mg/L)			2.0 - 10.0					
Total cyanide (mg/L)	1.0***	1.50	0.1 - 0.5	1.0	0.025			
Free cyanide (mg/L)		0.10						
Phenols (mg/L)	0.02***							
Biological oxygen demand (mg/L)	15***							
Dissolved solids (mg/L)			2500 - 5000					
Toxicity (%)	Nontoxic	Nontoxic	80 - 100					

* Lower limits are for new mills, higher limits are for older mills. Limits are guidelines as opposed to regulations.

** MMLER used by Manitoba, Nova Scotia, and New Brunswick. DIAND uses the MMLER as a starting point for effluent requirements in the Yukon and the Northwest Territories. At most sites, DIAND applies more stringent standards, including cyanide, mercury, and other parameters.

*** Typical values recently applied on Certificates of Approval (OWRA Section 24) in Ontario.

1.3 Objective of AQUAMIN

The objective of AQUAMIN was to examine the effectiveness of the MMLER. This objective was realized by assessing existing information on the effects of metal mining on aquatic ecosystems in Canada. The AQUAMIN Steering Group recommended that the study focus on the effects of mine effluents on freshwater environments. Accordingly, with two exceptions, mines included in the review were limited to those that discharge effluents into such environments.

The findings of AQUAMIN provide the basis for the formulation of recommendations in three key areas:

- amendments to the MMLER[9]

- the design of a national environmental effects monitoring program for metal mining

- information gaps and research needs

Recommendations included in this Final Report are to be considered by Environment Canada and the Department of Fisheries and Oceans in the regulatory review process.

Section 6.1 of the Environmental Code of Practice for Mines states that “tailings should not be discharged to an unconfined disposal area unless confined disposal is shown to be impractical or unless the unconfined disposal alternative is environmentally preferable.” In recognition of the unique status of mines that have employed this type of disposal, and increasing interest in this technique, an assessment of the effects of mine effluent and tailings discharged into the marine environment is being conducted under contract to Environment Canada. This endeavour is separate from, but complementary to, AQUAMIN. Results will be made available to Environment Canada for consideration. Further details on the project are provided in Appendix 1.

AQUAMIN was carried out based on several operating principles:

1) The assessment was *science-based*, using existing information (i.e., no new research was performed) on the effects of metal mining on aquatic ecosystems.

2) The assessment was conducted by a multistakeholder group, and all participants provided meaningful input.

---

[9] This is interpreted to mean the regulatory framework for mining in Canada (including provincial regulation).

3) The assessment was conducted in as timely a manner as possible.

4) There was a commitment from Environment Canada to consider the results of the assessment, and to allow the assessment process to take a reasonable course prior to amending regulations.

5) The assessment was properly framed. Criteria to evaluate data quality were developed and applied.

6) Consideration was given to harmonization of provincial and federal requirements, while recognizing site-specific needs.

The stakeholder groups that participated in AQUAMIN were:

- the provincial governments of British Columbia, Saskatchewan, Manitoba, Ontario, Québec,[10] New Brunswick, Nova Scotia, and Newfoundland
- the Mining Association of Canada
- the Inuit Tapirisat of Canada
- the Cree Regional Authority
- delegates from the Mining Caucus of the Canadian Environmental Network
- five federal government departments and agencies: Environment Canada, the Department of Fisheries and Oceans, Natural Resources Canada, the Department of Indian Affairs and Northern Development, and the Atomic Energy Control Board of Canada.

All individuals who participated in AQUAMIN are listed in Appendix 2.

The assessment examined the effects on receiving environments caused by discharges from base metal, precious metal, and uranium mines. Information from all phases of mining was considered, but the emphasis was on information from operating mines. It is important to note that little information from abandoned and orphaned sites was examined. Significant concerns remain about the effects such sites are having on receiving environments.

Physical, chemical, and biological effects on the receiving environments were examined, including changes in water and sediment quality, and short- and long-term biological effects on individuals, populations, and communities resident in the receiving environments. Where possible, potential mining related and nonmining related causes of effects were identified. The assessment was based primarily on studies conducted at actual mining sites.

---

[10] The Government of Québec withdrew from AQUAMIN in September 1995, and had limited input into the Final Report, except Chapters 1 and 2.

1.4 Operation of AQUAMIN

Overall direction for AQUAMIN was provided by a Steering Group, which included representatives of all stakeholder groups. It was cochaired by Mining Association of Canada and Environment Canada representatives. The Steering Group guided the assessment and ensured that the resources necessary to complete the assessment were available. Specific tasks identified by the Steering Group were assigned to Working Groups.

Eight multistakeholder, multidisciplinary Working Groups were formed to prepare various documents for AQUAMIN.

Coordination and management of the assessment were provided by the Secretariat, which also provided administrative and technical support to the Steering Group and the Working Groups. The Secretariat, housed at Environment Canada, also coordinated communications among AQUAMIN groups and provided information on AQUAMIN to interested groups and individuals not involved in AQUAMIN.

Funding for AQUAMIN was provided by:

- Environmental Conservation Service, Environment Canada
- Environmental Protection Service, Environment Canada
- CANMET, Natural Resources Canada
- Department of Fisheries and Oceans
- Department of Indian Affairs and Northern Development
- Mining Association of Canada

1.5 Outline of the AQUAMIN Document

The deliverable from AQUAMIN is this document, the Final Report, and two accompanying supporting documents.

1.5.1 Final Report

This document was prepared by Working Groups 7 and 8. It provides a summary of key findings regarding the effects of mining on aquatic ecosystems in Canada, as documented in Supporting Document II. It also contains recommendations and supporting rationale regarding:

- a cooperative national environmental protection framework
- revisions to the MMLER
- site-specific requirements
- the design of a national environmental effects monitoring program for metal mining in Canada
- revisions to the Environmental Code of Practice for Mines
- information gaps and research needs

1.5.2 Supporting Document I

This document, prepared by Working Group 2 and the Secretariat, is divided into three sections.

Section I: Geology and Ore Deposits of Canada

An overview of the geology of Canada, for nongeologists, and a summary of the key characteristics of ore deposit types occurring in Canada are presented. This section also introduces some concepts of environmental geochemistry, including the oxidation of sulphide minerals in natural environments.

Section II: Metal Mining and Milling Processes

An overview of mining and milling processes from exploration to mine closure is presented. Effluent management and treatment technologies are also summarized.

Section III: The Regulatory Regime

A summary of federal and provincial environmental regulations for operating mines, and a comparison of federal regulations in Canada with those in other countries are presented.

1.5.3 Supporting Document II

This document, prepared by Working Groups 3, 4, 5, and 6, is based upon information drawn from a wide range of sources, including:

- reports completed for mining companies by consultants or company staff
- reports completed by government regulatory and research agencies
- articles from scientific journals
- conference proceedings

The cooperation of the Canadian mining industry in supplying reports for AQUAMIN was particularly valuable to the success of the assessment.

Prior to preparing Supporting Document II, a preliminary screening of all documents was conducted and documents were entered into a database. The objective of the screening process was to assess the quality of the reports in each subject area addressed within the reports using criteria and subcriteria developed by Working Group 1. For each subject area within a report, each subcriteria was evaluated on a presence/absence basis by a contractor. All screening was completed by a single contractor to maximize consistency in the process. All reports were then entered into the database and were cross-referenced by title, author, study site, province, mine type, date, keywords, and screening results. A self-contained version of the database was distributed to members of the Working Groups preparing Supporting Document II. Over 700 references were entered into the database. It is recognized, however, that considerable data were not included in this review.

The four Working Groups preparing Supporting Document II were divided geographically:

Working Group 3:	Appalachian Region (Newfoundland, Nova Scotia, and New Brunswick)
Working Group 4QUÉ:	Eastern Canadian Shield (Québec)
Working Group 4ONT:	Eastern Canadian Shield (Ontario)
Working Group 5:	Western Canadian Shield (Manitoba, Saskatchewan, and the Northwest Territories)
Working Group 6:	Western Cordillera (British Columbia and the Yukon)

For each region, a report on the aquatic effects of mining was prepared. These reports include case studies, regional syntheses of the case studies, and material from non-case study sites.

The case studies are an important component of Supporting Document II and the Final Report. The goal of the case studies was to compile and analyse as much relevant information as possible for the selected sites. Through this site analysis, the effects on the receiving environment were identified and, where possible, the causes/sources of the effects were described. The case studies also assessed whether or not the monitoring conducted at the sites was adequate to identify and quantify environmental effects on the receiving environment. The goals of assessing the monitoring were to:

- identify gaps in monitoring that may affect the conclusions reached in the case studies
- provide guidance to Working Group 7, which prepared recommendations on the design of an environmental effects monitoring program

Mining companies at all case study sites were contacted, and in many cases, company representatives participated in the preparation and/or review of the case studies.

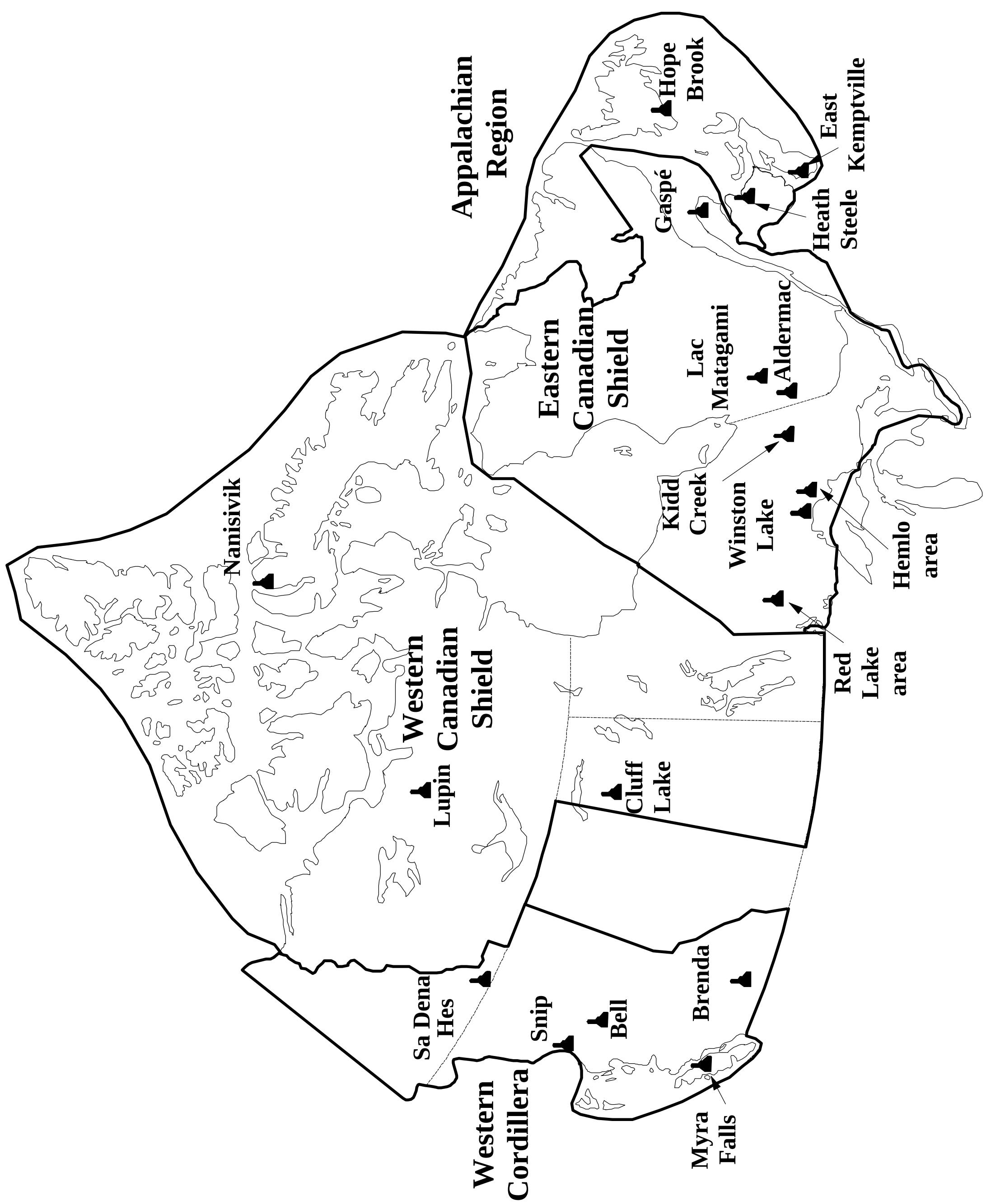
Case studies were prepared in a consistent manner following an assessment model developed by the chairs of the four regional Working Groups. In total, 18 case studies were prepared for sites illustrated in Figure 1.

1.6 Other Influences and Initiatives

In developing and implementing a cooperative national environmental protection framework, revising the MMLER, and designing and implementing an environmental effects monitoring program, Environment Canada and other stakeholders will have to consider several policies and initiatives, in addition to the recommendations of AQUAMIN. These policies and initiatives are listed below and are summarized in Appendix 1.

- Toxic Substances Management Policy
- Pollution Prevention — A Federal Strategy for Action
- *Canadian Environmental Assessment Act*
- Pulp and Paper Environmental Effects Monitoring program
- Treasury Board Policy
- Whitehorse Mining Initiative
- Aquatic Effects Technology Evaluation
- Mine Environment Neutral Drainage program
- Report on the Assessment of Metal Mine Submarine Tailings Discharge to Marine Environments

Figure 1: Case study sites



2 Summary of Key Findings

2.1 Summary of Effects on Aquatic Ecosystems[11]

Over the past 25 years, the number of operating metal mines in Canada at any given time has ranged between 103 and 177 active mines. Figure 2 shows the locations of currently operating metal mines in Canada. As mentioned earlier, over 700 documents were compiled, screened for content and quality, and entered into the AQUAMIN database. Information from over 95 mine sites was reviewed by Working Groups 3, 4, 5, and 6 (Supporting Document II, Report Review Compilations). These reports, together with the collective experience and knowledge of AQUAMIN Working Group members, provided the basis for examining the effects of mining in Canada on the aquatic environment. The documents described studies that were initiated for a variety of site-specific purposes and at different stages of mine operation. Hence, they varied greatly in their approach, methodologies, goals, and output. The documents in the database were sorted by geological region for review by the appropriate regional Working Group. The Working Group conducted a technical review of all reports, and selected a limited number of sites as case studies for detailed evaluation of effects.

Criteria used for the selection of case study sites included the:

- type of mine (to represent different ore types)
- extent (spatial and temporal) and completeness (abiotic and biotic) of data available
- reliability of the data
- discharges of water to the receiving environment
- availability of background or baseline data

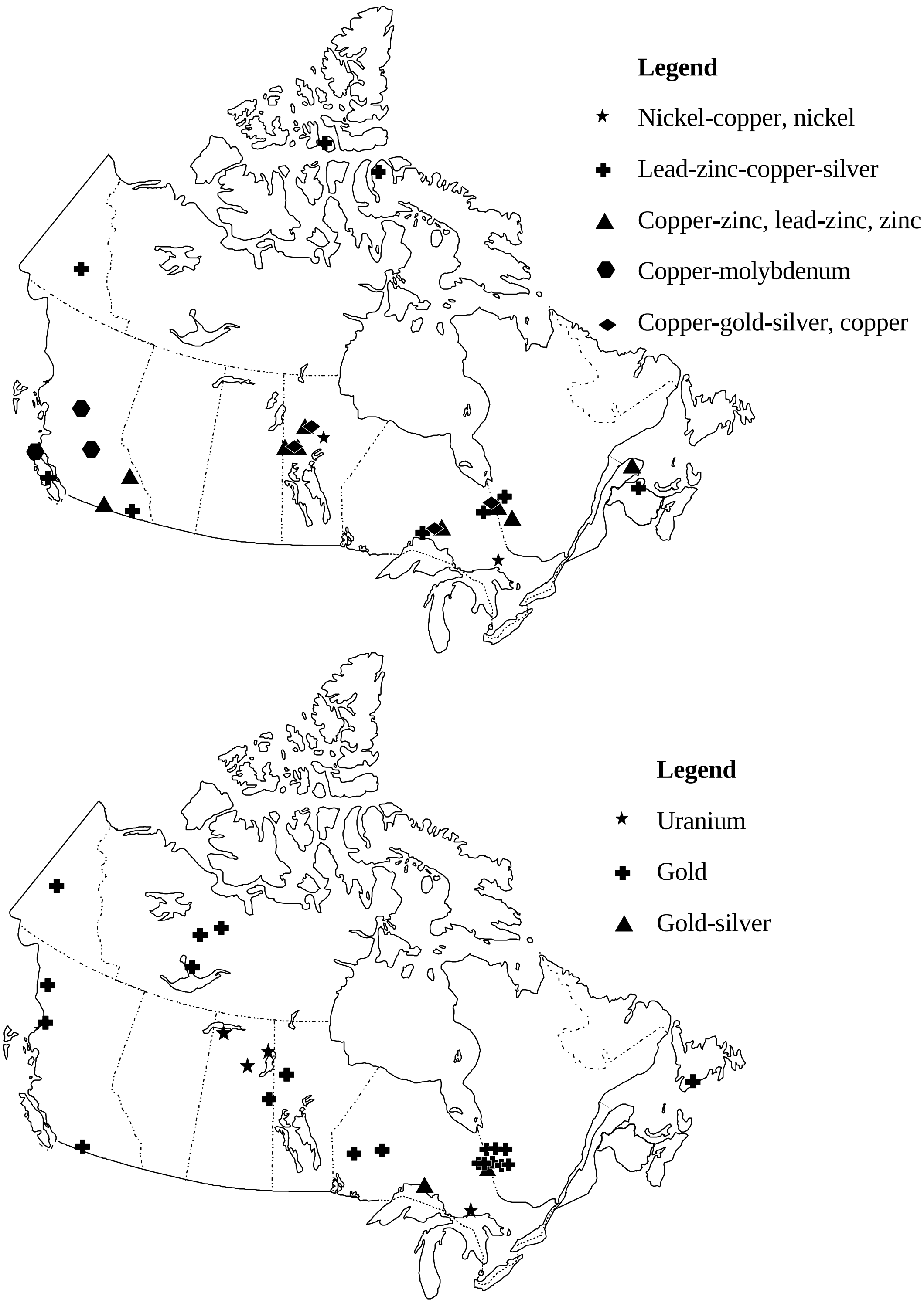
A total of 18 mines were selected as case studies (see Figure 1 and Table 4), including base metal, gold, and uranium mines. Of these, one site was abandoned. Key findings from non-case study reports were also identified. Detailed results of the case study reviews are presented in Supporting Document II.

During the course of gathering information upon which to base a study of the aquatic effects of mining, AQUAMIN Working Groups faced many challenges. The main challenge was the wide variety of purposes for which studies were carried out. Aquatic monitoring may be more frequent at sites where environmental problems are known or suspected to exist. Therefore,

---

[11] Case studies of Working Group 5 were not available to Working Groups 7 and 8 at the time of writing. Information from Working Group 5 was added by the AQUAMIN Secretariat as this document was finalized.

Figure 2: Base metal, precious metal, and uranium mine sites in Canada.



the findings of this review could be biased toward problem areas. It is clear that for a large number of sites there is very little information on which to base an assessment of effects. Although this review cannot give an accurate picture of the incidence of effects, it does identify the types of effects that may occur. Data on the effects of exploration activity, and orphaned and abandoned sites were limited. The following summary of aquatic environmental effects, based on the results of the case studies and the Regional Syntheses (Supporting Document II), is therefore unlikely to fully reflect the Canadian situation as a whole.

The types of data available from any one site also varied. Few operations had regular monitoring programs that examined effects on biota as well as on water and sediments. Also, monitoring was often limited in scope, the emphasis being on water quality as reflected in the summary of site report topics. For example, the topic summary report of Working Group 6 indicated that in 94 reports covering 17 mines, regular biomonitoring was reported for only four mines (12 fish studies and 35 benthic studies). Similarly, very limited biotic information was available in the Appalachian region. As a result, the Working Group, in reporting a lack of apparent effects in some mines, had to qualify this finding by stating that environmental monitoring at most of the sites was very limited. The Regional Synthesis of Working Group 4 (Québec) emphasized the lack of information on aquatic effects.

Working Groups were charged with the task of assessing the information available from each mine site, and determining the magnitude and extent of aquatic effects, if any. For the purpose of evaluation, an “effect” was defined as “a measurable difference in an environmental variable (physical, chemical, or biological) between a point downstream in the receiving environment and an adequate reference point (either spatial or temporal).”

Downstream chemical levels higher than appropriate water or sediment quality guidelines were also considered to be effects. The aquatic environment was separated into several topic areas. Major topics included water quality, sediment quality, toxicity, benthos, and fish. Other topics included zooplankton, phytoplankton, shellfish, and macrophytes. In some cases, physical disturbances were deemed to be involved or even dominant factors in environmental effects.

Aquatic effects at case study sites are summarized in Table 4, and examples from case study sites and some non-case study sites are provided below. In Table 4, a yes/no indicates whether or not an effect was measured. If the topic area was sampled but it was not possible to measure a response due to inadequate data, limited survey design, natural variability, or some other reason, the effect was designated as inconclusive. Notwithstanding the existence of documented effects, it was frequently difficult to make conclusive statements regarding the specific cause or the ecological significance of effects.

Table 4: Summary of aquatic effects for case studies, Appalachian region (Working Group 3).

Mine Site Information				Receiving Environment Effects						Remarks
Name of Mine (Prov.)	Years in Operation	Type of Mine	Effluent Toxic?	Water Quality	Sediment Quality	Benthos PC	Fish PC	Fish TR	Other	
Hope Brook (Nfld.)	1987-present	gold	NA	**Y**	**Y**	?	NA	N(1)	**Lobster TR: Y**	Elevated concentrations of copper and cyanide in waters: improvement over last few years. Increasing concentrations of metals in sediments.
East Kemptville (N.S.)	1985-1992	tin (copper, zinc)	N(2)	**Y(3)**	N(4)	N(4)	?(5)	**Y(6)**	NA	Increase of fluoride in water and fish skeletal tissue. Siltation during construction may have caused habitat damage in immediate receiving waters and contamination of sediment by arsenic.
Heath Steele (N.B.)	1955-present	zinc, copper, lead	N(7)	**Y**	**Y**	**Y**	**Y(8)**	?(9)	NA	Reduction of these effects over the past few years following control of acid mine drainage and effluent discharge. Effects on benthos and fish extend 22 km downstream (historically 36 km).

1 No fish captured in 1989 and 1990 — effects attributed to degraded water quality.
2 Few occurrences of lethal toxicity in fish and daphnia.
3 Not exceeding specific water quality objectives.
4 Conclusions based on short-term data: sampling was inadequate to assess long-term effects.
5 Nonquantitative survey.
6 Fluoride tested only: no adverse effect detected with pathological examination.
7 Historically, alkalinity was lethal to fish.
8 Prior to 1994, salmon were deterred from entering Tomogonops River.
9 Limited sampling showed no unusual metal concentrations.

LEGEND

N = No
NA = No results, not available, not tested
PC = Population/communities
TR = Tissue residues/physiological indicator
(H) = Historical effects
Y = Yes
? = Inconclusive: data quality/quantity insufficient

Table 4: Summary of aquatic effects for case studies, Eastern Canadian Shield region — Québec (Working Group 4).

Mine Site Information				Receiving Environment Effects						Remarks
Name of Mine (Prov.)	**Years in Operation**	**Type of Mine**	**Effluent Toxic?**	**Water Quality**	**Sediment Quality**	**Benthos PC**	**Fish PC**	**Fish TR**	**Other**	
Gaspé (Qué.)	1955-present	copper	N(1)	**Y(2)**	**Y(3)**	**Y**	**Y(H)**	**Y(4)**	**Zooplankton TR: Y (4)**	Receiving waters characterized by high hardness Improvement in benthos communities and juvenile salmon densities after 1985 following reduced mining production and water quality improvements.
Aldermac (Qué.)	1932-1943	copper, gold, silver	NA	**Y**	**Y**	NA	**Y**	NA	NA	Abandoned mining site.
Lac Matagami (Qué.)	1963-present	zinc, copper	N(5)	**Y**	**Y**	**Y**	N	N	NA	High buffering capacity in the receiving waters. Water quality is affected by zinc, sediments by zinc and copper.

1 One case of toxicity with daphnia.
2 Reduced concentrations of total and dissolved copper since 1982 (after spill) close to the discharge.
3 Copper accumulation in sediments at site close to the mine.
4 Based on one survey with very limited sample number and at the outlet of the clarification pond.
5 No toxicity from 1989 to 1992, daphnia and rainbow trout.

LEGEND

N = No
NA = No results, not available, not tested
PC = Population/communities
TR = Tissue residues/physiological indicator
(H) = Historical effects
Y = Yes
? = Inconclusive: data quality/quantity insufficient

Table 4: Summary of aquatic effects for case studies, Eastern Canadian Shield region — Ontario (Working Group 4).

Mine Site Information				Receiving Environment Effects						Remarks
Name of Mine (Prov.)	**Years in Operation**	**Type of Mine**	**Effluent Toxic?**	**Water Quality**	**Sediment Quality**	**Benthos PC**	**Fish PC**	**Fish TR**	**Other**	
Winston Lake (Ont.)	1987-present	copper, zinc	N	**Y(1)**	**Y**	**Y**	**Y**	N	NA	Improvement related to rehabilitation of the abandoned mine. Elimination of brook trout population in Cleaver Lake since 1992.
Kidd Creek (Ont.)	1966-present	copper, zinc, lead, silver	**Y(2)**	**Y**	NA	?(3)	NA	NA	NA	Numerous confounding factors: drainage from waste rock pile, historical discharges from several gold mines, existing gold mine, municipal sewage treatment plant.
Red Lake area (Ont.)(4)	1930s-present	gold	**Y(5)**	**Y(H)**	NA	**Y**	**Y**	**Y**	NA	Effluent data showed continued improvement in quality from 1992-1994. Habitat loss due to changes in water flow (periodically). Balmer Lake has historically been used as tertiary pond.
Hemlo area (Ont.)(6)	1982-present	gold	N	**Y**	**Y(7)**	?	?	N(8)	NA	Effluent discharge since 1987. Metal reduction since 1987 in Lim Lake achieved through effluent process changes (mainly total cyanide, molybdenum, and antimony).

1 Abandoned Zenmac Mine seepage is the main source of zinc in Kenabic Creek and in the river system.
2 Daphnia and trout: pH-dependent toxicity (not toxic using adjusted pH).
3 Conflicting conclusions (due to habitat variability, lack of statistical analysis).
4 Active mines are Red Lake Mine and Campbell Mine.
5 In 1991 only: acutely toxic to daphnia, periodic lethality to rainbow trout.
6 Includes: Golden Giant Mine, David Bell Mine, and Williams Mine.
7 Metal concentrations in Frank Lake sediments were not different from preoperational and reference lake.
8 Metal concentrations in fish (flesh?) were low. Preoperational mercury levels were high.

LEGEND

N = No
NA = No results, not available, not tested
PC = Population/communities
TR = Tissue residues/physiological indicator
(H) = Historical effects
Y = Yes
? = Inconclusive: data quality/quantity insufficient

Table 4: Summary of aquatic effects for case studies, Western Canadian Shield region (Working Group 5).

Mine Site Information				Receiving Environment Effects						Remarks
Name of Mine (Prov.)	**Years in Operation**	**Type of Mine**	**Effluent Toxic?**	**Water Quality**	**Sediment Quality**	**Benthos PC**	**Fish PC**	**Fish TR**	**Other**	
Cluff Lake (Sask.)	1980-present	uranium	N	**Y**	**Y**	**Y**	**Y**	**Y**	**Macrophytes TR: Y** **Macrophytes PC: Y**	Deleterious effects are largely confined to a mixing zone upstream of a wetland. The wetland removes up to 96% of contaminants (e.g., uranium). The site has been monitored extensively.
Nanisivik (N.W.T.)(1)	1976-present	zinc	?	**Y**	**Y**	N	N	**Y(H)**	**Benthos TR: Y(H)** **Macrophytes TR: Y(H)**	Limited biomonitoring since the mid-1980s. Current extent and magnitude of biological effects not known. Current sediment information suggests that the spatial extent of lead and zinc contamination has increased.
Lupin (N.W.T.)	1982-present	gold	N(2)	**Y**	**Y**	**Y(H)**	N	**Y(H)**	NA	

1 The mine is adjacent to Strathcona Sound and is drained by a creek that empties into the sound. Water quality monitoring has been conducted in the creek, whereas a range of monitoring has been conducted in the sound.
2 Some incidents of effluent toxicity were observed in 1991. Generally, cyanide, arsenic, zinc, and copper are present in effluent at concentrations that could cause toxicity, but the pH and hardness are acting as modifying factors to reduce toxicity.

LEGEND

N = No
NA = No results, not available, not tested
PC = Population/communities
TR = Tissue residues/physiological indicator
(H) = Historical effects
Y = Yes
? = Inconclusive: data quality/quantity insufficient

Table 4: Summary of aquatic effects for case studies, Western Cordillera region (Working Group 6).

Mine Site Information				Receiving Environment Effects						Remarks
Name of Mine (Prov.)	**Years in Operation**	**Type of Mine**	**Effluent Toxic?**	**Water Quality**	**Sediment Quality**	**Benthos PC**	**Fish PC**	**Fish TR**	**Other**	
Bell (B.C.)	1970-1992 (closure 1982-1983)(1)	copper	N	**Y(2)**	**Y**	?	?	**Y(3)**	Zooplankton PC: N **Zooplankton TR: Y** Metallothionein: ?	Since late 1980s, improvement in water quality in Hagan Arm following control of seepage and effluent discharge.
Brenda (B.C.)	1970-1990	copper - molybdenum	N	**Y**	**Y**	?(4)	?(5)	NA	Periphyton: ?	Control of runoff in 1980 improved water and sediment quality. Meeting molybdenum criteria for irrigation water sources is a concern. Zero discharge —- problems have been associated with seepages.
Snip (B.C.)	1991-present	gold (non-cyanide)	N	N	N	N	NA	NA	Sediment and fish eggs toxicity test: N (6)	Good recent example of effective permit strategy.
Myra Falls (B.C.)	1967-present	zinc, copper, silver, lead, gold	NA	**Y(H)**	**Y(H)**	**Y(H)**	?	**Y(H)**	**Phytoplankton, Zoo-plankton PC: Y(H)** **Metallothionein: Y(H)** **Periphyton: Y(H)**	After remedial actions (1982), improvement in water quality and biological parameters; improved health of fisheries. (7)
Sa Dena Hes (Yukon)	1991-1992	zinc, lead, silver	N	**Y**	**Y**	?	NA	?	NA	Limited availability of monitoring data.

1 Prior to 1982, no discharge.
2 Babine Lake is characterized by a high organic complexing capacity for copper.
3 Cadmium, copper, zinc elevated in liver tissues.
4 Post-1980 effect cannot be determined: study designs allow detection of only gross effects and times of the studies were inadequate.
5 Harvesting and habitat disturbance are confounding factors.
6 No conclusive evidence of potential for sublethal effects.
7 Historical effects mainly attributed to low pH.

LEGEND

N = No
NA = No results, not available, not tested
PC = Population/communities
TR = Tissue residues/physiological indicator
(H) = Historical effects
Y = Yes
? = Inconclusive: data quality/quantity insufficient

A summary of this nature cannot adequately reflect the tremendous amount of work and review undertaken by the mining industry, as well as by the AQUAMIN Working Groups. Readers may consult Supporting Document II for additional information on the aquatic effects observed.

2.1.1 Water Quality

The summary tables clearly indicate that in every case study, as at many of the other mine sites reviewed, changes to receiving water quality could be attributed to the mining operation. This finding is not unexpected as the effluent metal concentrations usually exceed background levels. Changes in water quality were sometimes limited to very small areas near the point of discharge, whereas in other situations effects were measured tens of kilometres downstream. The magnitude and extent of the water quality effects depend on several factors, including chemical loading rates, the hydrological regime of the receiving waters, and mine management and operating procedures. Although correlations between water quality and specific effects were difficult to establish, Working Groups felt confident in attributing some negative impacts on fish or benthos to elevations in, for example, concentrations of zinc, cyanide, fluoride, aluminum, nickel, ammonia, nitrates, and copper. The extreme pH of effluent was considered to be the cause of observed effects in a number of cases.

Observed effects as illustrated in studies included the following:

- Elevated levels of contaminants not regulated under the MMLER were found in receiving waters (e.g., Heath Steele, East Kemptville, Brenda).

- Effluent discharges increased the concentration of some substances downstream, but it was difficult to differentiate increases from natural variability. The degree of dilution and varying effluent concentrations were complicating factors (e.g., Bell, Sa Dena Hes).

- Naturally elevated background levels and particular receiving water quality characteristics (e.g., organic metal complexing, buffering capacity) complicated the application of “generic” water quality guidelines or objectives (e.g., Bell, Gays River, Myra Falls, Hemlo area, Gaspé).

- Effluent quality from historical sites has been improving over time, which is reflected in improved downstream water quality (e.g., Red Lake area, Myra Falls, Bell, Heath Steele, Brenda, Hemlo area).

- Effects varied with the type of receiver, for example, lime-treated effluent can promote chemocline formation in a lake (Winston Lake Mine).

- Downstream water quality (metal concentrations, pH, and other parameters) may be affected over many kilometres (e.g., Red Lake area, Heath Steele, Brunswick No. 12).

- Activities both upstream and downstream of the sites (abandoned mines, mining, wastewater treatment, landfills) contributed to increased concentrations in the receiver, confounding interpretation of results (e.g., Kidd Creek, Winston Lake, Red Lake area, Gaspé).

- Since 1987, cyanide and metal levels (particularly antimony and molybdenum) were successfully reduced in Lim Lake following effluent process changes (Hemlo area).

- Thiosalt oxidation reduced the pH in receiving waters (e.g., Heath Steele, Brunswick No. 12).

- Uncontrolled discharges, such as seepage or acid mine drainage, have led to increased metal concentrations and altered pH in receiving waters (e.g., Myra Falls, Mount Washington, Heath Steele, Buchans, Brunswick No. 6, Nanisivik).

- Zinc and lead concentrations in Strathcona Sound were significantly higher than those typically found in open oceans, with a clear trend towards higher zinc concentrations closer to the Nanisivik site.

- Uranium, molybdenum, lead, salinity, and sulphate elevated in surface waters downstream from the Cluff Lake Mine.

2.1.2 Sediment Quality

Changes to sediment quality were reported in most case studies where adequate sediment surveys were undertaken. Sediments were not sampled in two case studies and results were inconclusive in a third study. Reviewers noted that there were major difficulties in obtaining representative sediment samples and concluded that quantitative estimates of the magnitude and extent of effects on sediments were not possible for most mine sites. Difficulties encountered included sediment particle size, a lack of appropriate reference stations, sampling problems, and the influence of geochemical properties of individual metals. Also, contaminant trends may not be evident in river sediments because of constant mixing and grading of sediments in high gradient streams. Information on the bioavailability of metals in sediments was lacking.

Examples of observed effects reported in studies are as follows:

- At Brenda, releases of molybdenum from contaminated mine site runoff caused enrichment of molybdenum in sediments downstream of the lake.
- Increases in lead, zinc, cadmium, and arsenic were observed downstream in False Canyon Creek at Sa Dena Hes.
- Elevated concentrations of copper, zinc, and/or arsenic in surficial sediments at several sites adjacent to mine workings have been documented (e.g., Bell, Lac Matagami, Lupin).
- River sediment samples showed elevated copper and zinc levels relative to control station levels (e.g., Winston Lake, Kidd Creek, Heath Steele).
- In the Hemlo area, metal concentrations in Lim Lake sediments (antimony, copper, manganese, molybdenum, nickel, tin, and zinc) were higher than preoperational levels or levels in the reference lake, whereas concentrations in Frank Lake sediments were either lower or unchanged.
- Baseline information revealed that metal concentrations in sediments in many of the case study areas naturally exceeded sediment quality guidelines (e.g., Hemlo area, Winston Lake, Kidd Creek).
- Historical tailings deposits within the receiving body (Balmer Lake and Balmer Creek) have affected both the chemical and physical quality of sediments (Red Lake area). Sediments are overlain by tailings material released prior to construction of tailings dams.
- Marine sediments contain elevated concentrations of zinc and lead in the vicinity of Nanisivik.
- Uranium, molybdenum, and nickel elevated in sediments downstream from the Cluff Lake Mine. Minor accumulations of radionuclides (lead-210, polonium-210, and radium-226) were observed in sediments relative to historical levels.

2.1.3 Benthic Macroinvertebrates

Changes in the benthic invertebrate community were noted in about half of the case studies. The results of benthic surveys were inconclusive in seven case studies. Most of the studies reviewed were simply one-time or scattered assessments. In most cases, determination of absolute magnitude and extent were confounded by factors such as natural variability, insufficient data analysis, variable sampling seasons, poor sampling design, or a lack of sufficient habitat information.

Examples of observed effects reported in studies include the following:

- In south Buttle Lake, the benthic fauna had low population densities and contained several pollution-tolerant species (Myra Falls).

- Impacts on benthic communities were attributed to increased levels of zinc and copper in water and sediments resulting from both current and historical mining activity (e.g., Winston Lake).

- Gross changes in benthic populations were sometimes easily identified (e.g., Red Lake area, Winston Lake, Heath Steele, Gaspé) where there had been historical mining operations. In the past, only metal-tolerant species were present; current conditions, however, show improvement.

- Where changes were more subtle, it was difficult to establish a cause–effect relationship due to a lack of detailed information on habitat or a lack of taxonomic resolution for benthic organisms (e.g., Kidd Creek).

- At Winston Lake, reclamation work under way since 1989 at the abandoned Zenmac Mine resulted in reduced metal levels water of the Whitesand River. Benthic invertebrate communities reflected this improvement. In 1991, all river stations exhibited an increase in the number of sensitive species (*Ephemeroptera* sp.).

- Mercury and arsenic accumulated in benthic invertebrates (Nova Scotia Gold).

- In Strathcona Sound, zinc and lead concentrations in clams and sea urchins were elevated in the vicinity of Nanisivik.

- Significant changes were observed in the composition of benthic communities in Island Lake, principally due to increases in salinity (Cluff Lake).

2.1.4 Fish Populations and Communities

Fish were sampled to determine residue levels in tissues and/or to collect information on populations or fish community structure. In general, the fisheries surveys seemed less rigorous than surveys for the preceding topic areas. In many situations, fish were collected for trace metal analysis only, not to provide insight into relative abundance. Not surprisingly, results were generally less conclusive, particularly with respect to population effects. Natural (including seasonal) variability in fish populations was often cited as a factor confounding clear interpretation of survey results. In five case studies as well as in a number of other mine site reports, however, the local absence of fish populations was attributed to mine operations (historical and/or current).

Examples of observed effects reported in studies include the following:

- Variations in fish populations could not be clearly related to mine discharges, but may have resulted from physical changes (i.e., stream flow alteration) (e.g., Equity Silver, Brenda).

- Resident brook trout populations were self-sustaining and more abundant prior to mine operation than they were 5 years later (Winston Lake). A chemocline in Cleaver Lake (anoxia, high concentrations of ammonia, calcium, sulphate, iron, and copper) reduced available fish habitat.

- A viable lake fishery was lost when a lake was used as a final treatment pond, mainly due to the presence of arsenic and cyanide. Downstream in Balmer Creek, various species (walleye, pike, perch, and white sucker) were observed exhibiting a wide range of size and age classes. However, some effects, such as a low number of young-of-the-year and female walleye and an absence of spawning activities, may be due to watercourse alteration (Red Lake area).

- Prior to 1994, salmon were deterred from entering former spawning habitat in the Tomogonops River by the combination of metals in mine discharges. Salmon spawning in the upper Tomogonops River has been observed, however, following improvements in water quality (Heath Steele).

- Thiosalt oxidation reduced river pH, resulting in the absence of downstream fish populations (Brunswick No. 12).

- Arnoux Lake, which had a large fish population, lost all aquatic life because of acid mine drainage from an abandoned mine (Aldermac).

- A lake was lost as a result of its use for tailings disposal (e.g., Lac Matagami).

2.1.5 Fish Tissue Residues and Physiological Indicators

Elevated levels of some metals in fish tissues were reported in six case studies and a number of other mine reviews. These measurements serve as indicators of exposure to the chemical parameters, but the relevance of the observations to the health of individuals or populations is not clear because fish health was not examined. To evaluate the bioavailability of contaminants to fish, it is important to analyse the appropriate tissues (e.g., kidney, liver for many metals). Except for mercury analysis, muscle is not an appropriate tissue for use in biomonitoring (Regional Syntheses, Ontario and British Columbia).

Examples of observations drawn from studies are as follows:

- Although no elevated metal concentrations were detected in the muscle tissue of fish from Babine Lake, cadmium, copper, and zinc concentrations in liver tissue were significantly above levels observed in unimpacted waters (Bell).

- Relatively high metal concentrations in salmonid muscle and liver tissues were historically associated with increased metal concentrations in water. As mine effluent treatment improved, metal concentrations decreased in muscle tissue, but copper and cadmium remained elevated in liver tissue (Myra Falls).

- Increased metal concentrations in fish liver tissue were accompanied by elevated metallothionein (Myra Falls).

- Increased mercury and arsenic were found in fish in the vicinity of a gold mine (Nova Scotia Gold).

- Metal concentrations in fish muscle tissue were unaffected by mine operations (e.g., Winston Lake, Hemlo area).

- Metal concentrations increased in lobsters and mussels in a marine receiving environment (Hope Brook).

- Uranium and molybdenum concentrations were elevated in fish tissue downstream from the Cluff Lake Mine.

2.1.6 Zooplankton, Phytoplankton, and Periphyton

An assortment of other aquatic communities was monitored at various sites. The topic areas included metal uptake in periphyton, and the population structure of zooplankton and phytoplankton. Mobile plankton are not commonly studied owing to the natural variability of the parameters being measured and the complexity of background conditions. Studies that were reviewed did not generally consider patterns of temporal and spatial variability.

Examples of observations from studies are as follows:

- No apparent effects were identified from a limited review of zooplankton data (Bell).

- Impacts on the density and diversity of zooplankton and phytoplankton attributed to zinc showed improvement following the installation of mine water treatment facilities (Myra Falls).

- An impact on the periphyton community was observed at Myra Falls.

- Zinc, lead, and cadmium concentrations in seaweed were elevated in Strathcona Sound in the vicinity of Nanisivik, and were elevated relative to preoperational levels.

- Uranium, molybdenum, arsenic, and radium-226 concentrations were elevated in macrophytes downstream from the Cluff Lake Mine.

- Changes in the structure of the macrophyte community were consistent with those associated with an increase in salinity (Cluff Lake Mine).

2.1.7 Conclusions

The review process identified a variety of aquatic effects that could be attributed to mining operations and effluent release, including effects attributed to closed and abandoned sites. There was a wide range in the magnitude and extent of effects, including findings of no observed effects at some mines. Both the nature of mining operations and their receiving environments also varied widely.

Changes to water quality in areas downstream of effluent outfalls were always related to mine effluent, whereas changes in sediment quality were sometimes related to discharges from mines. Insufficient data or inadequate survey designs sometimes precluded evaluation of the ecological or biological significance of changes in water and sediment quality. In some situations, mining operations clearly had an adverse effect on benthic invertebrate communities and fish populations. However, the biological effects could not be directly related to the specific contaminant limits established by the MMLER. In general, older mine sites, and/or those with acid mine drainage, typically had more pronounced effects than newer sites. Often, conditions have improved over time as a consequence of improvements in effluent quality or mine wastewater management.

Many important questions were raised by the AQUAMIN review that can only be answered through consistent application of environmental effects monitoring and/or additional research efforts.

2.2 State of Environmental Monitoring in the Canadian Mining Industry

Currently, there is no comprehensive monitoring framework providing data that could be used to assess the aquatic effects of mining throughout Canada. Federally, monitoring of effluent quality is required by the MMLER, but aquatic monitoring in receiving waters is not. More detailed monitoring of the receiving environment is sometimes a provincial or territorial requirement, or the result of an environmental assessment.

Evaluation of the reports contained in the AQUAMIN database, and detailed review of the case studies in particular, shed considerable light on the state of aquatic effects monitoring in the Canadian mining sector. The quality of reports, and subsequent ability to interpret aquatic effects, ranged from inadequate to comprehensive environmental assessments. In fairness to individual reports, none of the studies were undertaken for the purpose of AQUAMIN. As a result, some otherwise worthwhile studies could not be used to achieve the AQUAMIN objectives.

The above review of aquatic effects indicated that most water and sediment surveys in the case studies were able to detect cause–effect relationships among a mine site and indicators in the receiving environment. This was not true for all studies reviewed, however, as there were a number of studies, including recent reports (prepared within the last 10 years), that could not detect aquatic effects due to inadequate study design or levels of sampling. For instance, few mine sites provided a valid time series of data.

To some extent, survey results and monitoring reports have improved in recent years as the science of environmental assessment has progressed and survey designs have evolved. In many cases, however, quantitative assessment of effects could not be undertaken due to a lack of baseline data. This was particularly true for older mine sites. Working Group 6 suggested that the only way to assess cause–effect relationships for changes in water quality related to mining activity is to establish baseline data before mining activities commence. A lack of consistency among studies was frequently cited by the Working Groups as a limitation in using the data for evaluation purposes; but, as Working Group 3 observed, aquatic effects monitoring at mine sites was more often conducted on an ad hoc basis in response to a particular concern or event. Therefore, even though acceptable techniques were employed, the resultant data were not useful for spatial or temporal comparisons, or for AQUAMIN purposes.

The limitations identified in the mining case studies were organized into four categories: study design, methods and techniques, data analysis, and follow-up.

2.2.1 Study Design

This is a catch-all for survey deficiencies and includes insufficient numbers of samples, insufficient replicates, poor or too few sampling locations, and a poor choice of reference sites or none at all. Poor study design may be due to a lack of clear objectives for the monitoring program. Study design also incorporates the features of a quality assurance/quality control program required to identify variability due to sample handling, within-site variability, and laboratory error.

A good study design requires careful planning and execution, and adequate resources (financial, technical, expertise) to be properly executed. Aquatic effects from some individual mining operations may be very difficult to discern due to historical impacts and/or other mining activities in the watershed.

The most useful studies for evaluating aquatic effects for AQUAMIN were those that measured a chemical or biological parameter with adequate replication, spatially and/or temporally, using consistent methods.

Selection of appropriate sampling sites was an issue. For instance, in the Hemlo area, preoperational and operational benthos sampling indicated little change. However, sampling locations in lakes were inadequate (limited to habitats dominated by pollution-tolerant chironomids) and could not reflect potential effects on sensitive organisms. Interpretation of data on benthos from creeks and rivers was difficult because habitat conditions were not taken into account.

The state of knowledge on this subject in Canada is such that properly designed aquatic effects studies can be implemented for mine sites. However, clear advice on study design should be made available to meet the needs of the mining sector considering both the unique characteristics of each mine and their receiving environments.

2.2.2 Methods and Techniques

AQUAMIN did not include in-depth evaluation of sampling procedures and analytical techniques. However, a lack of adequate conduct and reporting of quality assurance/quality control was frequently identified as a concern by the Working Groups. For example, many studies inadequately described sampling methodologies. There were many differences in the techniques used for collecting, sorting, and enumerating benthic samples, even among studies within the same site. This makes comparisons of year-to-year results difficult.

Consistent and appropriate sampling protocols and analytical techniques are required. Laboratory analytical methods must also be appropriate for chemical analysis of water, sediments, and tissues. In particular, routine analytical detection limits for contaminants are sometimes higher than the water quality guidelines or objectives for those contaminants. In these situations, potential effects could go undetected despite samples being collected to examine water quality.

2.2.3 Data Analysis

The Working Groups identified weaknesses in statistical analysis and data interpretation. However, this may not be a function of poor statistical analysis, but rather a function of insufficient planning for data collection to allow for a proper statistical evaluation.

It was difficult for the reviewers to link effects with probable causes because monitoring reports often failed to include information on the quality, loadings, and duration of mine effluent entering the receiving environment.

2.2.4 Follow-up

The Working Groups identified several cases where regulatory agencies requested environmental monitoring as a condition for granting a permit or licence, but the agencies did not review the results adequately nor did they provide timely feedback on the studies.

To date, a considerable number of aquatic effects studies have been completed by the mining sector. As there is no national monitoring framework, however, the quality and nature of aquatic monitoring studies conducted throughout Canada have been variable, and the lack of consistency, even within particular sites, was a concern for the Working Groups. It was also reported that adequate guidance for designing and implementing a proper effects monitoring program for the mining sector was lacking.

2.3 Effectiveness of the MMLER

The objective of AQUAMIN was to examine the effectiveness of the current MMLER, including the application of and parameters in the current MMLER. This examination was based on the information collected through AQUAMIN.

2.3.1 Application

Many metal mines in Canada are not subject to the current MMLER because they were in operation prior to 1977, because they are gold mines, or because they are closed or abandoned. Even though mines in operation prior to 1977 are subject to the MMLEG, the narrow scope of the MMLER, in terms of the types of mines covered and activities considered, represents a deficiency in the application of the current MMLER.

The mine sites examined in AQUAMIN were selected to make optimal use of available environmental data and to ensure broad coverage of different categories of mining operations.

2.3.2 Parameters

Members of Working Groups 3, 4, 5, and 6 were not specifically tasked with identifying parameters of concern, and no criteria were developed to guide Working Group members on which parameters to study. Furthermore, data to definitively link specific contaminants to environmental effects at study sites were lacking in many cases. In a number of case studies, however, specific parameters were identified that occurred in elevated concentrations in at least one environmental compartment.

2.3.3 Limitations of the AQUAMIN Data

There were limitations in the AQUAMIN data that made it difficult to complete a comprehensive evaluation of the MMLER. Although this may be a disappointing outcome of AQUAMIN, the nature of these limitations provides useful information and insight into the need for environmental effects monitoring and a site-specific approach.

Limitations in the AQUAMIN data can be attributed to the following factors:

- studies examined were not designed specifically to evaluate the effectiveness of the MMLER
- many operations were subject to more stringent provincial limits and/or site licences

- some operations were not subject to the MMLER or the MMLEG
- many operations lacked adequate monitoring data to determine aquatic effects related to mining
- studies generally examined effluent chemistry, or parameters in the receiving waters, but only in a few cases were these components combined in an attempt to relate cause and effect
- specific causes of observed biotic effects could not be identified in many of the studies examined
- in several cases where the causes of effects were identified, the causes were parameters not regulated in the MMLER
- not all mining discharges are monitored
- in situations where aquatic effects were observed, it was not always possible to determine if these effects were related to periods of noncompliance or to other operational activities, accidents, acid mine drainage, or other factors
- co-occurrence of a number of parameters regulated in the MMLER added to the difficulty in identifying individual causative agents

2.4 Need for a National Environmental Effects Monitoring Program

It was obvious from the review of case studies that guidance on consistent and appropriate survey methodologies for environmental effects monitoring (EEM) studies was lacking, and the Working Groups recognized the need for an EEM program for the mining sector. A proposed framework for an EEM program and various concepts are outlined later in this document to provide a foundation for future discussion.

The Working Groups were diligent in providing many recommendations that could be applied to an EEM program. Many of the comments and recommendations were specific in nature, but some guiding principles regarding an EEM program emerged. These included the following:

- the objectives of the program must be clearly articulated
- the program must be scientifically sound
- the program must be related to preoperational baseline conditions, or conditions on an unimpacted comparable water body or stream if preoperational baseline data do not exist
- studies should be effective and efficient
- overlap with other federal and provincial programs should be avoided
- there should be provisions in the reporting framework to harmonize with other programs
- standards for study design and quality assurance/quality control measures should be provided
- the program should be simple, but able to detect environmental changes

- the program should be able to isolate natural spatial and temporal variability
- the program must provide flexibility for site-specific requirements
- timely and appropriate review and feedback from regulatory agencies is required
- the reporting framework and frequency of monitoring should be clearly established
- monitoring should focus on the parameters most likely to be affected
- the program should not be research-based

On the surface, these principles may appear obvious, but they underlie important fundamental observations and concerns identified by the Working Groups. Some of the Working Groups made recommendations regarding components and parameters that could be included in an EEM program. It is evident that relatively simple, well-designed monitoring programs can detect aquatic effects and provide the information necessary to assess the adequacy of control measures in place at a given site.

3 Proposed Environmental Protection Framework

Ultimately, all life, including human activity, depends upon the maintenance of a healthy environment (including air, soil, water, and organisms). In the Canadian metal mining sector, the quality of effluents that may impact aquatic environments is regulated by both federal and provincial governments. The federal and provincial roles need to be coordinated within a cooperative national environmental protection framework. The objective of the framework, as outlined below, is to protect and sustain the aquatic environment and to ensure that fish are acceptable for consumption.

3.1 Principles

Recommendations contained in this document are founded on the following principles, which AQUAMIN recommends to Environment Canada as the basis for revising the MMLER:

Precautionary principle:[12] Where there are threats of serious or irreversible damage, the lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

Pollution prevention:[13] Focus on the anticipation and prevention of the creation of pollutants and waste, rather than on the remediation of pollution; the objective is a healthy ecosystem, the means is the efficient and effective use of energy, raw materials, and other commodities.

Sustainable development:[14] "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

The goal of sustainable development in the context of minerals and metals is "to find, extract, produce, add value to, use, re-use and recycle mineral and metal products in the most efficient manner possible, while respecting the needs and values of other resource users and

[12] United Nations Conference on Environment and Development. 1992. The Rio Declaration on Environment and Development, Principle 15. June 3–14, 1992, Rio de Janeiro, Brazil.

[13] "It's About Our Health! Towards Pollution Prevention — CEPA Revisited." Report of the House of Commons Standing Committee on Environment and Sustainable Development, June 1995.

[14] World Commission on the Environment and Development. 1987. Our Common Future. Oxford University Press.

maintaining and/or enhancing environmental quality for present and future generations."[15]

Knowledge-based approach: This approach acknowledges the contribution of western science, of local information and understanding based on observation and experience, and of aboriginal or indigenous traditional knowledge. The combination of various traditions, each providing a set of insights into environmental systems and how they are affected, results in a fuller and more comprehensive understanding than could be expected from relying solely on any approach in particular.

Ecosystem-based approach:[16] This approach recognizes the need to base environmental protection on the protection of ecosystem integrity, rather than on the protection of specific environmental components.

Multistakeholder participation: This principle recognizes the diverse values and experience of all stakeholders and the need for appropriate opportunities to provide timely and meaningful input into decision-making processes. Effective participation requires timely access to relevant information.

Effectiveness and efficiency: Compliance monitoring and EEM must be effective and efficient. Monitoring at each site, and among sites within a basin, should be integrated and coordinated to maximize effectiveness and efficiency in the collection of necessary data and information at a reasonable cost.

Compatibility of requirements: Federal requirements should be compatible with the requirements of provincial, territorial, and aboriginal governments. The federal government's role should be clearly defined in relationship to the roles of other governments, and reporting requirements should be streamlined to minimize duplication of effort, while preventing gaps.

Enforcement: All requirements should be enforceable and enforced. This implies monitoring and reporting requirements for the operator, and a verification function.

---

[15] Natural Resources Canada. 1995. Sustainable Development and Minerals and Metals. Discussion paper.

[16] "It's About Our Health! Towards Pollution Prevention — CEPA Revisited." Report of the House of Commons Standing Committee on Environment and Sustainable Development, June 1995.

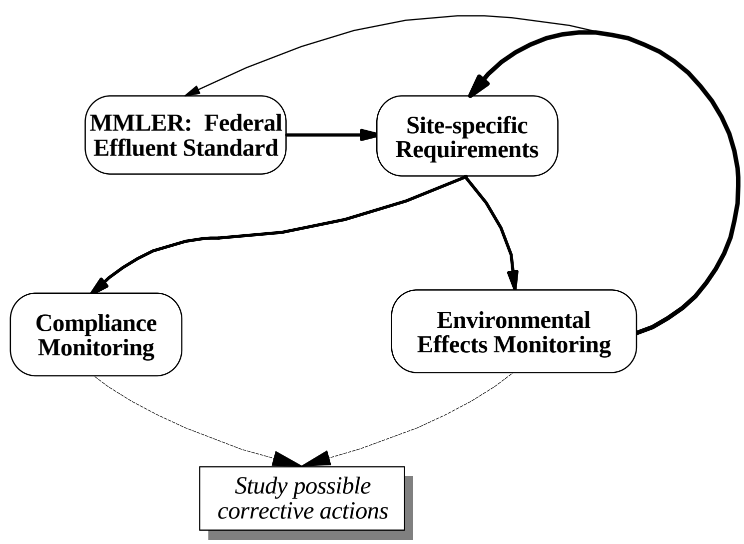
3.2 Essential Components

➥ ***It is recommended that a cooperative national environmental protection framework be implemented. This framework should include three components:***

- ***MMLER:** **a federal regulation to ensure a consistent, minimum quality of effluent being discharged to aquatic ecosystems***
- ***Site-specific requirements:** **more stringent site-specific requirements may be necessary to ensure adequate protection of some aquatic ecosystems***
- ***Environmental effects monitoring:[17]** **constitutes a feedback loop, providing information to decision-makers and the public regarding the effectiveness of both environmental protection measures and long-term regulatory strategies***

No single component is sufficient to achieve the overall objective. Effective implementation of all three components of the framework is essential. The relationship between the components is illustrated in Figure 3.

Figure 3: Relationship among the essential components of the environmental protection framework.



[17] In the interests of acceptability and usefulness of the identification of the program, the term environmental effects monitoring (EEM) will be used in this document. Other potentially appropriate terms were considered by the Working Groups.

3.2.1 MMLER: Federal Effluent Regulation

Objective

The objective of the revised MMLER, as a regulation under the *Fisheries Act*, should be to protect fish, fish habitat, and the use of fisheries resources by ensuring a consistent, minimum quality of effluent discharged to aquatic ecosystems and national consistency in its application, the parameters regulated, concentration limits, compliance monitoring, and reporting requirements.

Current Status

The findings of AQUAMIN, as summarized earlier, indicate that effects on receiving environments have occurred and continue to occur as a result of liquid effluent discharges from some Canadian metal mines. Substantial improvements have been made by mine operators and adverse effects have been eliminated or reduced in magnitude and/or extent in many cases. Monitoring at other sites revealed no adverse effects, although monitoring techniques may be inadequate to detect effects in some cases. Effects may occur even in cases where site-specific regulations are more stringent than MMLER limits. In addition, because of inconsistent application of the current MMLER, certain types or stages of mining activity have not been covered by the regulations. This indicates the need to update and strengthen the MMLER.

Other Considerations

AQUAMIN participants noted that harmonization initiatives of the Canadian Council of Ministers of the Environment could influence the design and delivery of the MMLER in the future. The respective roles and functions of the federal government, and of provincial, territorial, and aboriginal governments would be clearly defined. New and existing legislation would be reviewed with the objectives of reducing unnecessary overlap, increasing compatibility, and clarifying accountability while ensuring the absence of gaps.

The data reviewed through AQUAMIN were insufficient to establish the causes/sources of effects at all sites with observed effects. Recommendations regarding revisions to the MMLER and other elements of the framework, therefore, are based on the collective knowledge, experience, and judgement of Working Group members, as well as on the AQUAMIN review. Further investigation would be necessary to identify causes and potential remedial actions required at specific sites.

Recommendations

➥ ***It is recommended that the MMLER be amended as detailed in Section 4 to improve the quality of effluent discharged to aquatic ecosystems.***

Future revisions to the MMLER should be based on a balanced evaluation of the performance of new treatment or analytical technologies and the potential impact that compliance with current regulations will have on fish, fish habitat, and the use of fisheries resources. It will also be necessary to demonstrate the net benefit to society that will occur as a result of revisions.

➥ ***It is recommended that Environment Canada establish a process to review the MMLER in light of future environmental effects monitoring results. A mandatory review after a specified period could be incorporated into the revised MMLER to ensure that such a review does take place.***

3.2.2 Site-specific Requirements

Objective

The objective of site-specific requirements is to meet site-specific needs for enhanced protection of the receiving environment by specifying additional or more stringent pollution control or administrative requirements.

Current Status

Additional or more stringent requirements have been imposed at most mine sites by provincial or federal regulators. Requirements include legally enforceable limits and objectives or targets for effluent quality, flow, dilution, and contaminant loading, as well as receiving water quality. There are also additional requirements for technology development, discharge and environmental effects monitoring, and reporting, including static or *in situ* toxicity testing. Several mechanisms may be used to implement such requirements, with regulations and site-specific permits, licences, and approvals being most prevalent.

The federal government also has the authority to establish site-specific requirements. A site-specific regulation may be promulgated under Subsection 36(5) of the *Fisheries Act* to control effluent quality. In practice, a site-specific regulation has not been developed to impose more stringent requirements for effluent quality on a mine operator, but that authority has been used to regulate discharges from a pulp and paper mill. A mine operator may also be required, under Section 37 of the *Fisheries Act*, to conduct studies by regulation or to do so at the request of the Minister of Fisheries and Oceans.

Other Considerations

To identify and consider public concerns and all relevant information, processes for developing and implementing site-specific requirements should provide appropriate opportunities for public participation.

Provincial governments or other federal regulators are generally in a position to identify the need and justification for site-specific requirements and to develop and implement such requirements using existing approval schemes. This approach would be consistent with harmonization initiatives being considered by the Canadian Council of Ministers of the Environment.

Recommendations

➥ ***It is recommended that site-specific requirements be developed and implemented as appropriate by provincial, territorial, or aboriginal governments or other federal regulators where necessary to ensure protection of fish, fish habitat, and the use of fisheries resources.***

Site-specific requirements should be established taking into account social, economic, and environmental factors, as well as available control technologies.

➥ ***It is recommended that the federal government retain and enhance the ability to establish site-specific requirements in cases where a provincial, territorial, or aboriginal government is not in a position to do so.***

3.2.3 Environmental Effects Monitoring

Objective

The objective of environmental effects monitoring is to evaluate the effects of mining activity on the aquatic environment, including fish, fish habitat, and the use of fisheries resources. In addition, a nationally consistent EEM approach should reveal the effectiveness of pollution prevention and control technologies, practices, programs, and regulations, and indicate when there is a need for enhanced protection.

Definition of an Effect

For the purpose of completing AQUAMIN Supporting Document II, an effect was defined as “a measurable difference in an environmental variable (physical, chemical, or biological) between a point downstream in the receiving environment and an adequate reference point (either spatial or temporal).” For the purpose of an EEM program, however, this definition requires elaboration because measuring an effect is only the first step in understanding the meaning and importance of such a measurement. Effects may or may not be statistically demonstrable. Statistical significance is a scientific determination and, as such, is affected by the precision and reliability of measurement techniques used as well as by the degree of background variability in the parameter measured.

In turn, a statistically significant effect may or may not be biologically significant. Biological significance is a matter of judgement on the part of users of a particular ecosystem and biologists. It depends greatly on the level of understanding of a particular species or system that is present in the scientific community at any time. Regardless of whether or not an effect is considered to be biologically significant, it may be deemed socially or culturally significant — a determination that must involve affected public stakeholders. In the context of a particular mine site, effects that are significant in statistical, biological, social, or cultural terms may be considered to be acceptable or unacceptable, depending, in part, on the historical conditions and current public expectations of environmental quality. A mechanism to determine the acceptability of an effect for any particular site is discussed later in this document.

Current Status

Since the 1970s, mines have been monitored to assess their potential effects on the aquatic receiving environment. During the AQUAMIN review of mine monitoring, it was noted that insufficient data or inadequate study design often precluded evaluating the biological significance of changes in water and sediment quality. These biological effects could not be directly related to regulatory limits. Thus, a national EEM program would provide basic data by which aquatic effects could be assessed by mine operators, regulators, and concerned individuals throughout Canada.

Other Considerations

In Sections 6 and 7, a framework for monitoring potential aquatic effects stemming from the release of contaminated water from mine or mill sites is presented. This framework is **not** a template of monitoring requirements to be imposed on every site; rather it provides **guidance** for public process, data standards, and coordination of EEM, and identifies a suite of potential approaches that can be applied as dictated by local conditions (e.g., type of facility, type of receiver, local concerns).

Recommendations

➥ ***It is recommended that an environmental effects monitoring program be developed for all metal mines in Canada as detailed in Section 6 of this document. It is also recommended that implementation of the program follow the guidelines provided in Section 7.***

3.2.4 Cost of Implementing the Framework

In developing, implementing, and managing this framework, it is recognized that expenditures of time, energy, and financial resources will be necessary. However, estimation of the costs is beyond the scope of AQUAMIN.

➥ ***It is recommended that the costs of developing, implementing, and managing the environmental protection framework be assessed by the federal government and be understood by all stakeholders.***

It is also recognized that negotiations among stakeholders will be necessary to determine which stakeholders bear associated costs.

3.3 Stakeholder Involvement

Through the Whitehorse Mining Initiative Leadership Council Accord, the mining industry made a strong commitment along with government, labour, environmental groups, and aboriginal peoples to expand the opportunity for meaningful and responsible participation by aboriginal peoples, local communities, and environmental groups in decision-making processes that affect public interests.

Mining operations should be accountable not only to the Canadian public through federal and provincial regulators, but also to the community at large that is affected by the mine's activities. Accountability involves a two-way flow of information — information from the mine operator to the public, and information and concerns from the public to the mine operator. Experience has shown that communities are not always included in the information loop, particularly aboriginal communities. The Nanisivik Mine on Baffin Island (Working Group 5 case study) is a case in point. Located next to the Inuit community of Arctic Bay, neither the mine operator nor government inspectors have made adequate information available to the community regarding environmental effects of the mine or compliance monitoring.

On the other hand, there are also success stories of public stakeholder participation in mining operations. Examples include:

- community liaison committees set up through the Nova Scotia environmental assessment process
- participation of Heath Steele Mines in the Miramichi Environmental Assessment Committee, which includes several industrial operations within the Miramichi River watershed
- the East Tusket River Monitoring Committee, in the area of the East Kemptville Tin Mine in Nova Scotia
- participation of Cominco in the Columbia River Integrated Environmental Monitoring Program

3.3.1 The Role of Public Stakeholders

Properly informed public stakeholders can play key roles in each component of the national environmental protection framework.

A committee of representatives, each responsible for reporting back to their stakeholder group, would meet regularly with the mine operator to evaluate the mine operation, exchange information, and present recommendations to the operator and/or federal and provincial regulators. This arrangement depends on the willingness and effort of the mine operator and the stakeholder groups to work cooperatively. The ability of public stakeholders to participate effectively may also depend on the resources to which they have access, the accessibility of mine information, and the ability to obtain a third-party review of mine data.

The most intensive period of public stakeholder participation involves documenting environmental background information, identifying local sensitivities, setting objectives and goals for site-specific regulations, and establishing the scope and focus of the site-specific

EEM program.

Once regulations and an EEM program are in place, public stakeholders require access to timely, accurate, and concise summaries of compliance data and the results of EEM. Establishing a public liaison committee, preferably during the initial stage of environmental assessment, provides the public with a transparent, accountable mechanism to gain information and influence decisions regarding the management of impacts of public concern.

3.3.2 Reporting to Public Stakeholders

There are no requirements in the current MMLER for mines to actively distribute information, although in some provinces operators must make compliance information available in the mine office. This means that people must know that information exists and feel comfortable about approaching the mine operator to ask for it. There are also no requirements or guidelines regarding what form this information should take.

The information reported will depend to some extent on what the community needs to know. Therefore, the mine operator and regulators must meet with public stakeholders to determine their information needs and concerns. Generally, the mine operator and regulator should report on compliance with regulations, and the effects of mining effluent on the receiving environment and the significance of these effects.

People need sufficient information so that they can evaluate the implications of mining on their use of the fisheries and water resources. Data released to the public must be provided in meaningful or "plain language" terms. The information may also have to be translated into another language if the community concerned is aboriginal or of another significant ethnic background.

Where mining effluent poses a potential risk, this information should be made clear. It is the responsibility of the mine operator to work closely with government authorities in communicating such information. Signs should be posted around any area where there is a potential risk that clearly inform the public about the level of risk without causing undue alarm. In areas where the fishery resource is a major component of a community's livelihood, as is the case in many aboriginal communities, the risk of consuming fish must be made known to the community.

➥ ***It is recommended that Environment Canada, in consultation with other stakeholders, develop guidelines for the establishment of public liaison committees, including the reporting of information to public stakeholders.***

4 Revisions to the MMLER

4.1 Application of the Revised MMLER

4.1.1 Metal Mines

The current MMLER address new, expanded, and reopened metal mines other than gold mines, as defined within the regulations, whereas other metal mines are subject to Guidelines for the Control of Liquid Effluents from Existing Mines. The guidelines establish effluent quality objectives with the same acceptable levels of substances as those prescribed in the MMLER and are intended to provide an opportunity for operators of existing metal mines to negotiate a compliance schedule with regulators. Compliance with the MMLER and the guidelines is now essentially the same.

➥ ***It is recommended that the revised MMLER apply to all metal mines.***

➥ ***It is recommended that there be a transition period to ensure that any mines that are not under regulation or not in compliance have a reasonable period to improve their control systems.***

The duration of the transition period should be determined by Environment Canada when revisions to the MMLER have been defined in detail.

Implementation of these recommendations would improve regulatory fairness and predictability and would establish legally enforceable national baseline standards.

4.1.2 Gold Mines

At the time the current MMLER were developed, the technology to control cyanide and metals in effluents discharged from gold mines using the cyanidation process was not well developed. New treatment technology, developed in Canada to meet this need, has now been implemented by gold mine operators to enable them to discharge effluents that comply with provincial cyanide concentration limits.

➥ ***It is recommended that the revised MMLER apply to all gold mines (excluding placer operations).***

4.1.3 Effluent Sources

The current MMLER address all liquid effluent discharges to waters frequented by fish, including:

- end-of-pipe discharges of process water, cooling water, mine water, and tailings or other effluents
- contaminated seepage that is outside the treatment system, from sources such as tailings, waste rock, and fill
- surface runoff and storm water
- groundwater discharges to surface water

➥ ***It is recommended that the revised MMLER continue to address those sources of liquid effluents addressed in the current MMLER.***

4.1.4 When Application Begins

The current MMLER applies to particular operations when they begin commercial production as defined in the *Income Tax Act*. However, potential effects are more closely related to the effluent discharge rate than the commercial production rate for a given operation.

➥ ***It is recommended that the revised MMLER begin to apply when the average effluent flow rate exceeds a minimum level, specified in the regulation, over a specified period of time.***

4.1.5 When Application Ceases

The current MMLER cease to apply when commercial production ends. However, effluent discharges may continue beyond the cessation of commercial production.

➥ ***It is recommended that the revised MMLER apply after commercial production ends,* during *the period when the closure plan for an operation is being implemented.***

➥ ***It is recommended that the revised MMLER cease to apply when the closure plan for an operation has been fully implemented to the satisfaction of the relevant regulatory agencies.***

4.2 Basis for the MMLER

The current MMLER is based on effluent concentration limits achievable through the application of “best practicable technology” available in 1977. Most recent regulatory requirements in a number of jurisdictions, in Canada and abroad, have been based on “best available technology” or “best available technology economically achievable” (BATEA). This section presents some of the strengths and limitations of this approach, and recommendations regarding the basis for revising the MMLER.

4.2.1 BATEA Approach

Best available technology may or may not imply technology that is commercially proven and economically viable; therefore, the term “best available technology economically achievable” was utilized by Ontario’s Municipal and Industrial Strategy for Abatement (MISA) Program, which completed a global review of BATEA for the control of effluents from Ontario metal and gold mines, mills, smelters, and refineries in 1991. The term “economically achievable” does not imply that individual mine operators must have the economic and financial capacity to meet a proposed standard, but that technology must be affordable on a sectoral basis. A detailed review of the current state of BATEA was beyond the scope of AQUAMIN.

Mines employ a variety of technologies and practices to manage tailings, waste rock, process water, and storm water. Examples of BATEA include settling ponds and lime neutralization–precipitation processes to control pH, metals, and suspended solids; chemical and biological processes to destroy cyanide; and explosives management practices to minimize ammonia concentrations. Other measures include technologies to prevent acid mine drainage and to reduce reagent and water use.

Strengths

If a regulation is to be effective, it must be clear what is expected under the regulation, and those regulated must be in a position to determine how to comply with the regulation. One of the key strengths of a BATEA based regulation is that expectations are clear and compliance is achievable. Furthermore, the application of BATEA based standards does not preclude the application of other technologies or practices that achieve more effective or efficient environmental protection.

Limitations

The main limitation of a BATEA based regulation is that a national, BATEA based regulation, on its own, may not be adequate to protect all receiving environments, particularly those that are small and/or sensitive. Effluents in compliance with a BATEA based regulation may still cause adverse effects depending on the nature of the receiving environment. Furthermore, effects may be associated with contaminants in effluent that are not regulated. An additional limitation of a BATEA based regulation is that concentrations of contaminants in effluent are controlled, but effluent flow and cumulative loadings are not.

4.2.2 Recommendations Regarding the Basis of the MMLER

➥ ***It is recommended that the revised MMLER be a BATEA based regulation, with feedback of results from EEM and toxicity identification evaluation/toxicity reduction evaluation to encourage continuous improvement in environmental protection.***

➥ ***It is recommended that a review of treatment technology be completed prior to revising the MMLER and that appropriate concentration limits for all regulated parameters be established on the basis of this review.***

4.3 Parameters in the Revised MMLER

The current MMLER prescribes deleterious substances and establishes the terms and conditions under which these substances may be deposited into waters frequented by fish. Key to revising the MMLER is the selection of appropriate parameters to be monitored and regulated. Ongoing monitoring of the selected parameters should provide assurance that the treatment processes and programs in place are performing as expected.

4.3.1 Selection of Parameters

The AQUAMIN process documented several parameters of concern that occur in receiving environments downstream from mine sites that are causing or may be causing environmental effects. To determine whether or not any of these parameters should be regulated in the revised MMLER they were screened using the following criteria:

- the parameter has been identified as a concern in the study sites examined by AQUAMIN[18]

- the parameter can be expected to occur commonly in metal mining and milling effluents

- the parameter can be controlled within established limits in the revised MMLER through the application of best available technology economically achievable

- the parameter can occur in effluents at concentrations that have been documented to cause adverse effects on biota[19]

Professional judgement based on a knowledge of geology, process chemistry, and waste geochemistry is also an important consideration.

In assessing these criteria, information was drawn from the case studies and Regional Syntheses presented in AQUAMIN Supporting Document II, as well as the following key sources and other sources as necessary.

- the Canadian Water Quality Guidelines
- the Ontario Ministry of the Environment and Energy's MISA Draft Development Document for the Effluent Limits Regulation for the Metal Mining Sector (1993)

Recommendations for each parameter of concern are presented in the following sections and summarized in Table 5. Detailed justifications are presented in Appendix 3.

In addition to recommendations regarding parameters to be regulated in the revised MMLER, the following sections contain recommendations regarding parameters that should be monitored in periodic effluent characterization. The objective of effluent characterization is to obtain information, on a regular basis, on concentrations of potential contaminants in effluents. Effluent characterization will assist operators in identifying causes of failed acute lethality tests and will assist regulators in establishing site-specific requirements.

---

[18] Parameters were identified as being of concern because they occur at elevated concentrations in water and/or sediment, or they are currently (post-1990) the cause, or potential cause, of effects on fish, fish habitat, or the use of fisheries resources.

[19] Note that this is not a detailed hazard assessment. Hazard assessments may need to be carried out for some parameters before the revised MMLER is promulgated.

Table 5: Summary of parameters of concern.

Parameters Regulated in the Current MMLER	Parameters of Concern Identified in AQUAMIN	Parameters Recommended for Inclusion in the Revised MMLER	Parameters Recommended for Monitoring During Effluent Characterization
	Acute lethality		Acute and sublethal toxicity
	Aluminum		Aluminum
Arsenic	Arsenic	Arsenic	Arsenic
	Cadmium		Cadmium
	Calcium		Calcium
Copper	Copper	Copper	Copper
	Cyanide	Cyanide	Cyanide
			Effluent flow
	Fluoride		Fluoride
	Iron		Iron
Lead	Lead	Lead	Lead
	Molybdenum		Molybdenum
	Mercury		Mercury
Nickel	Nickel	Nickel	Nickel
	Nitrogen compounds		Nitrogen compounds
pH*	pH	pH*	pH
Radium-226	Radium-226	Radium-226	Radium-226
	Thiosalts		Thiosalts
TSM**	TSM**	TSM**	TSM**
Zinc	Zinc	Zinc	Zinc

* Minimum limit only.
** Total suspended matter.

4.3.2 Parameters Currently Regulated by the MMLER

As outlined in Table 5, the current MMLER regulates the total concentrations of arsenic, copper, lead, nickel, zinc, radium-226, and total suspended matter, as well as effluent pH. Prescribed limits for these parameters are presented in Table 1. In this section, recommendations regarding the inclusion of these parameters in the revised MMLER are presented.

Metals

The metals regulated in the current MMLER (arsenic, copper, lead, nickel, and zinc) all occur in effluents from a wide range of metal mines across Canada. All can be toxic to aquatic organisms at some concentrations.[20] In addition, lead and its compounds and arsenic and its compounds are recognized as being "toxic" under the *Canadian Environmental Protection Act*. All of these metals were identified as contaminants of concern in AQUAMIN. BATEA exists for the control of these metals in metal mine effluents.

➡ ***It is recommended that arsenic, copper, lead, nickel, and zinc continue to be regulated in the revised MMLER.***

➡ ***It is recommended that arsenic, copper, lead, nickel, and zinc be included in the list of parameters to be measured in periodic effluent characterization.***

Radium-226 is also a metal regulated in the current MMLER. However, the concern with radium-226 stems from the fact that it is a radioisotope. Production of uranium as part of the nuclear fuel cycle is regulated by the Atomic Energy Control Board. Uranium may also be present in the ore of mines that do not produce uranium. Therefore, the MMLER limit the radioactivity of effluents, rather than the actual concentration of radium-226 metal.

➡ ***It is recommended that radium-226 be regulated in the revised MMLER.***

➡ ***It is recommended that radium-226 be included in the list of parameters to be measured in periodic effluent characterization.***

Total Suspended Matter

Total suspended matter is commonly found in metal mining effluents and usually consists of a mixture of silicate, oxide, carbonate, and sulphate minerals. Total suspended matter can affect the health of fish and fish habitat. Total suspended matter was identified as a parameter of concern by AQUAMIN. BATEA for the control of total suspended matter in metal mine effluents does exist.

➡ ***It is recommended that total suspended matter be regulated in the revised MMLER.***

➡ ***It is recommended that total suspended matter be included in the list of parameters to be measured in periodic effluent characterization.***

---

[20] Canadian Council of Resource and Environment Ministers. 1987. Canadian Water Quality Guidelines.

pH

The pH of effluents from metal mines in Canada is commonly a concern. Both high and low pH can have adverse effects on aquatic organisms. In addition, extremes of pH can affect the solubility and bioavailability of metals and other contaminants that may be present in mine effluent. Both high and low pH were identified as a concern by AQUAMIN. BATEA for the control of both high and low pH in metal mine effluents does exist.

Regarding a lower pH limit:

➥ ***It is recommended that the revised MMLER include a lower limit for pH.***

Regarding an upper pH limit, although there may be site-specific circumstances where an upper pH limit for effluent would be a concern, these circumstances can be addressed on a site-specific basis. Furthermore, as all mining effluent will be tested for acute lethality without the adjustment of pH, failures due to elevated pH will be identified.

➥ ***It is recommended that the revised MMLER not include an upper limit for pH.***

➥ ***It is recommended that pH be included in the list of parameters to be measured in periodic effluent characterization.***

4.3.3 Additional Metal Parameters[21]

Additional metals identified by AQUAMIN as being of concern include aluminum, cadmium, calcium, iron, and mercury. Brief justifications for recommendations pertaining to these metals are presented below. In some cases (e.g., aluminum, cadmium, and mercury), special concerns were expressed during the AQUAMIN review. It is not recommended that these substances be regulated in the revised MMLER; however, they will be included in periodic effluent characterization.

In addition, as all mining effluents will be tested for acute lethality, failures due to the following metal parameters will be identified through toxicity identification evaluation/toxicity reduction evaluation. Bioaccumulation or other environmental effects will be identified by the EEM program.

---

[21] Note that the case studies of Working Group 5 (Nanisivik, Cluff Lake, and Lupin) were not available to Working Groups 7 and 8 at the time of preparation. Working Group 5 recommended that uranium be included in the revised MMLER.

Aluminum

Aluminum is present as a minor component in effluents from many metal mines in Canada,[22] but was identified by AQUAMIN as a contaminant of concern at only one case study site. Because many operations did not include data on aluminum, however, it was impossible to assess the potential effects of aluminum at these other sites. Aluminum in mine effluent can be derived from natural sources. Furthermore, it is known to be toxic to aquatic organisms, particularly at extreme pH.[23] It is not known if BATEA for the control of aluminum in metal mine effluents exists, although control technology was in place at the case study site where aluminum was identified as a concern.

➥ ***It is recommended that aluminum not be regulated in the revised MMLER.***

➥ ***It is recommended that aluminum be included in the list of parameters to be measured in periodic effluent characterization.***

➥ ***It is recommended that in cases of receiving water sensitivity, or consistently elevated aluminum levels in effluent and the receiving environment, site-specific requirements should be implemented.***

Cadmium

Cadmium occurs in some metal mine effluents, particularly effluent from base metal mines milling ores containing zinc because cadmium is commonly associated with zinc and is expected to respond to treatment for zinc. Cadmium is known to be bioaccumulative and can be toxic to aquatic organisms at some concentrations. In addition, cadmium and its compounds are recognized as being "toxic" under the *Canadian Environmental Protection Act*. Cadmium was also identified as a contaminant of concern at a number of sites examined by AQUAMIN. BATEA for the control of cadmium in metal mine effluents does exist.

➥ ***It is recommended that cadmium be included in the list of parameters to be measured in periodic effluent characterization.***

---

[22] Ontario Ministry of the Environment and Energy. 1993. MISA Draft Development Document for the Effluent Limits Regulation for the Metal Mining Sector. Queen's Printer for Ontario, Toronto, Ontario.

[23] Canadian Council of Resource and Environment Ministers. 1987. Canadian Water Quality Guidelines.

➥ ***It is recommended that if cadmium concentrations in an effluent exceed a specified level, they should be monitored and reported on a more frequent basis.***

Calcium

Calcium commonly occurs at elevated concentrations in metal mine effluent because lime is used to raise the pH of acidic effluents and to precipitate metals from these effluents. Calcium was identified as a parameter of concern at one site examined by AQUAMIN. Its potential for impact is very site-specific.

➥ ***It is recommended that calcium not be regulated in the revised MMLER.***

➥ ***It is recommended that calcium be included in the list of parameters to be measured in periodic effluent characterization.***

Iron

Iron is very common in metal mining effluent because it occurs in the sulphide mineral pyrite (FeS_2), which is present as an accessory mineral in most ore deposits. Iron can be toxic to aquatic organisms, although only at higher concentrations than many other metals. At sites examined by AQUAMIN, it was identified as a concern mainly due to the formation of iron hydroxide precipitates in receiving environments. BATEA for the control of iron in metal mine effluents does exist.

➥ ***It is recommended that iron not be regulated in the revised MMLER.***

➥ ***It is recommended that iron be included in the list of parameters to be measured in periodic effluent characterization.***

Mercury

Mercury occurs in effluent discharged from some metal mines in Canada, particularly gold mines. Mercury is known to be toxic to aquatic organisms and can be biomagnified up the food chain. In addition, mercury and its compounds are recognized as being “toxic” under the *Canadian Environmental Protection Act*. Mercury was identified as a contaminant of concern at some sites examined by AQUAMIN; however, it can be difficult to determine whether or not the mine is the source of the contamination. Mercury is also known to be a long-range airborne pollutant. It is unclear whether or not BATEA exists for the control of mercury in metal mine effluents. Technology to control mercury is in place at at least one mine site in Canada.

➥ ***It is recommended that mercury not be regulated in the revised MMLER.***

➥ ***It is recommended that mercury be included in the list of parameters to be measured in periodic effluent characterization using the most up-to-date sampling and analytical methods.***

➥ ***It is recommended that if effluent characterization demonstrates a consistent presence of significant concentrations of mercury in effluent, a working group should be established to investigate possible control options.***

Molybdenum

Molybdenum occurs primarily at molybdenum mines located in British Columbia, although it has also occurred at some other mines (e.g., Hemlo area, Cluff Lake). Even though molybdenum can cause molybdenosis in cattle, concentrations at which it begins to affect aquatic organisms are generally quite high (e.g., reported 96 hour LC_{50} concentrations for rainbow trout range from 800[24] to 7340[25] mg/L). The toxicity of molybdenum is not as well understood as that of some other metals.[26]

➥ ***It is recommended that molybdenum not be regulated in the revised MMLER.***

➥ ***It is recommended that molybdenum be included in the list of parameters to be measured in periodic effluent characterization.***

---

[24] Eisler, R. 1989. Molybdenum Hazards to Fish, Wildlife and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service. Biology Report 85.

[25] Stephenson, G.L., B.W. Muncaster, and C.D. Wren. 1991. Draft Provincial (Ontario) Water Quality Guideline Development Document for Molybdenum.

[26] Eisler, R. 1989. Molybdenum Hazards to Fish, Wildlife and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service. Biology Report 85.

4.3.4 Additional Nonmetal Parameters[27]

Additional nonmetals identified by AQUAMIN as being of concern include cyanide, fluoride, nitrogen compounds, and thiosalts. Brief justifications for recommendations pertaining to these nonmetals are presented below. In addition, as all mining effluents will be tested for acute lethality, failures due to the following nonmetal parameters will be identified through toxicity identification evaluation/toxicity reduction evaluation.

Cyanide

Cyanide is commonly used as a reagent for the recovery of gold. It is also used in much smaller quantities as a flotation reagent for base metal mills. As a result, cyanide and/or its by-products occur in the effluents discharged from many mines in Canada, particularly gold mines. Cyanides are known to be toxic to aquatic organisms, and were identified as a parameter of concern at several sites examined by AQUAMIN. BATEA for the control of cyanides in metal mine effluents does exist.

➥ ***It is recommended that cyanides be regulated in the revised MMLER for operations that use cyanide as a process reagent.***

➥ ***It is recommended that cyanides be included in the list of parameters to be measured in periodic effluent characterization for operations that use cyanide as a process reagent.***

Fluoride

Fluoride is quite rare in Canadian metallic mineral deposits. It can accumulate in aquatic organisms, including in the bones of fish, but its effects on these organisms are not well documented.[28] Fluoride was identified as a contaminant of concern at one site examined by AQUAMIN.

---

[27] Further to footnote 21, Working Group 5 also identified salinity as a parameter of concern, for possible inclusion in the MMLER. Working Group 5 recommended that ammonia be included in the revised MMLER.

[28] Canadian Council of Resource and Environment Ministers. 1987. Canadian Water Quality Guidelines.

➡ ***It is recommended that fluoride not be regulated in the revised MMLER.***

➡ ***It is recommended that fluoride be included in the list of parameters to be measured in periodic effluent characterization for operations where it is likely to be present.***

Nitrogen Compounds

Nitrogen compounds, particularly ammonia, ammonium, nitrate, and nitrite, commonly occur in metal mine effluents in Canada. The main source of these compounds is ammonium-based explosives, which are the most common blasting agents used in Canadian metal mines. Spillage and incomplete detonation of these explosives can result in ammonium contamination of mine water. Ammonia can also be formed as a result of the breakdown of cyanides.[29] Ammonia can have an affect on aquatic organisms, with the ammonia concentration at which effects may occur being dependent on pH and water temperature. Nitrate is a major nutrient for aquatic vegetation. Because nitrates may stimulate plant growth, excessive amounts of nitrate may result in prolific growth. As a result, oxygen may be depleted, leading to fish kills.[30] Ammonia and nitrates were identified as contaminants of concern by AQUAMIN.

BATEA for the control of ammonia, nitrate, and nitrite does not exist within the metal mining sector. However, Natural Resources Canada and several mining companies are currently engaged in a jointly funded research program directed toward developing effective and efficient technologies that can be used to remove ammonia from mine effluents or reduce it to acceptable concentrations (10–50 mg/L). Ammonia has been successfully controlled in other sectors using pH adjustment, air stripping in water towers, and biological treatment in artificial wetlands. Nitrate and nitrite have also been controlled in other sectors using artificial wetlands.

Regarding ammonia:

➡ ***It is recommended that total ammonia be included in the list of parameters to be measured in periodic effluent characterization.***

---

[29] T.W. Higgs Associates Ltd. 1992. Technical Guide for the Environmental Management of Cyanide in Mining. Prepared for the Cyanide Subcommittee of the British Columbia Technical and Research Committee on Reclamation.

[30] Canadian Council of Resource and Environment Ministers. 1987. Canadian Water Quality Guidelines.

➥ ***It is recommended that the updated Environmental Code of Practice for Mines include pollution prevention measures, particularly explosives management practices, to reduce releases of nitrogen-bearing compounds to the receiving environment.***

➥ ***It is recommended that government/industry research programs to identify and develop effective and efficient pollution prevention and control technologies for total ammonia and nitrogen compounds continue.***

➥ ***It is recommended that in cases of receiving water sensitivity, or consistently elevated ammonia levels in effluent and the receiving environment, site-specific requirements should be implemented.***

Thiosalts

Thiosalts are a group of metastable oxysulphur anions formed by partial oxidation of sulphide minerals during ore processing. Thiosalts have relatively low toxicity, but may oxidize in the receiving environment, generating sulphuric acid and lowering the pH. Whether or not thiosalts have an affect on the receiving environment depends on a number of factors, including the rate of oxidation (which, in turn, depends on a number of factors), as well as water quality and flow rate in the receiving environment. Thiosalts have been documented as the indirect cause of significant impairment to the benthic community and fish for a distance of 35 kilometres downstream of Brunswick No. 12 Mine.[31]

➥ ***It is recommended that thiosalt impacts be monitored as part of EEM.***

➥ ***It is recommended that research be conducted to identify means of limiting thiosalt production.***

➥ ***It is recommended that current research efforts to identify and develop control technologies for thiosalts continue.***

[31] Supporting Document II, Appalachian region, case studies.

4.4 Toxicity Testing

The current MMLER do not include a requirement that effluent be non-acutely lethal.[32] However, other jurisdictions have incorporated non-acutely lethal effluent requirements in regulations to improve environmental protection. For example, the Ontario *Metal Mining Effluent Limits Regulation*, promulgated in September 1994, requires effluents to be non-acutely lethal (50% or more of test organisms must survive an exposure to undiluted effluent for a period of 96 hours for rainbow trout and 48 hours for *Daphnia magna*). Such a requirement is considered by some to be necessary for basic protection of aquatic resources.

Although acute lethality testing is not a federal requirement in Canada, information on the acute lethality of Canadian mining effluent is available. For example, as part of the Aquatic Effects Technology Evaluation program, the acute lethality of effluent from 21 Canadian mines was tested in 1995. There was a 62% pass rate for rainbow trout and a 73% pass rate for *Daphnia magna*.[33] These data, however, were collected to assess different toxicity testing methods, and may not be representative of the acute lethality of mining effluents in Canada. In Ontario, as part of the development program for the *Metal Mining Effluent Limits Regulation*, the acute lethality of metal mine effluents was monitored from February 1, 1990 to January 31, 1991. Results of this monitoring indicated that 54% of effluents were acutely lethal to rainbow trout and 48% were acutely lethal to *Daphnia magna*.

Important to the value of toxicity testing as a tool to improve environmental protection is the identification of the cause of failed acute lethality tests. As outlined in the MISA Draft Development Document for the Effluent Limits Regulation for the Metal Mining Sector, acute lethality can occur as a result of the effects of individual contaminants, as well as from the synergistic effects of several contaminants. The oxidation state and chemical species in which contaminants occur are also important. Additional factors that can affect lethality include pH, temperature, water hardness, and the presence of complexing agents such as naturally occurring humic and fulvic acids.

Methods for identifying the cause of failed acute lethality tests do exist. For example, the "toxicity identification evaluation/toxicity reduction evaluation" method is specified as part of the toxicity testing requirements of the *Pulp and Paper Effluent Regulations*, regulations

---

[32] Acutely lethal, in respect of effluent, means that the effluent at 100 % concentration kills more than 50% of test organisms subjected to it for a specified period of time.

[33] Rodrigue, D., R. Scroggins, and T. Moran. 1996. Comparison of Micro-scale and Standard Acute Toxicity Tests in Assessing the Toxicity of Effluents from Metal Mining Sites Across Canada. *In* Haya, K. and A.J. Niimi (eds). Proceedings of the 22nd Aquatic Toxicity Workshop: October 2 - 4, 1995, St. Andrews, New Brunswick. *Can. Tech. Rep. Fish. Aquat. Sci.* 2093.

under the *Fisheries Act*, that were revised in 1991. In some cases, however, the specific causes of toxicity cannot be identified.

It is important to bear in mind that demonstration of acute lethality based on testing a sample of effluent in a laboratory does not provide definitive evidence of adverse effects in a receiving environment. Rather, it is a measure of the hazard associated with exposure to undiluted effluent. The risk to aquatic organisms depends on a number of factors, including:

- water quality and flow rate in the receiving environment
- the design of the effluent outfall, and the quality and flow rate of the effluent
- the nature of the habitat
- the presence of fish, and the species present
- the duration of exposure to the effluent
- antagonistic and/or synergistic interactions between toxicants
- the organisms' response to exposure to the effluent

Many of these factors are site-specific, so an assessment of the actual risk to aquatic organisms can only be conducted on a site-specific basis.

A significant concern regarding toxicity testing is that no proven technology exists to produce non-acutely lethal effluent in all cases. In most cases, the application of effluent treatment technology will reduce the toxicity of effluents, but toxicity may not be eliminated in all cases. For example, metal concentrations may be reduced to non-acutely lethal levels, but some effluents may remain acutely lethal due to "the presence in effluents of ammonia (for which no economic treatment could be found), the antagonistic and synergistic effects of various combinations of substances, unexpected biological or chemical oxygen demands, unusual temperature variations, unstable sulphur species and so forth."[34]

Regarding toxicity testing, participants agreed on the overall objective that mining effluents be non-acutely lethal, but recognized that this goal may not be achievable at all sites at this time.

➥ ***It is recommended that the revised MMLER include a requirement that all metal mine operators conduct and report periodic testing of effluent for acute lethality using current standard test methods.***

[34] Ontario Ministry of the Environment and Energy. 1993. MISA Draft Development Document for the Effluent Limits Regulation for the Metal Mining Sector. Queen's Printer for Ontario, Toronto, Ontario.

- ***It is recommended that, if effluents are consistently non-acutely lethal, the frequency of testing should be reduced.***

A mechanism for determining the testing frequency should be developed.

- ***It is recommended that a failed test should trigger increased testing frequency.***

- ***It is recommended that, if an effluent is consistently acutely lethal, the operator should be required to conduct toxicity identification evaluation/toxicity reduction evaluation in an attempt to determine the cause of toxicity and to report the results. Results should be considered in establishing site-specific requirements.***

- ***It is recommended that as soon as a body of data on the results of acute lethality testing and toxicity identification evaluation/toxicity reduction evaluation is available, a review be conducted to determine if the MMLER should be revised to require non-acutely lethal effluent.***

4.5 Sampling, Analysis, and Reporting Requirements

- ***It is recommended that, in establishing sampling and reporting requirements in the revised MMLER, efforts be made to simplify and streamline requirements to increase compatibility or eliminate duplication, identify data gaps, and ensure that compliance data are forwarded to regulatory agencies of the appropriate jurisdictions in an acceptable format, to reduce compliance costs.***

Appropriate administrative mechanisms need to be developed and utilized to implement provisions related to sampling and reporting.

4.5.1 Sampling and Analysis

- ***It is recommended that a review of the current analytical procedures for the measurement of parameters (e.g., total or dissolved metals, nitrogen, or cyanide species) to be monitored and reported be completed prior to revising the MMLER.***

➥ ***It is recommended that, if a parameter is consistently measured at concentrations significantly lower than the regulated limit at a particular site, the monitoring frequency for that parameter should be reduced (similar to Schedule 2 in the current MMLER).***

The MISA Joint Technical Committee in Ontario did considerable work on determining appropriate frequencies. The resulting reports will be useful in determining appropriate requirements.

Requirements for compliance monitoring by mine operators should include data performance requirements to ensure data quality. Internal quality assurance/quality control programs should be augmented by occasional sampling and analyses by inspectors to verify compliance and data integrity, and strengthen the credibility of compliance monitoring programs.

➥ ***It is recommended that standard minimum quality assurance/quality control requirements for sample collection, handling, and analysis be developed and revised accordingly as technology improves.***

Quality assurance/quality control requirements should not be specific, rather they should set minimum performance standards.

➥ ***It is recommended that effluent flow be monitored.***

The frequency of flow monitoring and reporting should be compatible with the sampling frequency for other parameters.

4.5.2 Reporting

Several jurisdictions in Canada have regulations at least as stringent as the current MMLER. Furthermore, it is probable that some jurisdictions will have regulations at least as stringent as the revised MMLER, either at the time of promulgation or at some future date.

➥ ***It is recommended that, in cases where other jurisdictions have legally enforceable requirements, the federal government reach delivery agreements with the other jurisdictions to establish single reporting mechanisms.***

There is a recognized need to ensure that all Canadians are fully informed of the status of the metal mining industry's compliance with water pollution regulations.

➥ ***It is recommended that Environment Canada continue to publish periodic reports on the status of the metal mining industry's compliance with the MMLER.***

5 Site-specific Requirements

5.1 Need for Site-specific Responsiveness

BATEA based federal effluent regulations may not be sufficient to provide full protection to fish, fish habitat, and the use of fisheries resources in the receiving environment at every site. Each mining operation is unique in terms of its geology, and the quality of mine and mill effluents is strongly dependent on the ore type and mill process, both of which may vary widely from one location to another. Environmental factors, such as topography, climate, and receiving water characteristics (e.g., available dilution, complexing capacity, background metal concentrations), are also unique to each mine setting and must be considered, in addition to BATEA, when determining potential impacts on receiving waters and special regulatory requirements. Thus, there is a need, as outlined in the description of the environmental protection framework, for flexibility in applying regulations and/or developing special conditions on a site-specific basis to maintain receiving water quality and protect designated water uses.

5.2 Federal Role in Establishing Site-specific Requirements

Under the *Fisheries Act*, if site-specific requirements are necessary to protect a specific receiving environment, it is necessary to pass a site-specific regulation. Once the MMLER have given approval to deposit a deleterious substance in a prescribed concentration or quantity, this approval can only be retracted by a new regulation. It is not possible under the *Fisheries Act* to delegate to a federal government official the authority to make effluent standards more stringent. At present, the only more stringent site-specific regulation under the *Fisheries Act* is the *Port Alberni Pulp and Paper Regulation*.

Developing a site-specific regulation is a major and time-consuming task. Therefore, the first option would be to challenge the company to voluntarily meet more stringent requirements or encourage the province to incorporate more stringent requirements in the provincial licence.

Currently, Environment Canada and the Department of Fisheries and Oceans employ various mechanisms to discharge their responsibilities for the protection of fish, fish habitat, and the use of fisheries resources. One means is through cooperation with other federal, provincial, and territorial agencies. These other agencies frequently have the regulatory means to implement a wide variety of site-specific standards. The federal government may also address site-specific issues through the *Canadian Environmental Assessment Act*, although not all mining proposals are subject to this legislation. Most provincial and territorial agencies also have project review and licensing processes through which fish protection requirements may be addressed. Environment Canada and Fisheries and Oceans normally participate in these review processes and work cooperatively with industry and other jurisdictions to ensure conservation and protection of the fisheries resource.

Provincial and territorial agencies rely to varying degrees on the MMLER and may employ somewhat different means to develop and implement site-specific requirements. Provinces must apply effluent limits that are at least as stringent as those prescribed in the MMLER. Some jurisdictions (e.g., British Columbia, Nova Scotia, New Brunswick) may employ environmental assessment processes and many (e.g., British Columbia, Manitoba, Ontario) frequently use water quality objectives to derive effluent limits. In British Columbia, effluent discharge limits are based on dissolved contaminants in the final effluent, although effluent permits also specifically incorporate MMLER (i.e., total metal) levels.

➡ ***It is recommended that provincial, territorial, or aboriginal agencies be encouraged to develop and implement the site-specific requirements necessary to protect particular receiving environments.***

  ➡ ***It is recommended that the federal government continue to assist provincial, territorial, or aboriginal agencies by providing scientific and technical advice.***

➡ ***It is recommended that, in the event that neither a company nor a provincial, territorial, or aboriginal agency are in a position to implement more stringent environmental protection measures to adequately protect a particular receiving environment, the federal government should have the ability to implement site-specific requirements, using a simpler mechanism than that which currently exists, while ensuring that social and economic impacts are still considered.***

5.3 Evaluating Site-specific Requirements

Some factors to consider in evaluating the sensitivity of the receiving environment and in determining site-specific impacts and protective measures include:

- effluent quality (for each particular mine, a different combination of contaminants will be important and synergistic, antagonistic, and cumulative effects may occur)

- effluent quantity and the dilution capacity of receiving waters

- the type of water body receiving the discharge (e.g., lake, river, estuary, ocean)
- the magnitude, duration, and frequency of exposure of organisms to contaminants in the receiving environment
- the ability of the receiving environment to modify the toxicity and bioavailability of contaminants
- the potential for contaminants to have deleterious effects at the discharged concentrations
- the geology of the area and natural background levels of the prescribed parameters (e.g., arsenic, magnesium, aluminum, sodium, mercury, cadmium)
- other factors, such as water uses (e.g., drinking water versus aquatic life), affecting criteria (e.g., water, sediment, persistence, bioaccumulation, and toxicity)
- the potential for groundwater contamination
- the use of aquatic resources

➥ ***It is recommended that to foster a nationally consistent approach to the development of site-specific requirements, the federal government continue to provide leadership in developing environmental quality guidelines.***

6 Environmental Effects Monitoring

An EEM program for mines has been defined by AQUAMIN as a nationally consistent, site-specific, nonprescriptive program that will assist practitioners in determining whether a mine effluent has negatively affected its aquatic receiving environment. Monitoring tools are discussed in Appendix 4.

➥ ***It is recommended that the most important components of an EEM program be fish, fish habitat, and the use of fisheries resources as defined under the* Fisheries Act.**

➥ ***It is recommended that an EEM program take a progressive, phased approach to determine any effects in the aquatic environment in accordance with standard scientific methods.***

➥ ***It is recommended that an EEM program address site-specific questions, and that practitioners (stakeholders) be encouraged to design the most appropriate study for each site.***

➥ ***It is recommended that, at any time in an EEM process, if the cause of an unacceptable effect is known, recommendations for corrective action can be put forward.***

6.1 Design Strategy

A site-specific EEM program should:

- Consider the need for national consistency in its approach. This can be addressed through similarities in the objectives and questions to be examined for each environmental component (water, sediment, benthos, and fish).
- Resolve site-specific concerns. The intent of a national EEM program is not to be prescriptive, but to allow technical flexibility to respond to site-specific issues.
- Use a phased approach leading to environmental improvement. This implies that the focus is primarily on effect identification and then on investigation of the potential cause(s).

- Have clearly identifiable objectives (endpoints). Focus on objectives that relate to fish, fish habitat, and the use of fisheries resources.

- Identify and quantify the zone of influence and realize that the zone should be minimized.

EEM should apply to existing mining and milling operations. A national EEM program should improve the consistency of preoperational baseline information across Canada and ensure the validity and usefulness of data collected for comparison with future EEM data. The most powerful study designs include multiple sampling periods before and after development at both exposed and reference locations (Before–After, Control–Impact Design). The EEM program could also be used for a wide range of situations, such as new undertakings, advanced exploration, closure, post-closure, and reclamation.

➥ ***It is recommended that the EEM program be effective and efficient, that all information collected have a clearly identifiable purpose, and that maximum use be made of historical data and relevant regional data.***

6.2 Program Design and Components

The EEM process as a whole is intended to address the question raised in the environmental protection framework, are mining effluents (more generally mining operations) having a measurable effect on downstream aquatic ecosystems?

It is important to emphasize that an EEM program be designed to address site-specific issues. The approach described below is provided as an illustration of appropriate rationale and techniques. It should not constrain practitioners in developing study designs and approaches to meet local needs. The Working Group relied on available knowledge and expertise in this area to identify tools that might help meet stated objectives (see Appendix 4). The work conducted in the Aquatic Effects Technology Evaluation[35] will also identify useful tools.

An appropriate EEM program should recognize several activities in its investigation of the effects of mining. There are two main phases:

[35] See Appendix 1.

1) *Site Characterization*: This is the process whereby the mining company or mill operator collects the basic information needed to describe the operation, including characteristics of effluent and seeps, and information on the relevant features of the receiving environment and local biota needed to design the monitoring program.

2) *Field Investigation and Monitoring*: This phase examines effects and their potential causes. The range of activities is described below. Based on site-specific circumstances, a combination of the following activities could be adopted for a particular study.

   Assessment of Current Conditions: This is an investigation in which the company uses information gained from site characterization to carry out an initial assessment to screen for the effects of the mining operation. These assessments gather comparative information at candidate reference areas and information about parameter variability.

   Focussed Monitoring: This activity determines the extent and magnitude of observed effects. Investigation at this stage arises when evidence of effects has been found. Further investigation by the company is conducted to better define the magnitude and extent of effects.

   Investigation of Potential Cause(s): This investigation occurs when an unacceptable effect has been identified and the previous work has failed to provide a satisfactory explanation of the origin of the effect. In such cases, specialized multidisciplinary investigations may be required to determine the cause.

   Periodic Monitoring: This can be used to detect changes in environmental effects or to confirm the understanding of environmental effects. Periodic monitoring may include one or more environmental component and allows for the generation of trend data.

EEM program activities are illustrated in Figure 4. A matrix illustrating monitoring objectives and environmental components shows that a range of monitoring activities could be conducted for a particular program (Figure 5).

An EEM program begins with knowledge of current conditions, which may lead to recommendations for corrective measures when the cause(s) of an unacceptable effect has been determined. Identification and implementation of mitigation measures are outside the scope of EEM.

Throughout the site characterization phase and the subsequent EEM program, information requested and obtained must be scientifically defensible. Questions and hypotheses may arise from many sources: traditional knowledge, local knowledge, and input from the public or government and industry sources.

Figure 4: EEM program activities.

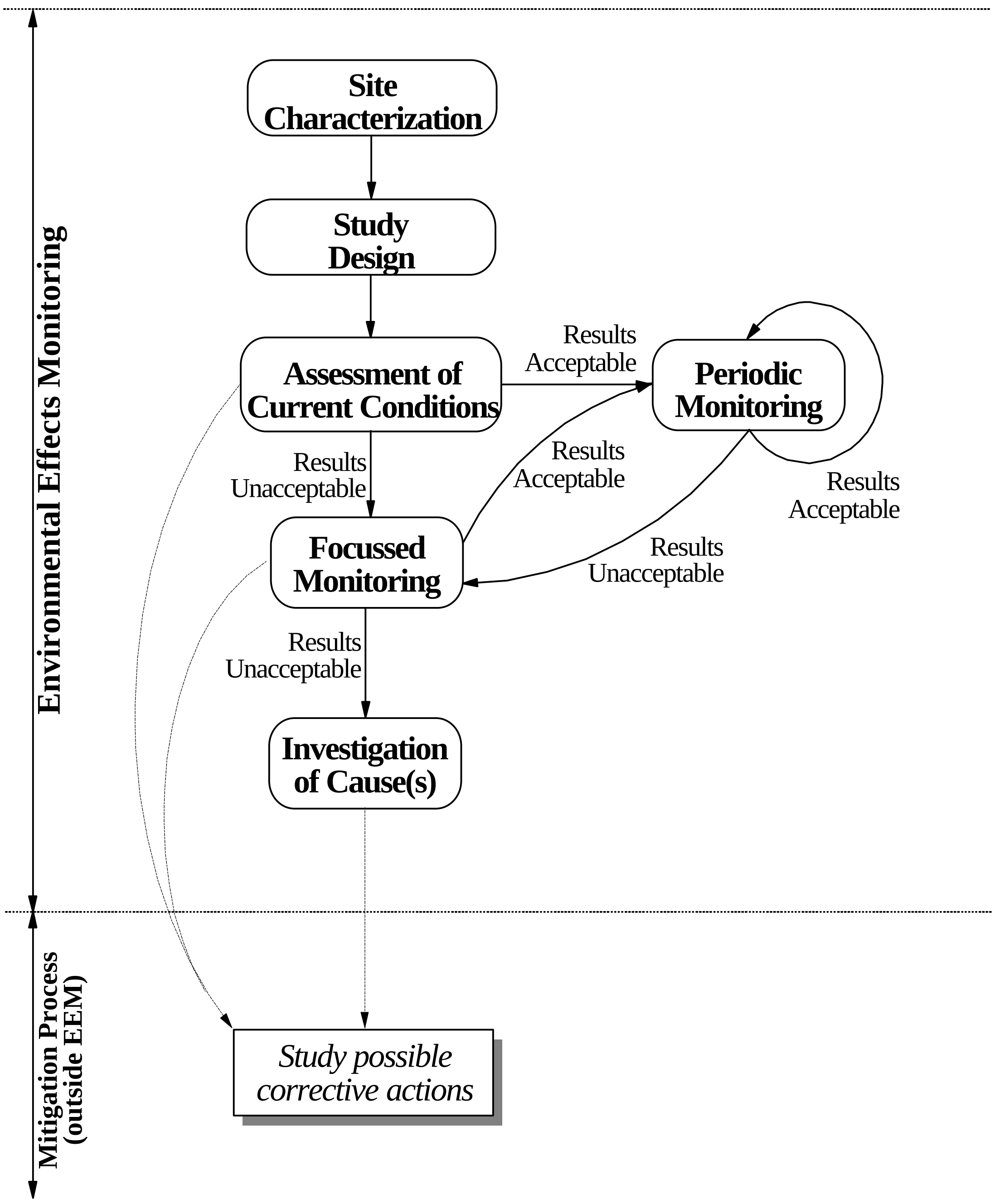


Figure 5: Study design matrix.

Assessment of Current Conditions

Field Investigation and Monitoring

Activities	**Environmental Components: Water, Sediment, Benthos, Fish**
Periodic Monitoring	If additional information is needed Purpose: detect changes and trends, or confirm conditions
Focussed Monitoring	If unacceptable effects have been found Purpose: determine extent and magnitude of effects
Investigation of Cause(s)	If an unacceptable effect has been observed and the cause is not known Purpose: determine cause(s)

Identify Need for Mitigation

Mitigation Process (outside EEM)

6.2.1 Site Characterization

Site characterization is described in Table 6.

The characteristics of the mining or milling operation (existing or proposed) and the receiving environment drive the development of any monitoring program. Many mining or milling operations are located in watersheds subject to other industrial uses. Some mines have long and complicated histories that may include historical impacts, or the accidental release of tailings or process chemicals. Site characterization involves documenting the development history of the site.

Table 6: Elements of Site Characterization.

Primarily information gathered from existing data sources and knowledge from local resource users (fishing community, aboriginals, public interest groups). Some additional field data may be required to provide adequate background for the study design.
Physical characteristics: e.g., hydrology, oceanography, climate, fish habitat classification, geology, sedimentation zone, effluent mixing zone
Surface water: e.g., temperature, dissolved oxygen, hardness, dissolved organic carbon, organic acids, total suspended matter, pH, alkalinity, metals
Aquatic resource inventory: e.g., fish species present (resident and migratory), sport fishery, subsistence fishery, commercial fishing activities, rare and endangered species, available benthic community data
Mine effluent characterization: e.g., discharge volume, chemical composition, seasonal variability, toxicity (see Table 5)

Site characterization should also identify significant data gaps or information needs (e.g., fish species present, hydrology) that should be met or considered when planning EEM and interpreting the results. The lack of any essential information will influence the design of the study. EEM should include rigorous and consistent standards and goals for study design. This objective should be kept in mind when deciding what information to collect for the purpose of site characterization. All information collected should have a clearly defined purpose.

The need for on-site surveys to collect additional field data will depend on the characteristics of the mine site, the history of the operation, and the quality and quantity of existing information. Special emphasis should be placed on fish and fish habitat for monitoring purposes, and on acquiring the descriptive information required to determine which aspects of fish biology or ecology should be documented for the purpose of EEM. In certain cases, where there is a lack of existing information, it may be necessary to carry out an exploratory survey of fish and benthic invertebrate communities.

Acute and sublethal toxicity testing of effluents do not provide actual measures of environmental effects, but they may be used as site-specific predictive tools. These tests may help practitioners develop site-specific study requirements. Hence, they should be included in site characterization as complementary information to *in situ* monitoring and to help evaluate the potential for environmental impacts.

➥ ***It is recommended that the objective of site characterization be to obtain sufficient understanding of the mine's effluent and aquatic receiving environment to develop an effects monitoring program that is scientifically sound and meets the needs of all stakeholders.***

6.2.2 Assessment of Current Conditions

The purpose of this activity is to determine whether the mine or mill or associated works are having an effect on the downstream aquatic receiving environment. The assessment of current conditions (and periodic monitoring) should include all of the key elements listed in Table 7 that are relevant to the site. Surveys should be conducted in areas exposed to mine discharges and in reference areas.

This activity should address the following questions:

1) Are levels of contaminants in the water, sediment, or biota of such magnitude as to be a concern or that they may have an effect on aquatic life downstream?

2) Is there evidence from the study of fish and benthic invertebrates suggesting abnormal conditions related to chemical contamination or physical disturbance from mining operations?

With respect to the first question, chemical analysis of the water, sediment, and biota should indicate whether, on the basis of current literature, there is reason to suspect that individual or combinations of metals, or other products of mining or ore processing, are present in concentrations that may influence the aquatic ecosystem. The biological availability of metals remains a site-specific concern. The accumulation of metals by benthic invertebrates from contaminated sediment and their subsequent consumption by fish may be relevant.[36] In some cases, there may be indications that the mining operation influences metal levels in fish muscle. Fish should then be collected to investigate metal levels and evaluate the risk to consumers. The issue of the accumulation of metals in other tissues (gills, kidney, and liver) depends on the metal and the question to be answered.

The second question can be addressed by a study of the receiving environment (the section of river, lake, wetland, estuary, or inlet) influenced by the mining operation. The study should evaluate the habitat to identify physical disturbances that might have an adverse impact on fish movement, feeding, or spawning. Biotic abundance and diversity should also be assessed.

Table 7: Assessment of Current Conditions.

The assessment of current conditions and periodic monitoring should include all of the key environmental components listed below that are relevant to the site. Studies should be conducted in areas exposed to mine discharge and in reference areas.	
1)	Surface water quality monitoring to determine contaminant concentrations in downstream and reference areas for comparison with site-specific water quality objectives.
2)	Sediment quality monitoring to determine contaminant concentrations in downstream and reference areas for comparison with site-specific sediment quality objectives.
3)	Fish community sampling (nondestructive) to determine which species are present and relative abundance levels compared with downstream and reference area conditions. Some fish tissue analyses for contaminants to assess bioaccumulation.
4)	Benthic community sampling to compare structure and diversity in downstream and reference areas.

Interpretation of Results

Based on a "weight-of-evidence" approach and a process described in Section 6.5, an assessment can be made as to whether there is an acceptable effect or an unacceptable effect. The next monitoring phase will depend upon the quality of the results obtained from previous work or the need for more information.

[36] Woodward, D.F., A.M. Farag, H.L. Bergman, A.J. DeLonay, E.E. Little, C.E. Smith, and F.T. Barrows. 1995. Metals-contaminated Benthic Invertebrates in the Clark Fork River, Montana: Effects on Age-0 Brown Trout and Rainbow Trout. *Canadian Journal of Fisheries and Aquatic Science*, vol. 52, 1994–2004.

If the results are acceptable, further assessments could be conducted as part of the periodic monitoring program.

➥ ***It is recommended that the objective of the assessment of current conditions be to determine whether the aquatic environment has been negatively affected by the mine effluent. Only if the assessment finds an unacceptable effect should studies proceed to a more detailed assessment.***

6.2.3 Focussed Monitoring

The scope of focussed monitoring depends on the results of previous studies. The objectives of focussed monitoring are to delineate more precisely the magnitude and extent of previously identified effects.

This stage should address the following questions:

1) What is the magnitude and extent of the effect?

2) Are other components of the ecosystem likely to be affected and to require monitoring?

3) Is the effect temporary or chronic?

4) Is the effect related to chemical contamination or physical disruption?

5) Are fish and/or benthic invertebrates directly affected or are effects mediated through their food webs?

Interpretation of Results

If, as a result of focussed monitoring, conclusions can be drawn with an acceptable degree of confidence regarding the source and nature of the effects, mitigative/corrective measures may be recommended. After an acceptable period, monitoring could be repeated to establish the efficacy of the mitigative/corrective measures. If the results of the monitoring were favourable, the conclusion could be drawn that the mitigative/corrective measures were effective.

If, on the other hand, the cause of unacceptable effects cannot be identified through focussed monitoring, the EEM would proceed to the investigation of potential cause(s).

6.2.4 Investigation of Potential Cause(s)

In this activity, the results of previous work are reviewed with emphasis on designing an investigative program to determine the potential cause(s) of the effects observed. This exercise is reserved for exceptional situations that require further interdisciplinary investigation.

The questions to be addressed include:

1) What are the specific causes of the effects under investigation?

2) Are the mine effluents causing the effects? If so, what components of the effluents are responsible for the effects?

6.2.5 Application of EEM to Effluent Regulations

The EEM strategy described above is designed primarily to provide information on associations among environmental "effects" and the chemical and physical properties of mining effluents. To the extent practicable, EEM should be planned and conducted in ways that make it possible to relate the effect being measured to specific properties of the effluent. Thus, EEM may provide a practical evaluation of the effectiveness of regulated levels of individual contaminants.

6.3 Study Design

Study design can be viewed as a stepwise process in which each step is equally important in establishing a sound monitoring program.[37] Study design involves more than determining where, what, and how often to sample.

Step 1. Define expectations and the goal of the monitoring program. Identify important parameters and monitoring objectives. Develop reporting procedures (type and timing of reports, reporting format). Plan and initiate a public consultation process. Define environmental quality objectives.

---

[37] Sanders, T.G., R.C. Ward, J.C. Loftis, T.D. Steele, D.D. Adrian, and V. Yevjevich. 1990. Design of Networks for Monitoring Water Quality. Water Resources Publications. Colorado.

Step 2. Establish statistical design criteria: development of hypotheses, selection of statistical methods, determination of data needs (statistical significance and power analysis), conduct exploratory studies as required.

Step 3. Design monitoring study: where to sample, what to measure, how frequently to sample.

Step 4. Develop operating plans and procedures: sampling procedures, laboratory analysis procedures, quality assurance and quality control procedures, data storage and retrieval, data analysis.

Step 5. Plan conversion of data into useful information and disseminate information, perform program evaluation (are objectives and information expectations being met?).

The frequency of monitoring should be linked to the parameter being monitored, its inherent variability, and the magnitude of the change to be detected. Numerous factors may affect the frequency of sampling. For example, sediment characteristics may vary in accordance with seasonal changes in flow, and such sediment quality changes may be cumulative. These changes could be monitored annually or every 3 years or through the use of a coring program where appropriate. At the other end of the spectrum, some water quality events may be transient (minutes/hours) due to storm events. Much more frequent monitoring would be needed to detect these changes if they were important to the goals of the monitoring program. Many biological parameters tend to vary seasonally and may have a strong relation to the age or sex of the organism. These confounding variables should be considered when the frequency of the sampling program is planned. Similar considerations may arise when choosing a strategy to take into account the spatial variability of the phenomena being studied.

➡ ***It is recommended that the EEM program ensure that study designs are scientifically defensible and that quality assurance is given high priority. Study designs should be placed in the context of multiple samplings before (where possible) and after development, and at both exposed and reference locations.***

6.4 Quality Assurance and Quality Control

Environmental effects monitoring can be time-consuming and expensive, but the results of EEM programs can lead to important environmental management decisions at a mining operation. Therefore, it is important that the results of EEM be accurate, precise, and reliable. To ensure that the results of environmental monitoring programs are effective and efficient and can be used conscientiously for making decisions about environmental effects or the lack of them, all EEM programs must have a thorough quality assurance and quality control aspect.

Quality assurance encompasses a wide range of management and technical practices designed to ensure that an end product is of known quality commensurate with its intended use; in this case, a reliable set of data upon which interpretation can be based. Quality control is an internal aspect of quality assurance. It includes the techniques used to measure and assess data quality and a course of remedial actions to be taken when data quality objectives are not realized. Quality assurance/quality control goes far beyond the analytical laboratory. The risk of sampling error or sample contamination must be considered and the study design must control all potential sources of error.

A clearly defined organizational structure is an essential part of a quality assurance/quality control program. Specific individuals are assigned quality assurance/quality control functions and data reporting channels are established. Certification of the generated data by signature and date encourages serious attention to quality assurance/quality control functions. The quality management plan for the organization should include a quality assurance policy statement. All field and laboratory work should follow written standard operating procedures. Whereas chemical analysis procedures tend to be reasonably well documented, field sampling procedures are often overlooked. Sampling error can be large and is often the dominant component of uncertainty in environmental measurements. Standard operating procedures will help reduce uncertainty and ensure that it is quantified. Components of a field quality assurance program should include standard operating procedures for: sampling techniques and equipment; sample containers; instrument calibration; collection of replicate field samples; recording of information regarding sample collection, labelling, storage, handling, and shipping; and crew training.

Laboratory quality assurance programs should incorporate available standard analytical operating procedures, the use of bench record sheets to record details regarding sample handling and treatment, records of instrument calibration and maintenance, analyses of standard reference materials, results of field and trip replicates, and the use of blank and matrix spikes.

6.5 Acceptable or Unacceptable Effects

Central to EEM as a tool for decision-making is the ability to answer the question, “Is the operation having an unacceptable effect on the downstream aquatic environment?” Answering this question requires that the monitoring techniques in use must be able to reliably distinguish environmental effects from background variability. Furthermore, the effect must be reliably attributed either to the operation or to an outside influence, implying that there must be adequate reference sites and a good knowledge of preoperational conditions. Careful attention to the selection of hypotheses to be tested and appropriate statistical design is part of the scientific method, and highly relevant to a successful EEM program. The ability of participating scientists (from government, industry, and consulting firms) to reliably detect effects will evolve and improve through experience.

Once an effect has been detected, there must be consensus on the magnitude and extent of the effect so that a determination can be made regarding its “acceptability.” This determination is the decision point for moving on to mitigation or further assessment, or returning to periodic monitoring.

For any mine discharging liquid effluent, some degree of degradation or enrichment of the receiving water is inevitable. Although the effect may be detectable by standard scientific methods, it will not necessarily be significantly injurious or unacceptable to downstream users of water or aquatic resources. The company, regulators, and public stakeholders need to agree in advance upon what degree of effect will be acceptable. In the absence of absolute surety regarding the ecological importance of detectable effects, acceptability will often be determined on the basis of desirable environmental quality, knowledge of historical environmental quality, and the needs of downstream users of water or aquatic resources. Thresholds of acceptability can be defined in terms of the magnitude or frequency of an effect and/or cumulative loading.

Compliance with MMLER and site-specific regulations that are put in place in response to local sensitivities is expected to prevent gross deleterious effects in most cases. The determinations made during the course of an EEM program, therefore, will typically concern chronic or cumulative effects. The effects may be poorly understood and may also be perceived to be more or less important depending on the cultural and social perspective of the stakeholder. In other words, determining what constitutes an unacceptable effect is a process that takes place in a specific environmental, cultural, and social setting at a site-specific level. It is also important that definitions of acceptable and unacceptable effects be revisited periodically because values, as well as what is known about an ecosystem, will change over time.

A federal guideline or regulation cannot determine *a priori* what the acceptable level of an effect will be. This will be influenced not only by the perceptions of local stakeholders but also by pre-existing environmental quality and the degree of nonmine related influences (for instance, background metal concentrations, atmospheric pollution, upstream polluters, non-point sources of contamination, etc.).

Guidelines for the process of determining an "unacceptable effect" should be included in the national standards for EEM. Determination of an acceptable or unacceptable effect must be carried out on a site-specific basis.

➥ ***It is recommended that guidelines for the process of determining what is to be considered an acceptable or unacceptable effect should be developed by Environment Canada in consultation with the Department of Fisheries and Oceans and other stakeholders.***

The following elements have been identified as useful steps in public consultation:

- Planning for stakeholder participation should begin as early as possible in the assessment of a new mine site. This recommendation is consistent with the recommendations of the Whitehorse Mining Initiative.

- A local committee should be put in place that includes all relevant and interested stakeholders (the mining company; federal, provincial, and municipal regulatory authorities; aboriginal, interested community, and environmental organizations; downstream users of the aquatic resource). To be consistent with the recommendations of the Whitehorse Mining Initiative, this committee will be referred to as the public liaison committee.

- The public liaison committee should be involved in all stages of planning of a site-specific EEM program. Results of EEM should be reviewed by the committee and it should also be consulted when decisions are being made regarding the need for mitigation or additional monitoring.

- The initial task of the public liaison committee is to review the environmental assessment of the mine and consider the relative importance of each potential effect that has been identified. The ranking of potential effects will assist the company in preparing a focussed EEM program that serves the needs of public stakeholders as well as regulators and the company.

- In preparing their recommendations, the public liaison committee requires access to such information as the type of ore body, proposed processing, site characteristics, proposed rates of production, and the volume and character of discharges. Depending on the level of confidence that there could be adverse impacts on fish or fish habitat, mitigation could be recommended at the planning stage, even before the actual EEM program and mining commence.

- With guidance from the public liaison committee, the mining company would then design an effective and efficient site-specific EEM program. Elements included in the program should be approved by the appropriate regulatory agency.

- Using baseline conditions as a reference point, and keeping in mind the degree of change that can reasonably be detected using modern methodologies, the public liaison committee would then seek consensus on what degree of change in each EEM program parameter would be considered unacceptable. Collectively, these thresholds would constitute site-specific environmental quality objectives. For instance, the public liaison committee could assist in the development of water quality objectives for a specific point downstream of the mine or mill (e.g., East Kemptville Tin Mine, Appalachian region). The process of developing objectives should be completed within an agreed time frame. In the absence of consensus at the end of this period, the public liaison committee should provide a limited number of options for further consideration. Options for environmental quality objectives should be subject to a specified period of public review and comment. Taking public feedback into account, the local regulatory authority would then make the final decision and approve the objectives.

- Results of EEM should be provided to the public liaison committee for review and comment within, at most, a year of completion of the program.

- Any excursion beyond predetermined environmental quality objectives would be considered an unacceptable effect and would trigger either mitigation or (if the probable cause or extent and/or magnitude of an effect was not clear) further monitoring.

- In the event of detecting an unforeseen effect, the public liaison committee would have to make a recommendation to the local regulatory authority regarding the level of an acceptable effect.

7 Implementation of Environmental Effects Monitoring

7.1 Cooperative versus Regulatory Approach

Two different approaches to the implementation of EEM were discussed. Industry participants favoured cooperative implementation based on federal guidelines, with the possibility of regulation at some future date should the industry fail to achieve a consistent and acceptable standard. Other stakeholders felt a need for mandatory implementation of a site-specific EEM program at all mine sites, with a minimum standard of effectiveness and a general approach including standard program elements as described earlier. The two approaches and some potential benefits and drawbacks are outlined below and discussed further in Appendix 5.

On the basis of the assessment of previous monitoring efforts documented in the AQUAMIN database, it is recommended that future EEM have consistency of application, a well-defined scope, standard methodologies with appropriate quality assurance/quality control, valid baseline and reference data, timely reporting and response procedures, standards for discernable effects, appropriate confidence levels for statistical design, and defined processes for public involvement.

An approach that encourages cooperation among various users of a watershed is desirable. In addition, studies conducted for other purposes (especially those performed during the environmental assessment of a new mine) should be used in an EEM database provided they meet approved standards. In fact, such studies should henceforth be planned to be in accordance with EEM data standards and baseline data requirements.

It was further agreed that monitoring programs must be tailored to requirements and priorities at each location to be effective, efficient, and ecologically meaningful. This requires that any federal guideline or regulation setting out an approach to EEM must allow for site-specific decisions and must avoid prescriptive detail. On the other hand, there must be sufficient guidance to ensure that the quality of information provided by EEM is sufficient to allow sound decision-making at mine sites throughout Canada.

Either cooperative or regulated EEM programs could incorporate the flexibility required to address site-specific issues, improve upon existing government and company EEM efforts, and promote cooperative watershed management among stakeholder groups. They would involve those directly linked to the aquatic and fishery resource, and encourage cooperation and understanding among the different stakeholders.

7.1.1 Conclusions

It is strongly recommended that all federally regulated EEM requirements be designed to encourage focussed, effective, and efficient site-specific program development and should include feedback loops that promote continuous improvement and innovation by industry and regulators.

It has been suggested that cooperative programs be promoted and that the industry is sufficiently mature and responsible to rise to the challenge. On the other hand, there is a need for regulators and public stakeholders to be assured that monitoring will be conducted and reported, on a regular basis, across Canada using established protocols. This latter requirement argues for implementation of a minimum standard of EEM by federal regulation. However, a regulatory approach must be flexible so that cost-effective, site-specific programs can be developed for each mine site in collaboration with provincial authorities and public stakeholders.

Ultimately, the utility and effectiveness of EEM depends on the extent to which its objectives are met. Every effort should be made to minimize changes to delivery of current programs, to reduce unnecessary expense, and to avoid duplication of effort by coordinating the use of existing channels and mechanisms, and harmonizing administrative systems.

After prolonged debate and based on the understanding that an EEM program would follow the agreed approach described in Section 6, AQUAMIN members came to the following recommendation:

➥ ***It is recommended that the revised MMLER include a requirement that mine operators develop, conduct, and report on a site-specific EEM program that***:

- ***monitors key components of aquatic ecosystems (e.g., water, sediments, fish, benthic invertebrates)***
- ***uses tools that are appropriate to site conditions***
- ***follows the approach to EEM recommended in Section 6 of this report***

Methodologies, sampling frequency, and other details should be determined at the local level.

7.2 Multistakeholder Process for EEM

7.2.1 Use of Traditional and Local Knowledge

During the determination and ranking of potential environmental effects, as well as during the development of an EEM program, information provided by local stakeholders (fishing and aboriginal communities and others with intimate knowledge of present and past environmental conditions, i.e., “traditional knowledge”) will be particularly valuable. Local knowledge may lead to the identification of potential effects other than those included in the original environmental assessment. By considering each potential effect in its local context, the public liaison committee can provide guidance for the development of an EEM program that will focus on those environmental resources that are most at risk and those perceived to be most important to affected stakeholders.

To benefit fully from local and traditional sources of environmental information during EEM, a simple mechanism should be set in place and publicly advertised to allow persons detecting any unforeseen or apparently unacceptable effect to bring this information to the attention of the public liaison committee. The committee would then consider whether the EEM program could or should be modified, or whether further analyses of existing data should be conducted, to test for a scientifically detectable effect.

7.2.2 Review Mechanisms

One of the objectives of EEM is to provide insight into the relationship between effluent quality and environmental effects. In some cases, it will be difficult or impossible to clearly determine the relationship between an effect and the mining effluent. The ability to distinguish effects and relate them to specific effluent constituents will develop over time through experience with EEM.

From a larger (national or regional) perspective, EEM provides the means for periodic assessment of the overall effectiveness of control strategies employed in the mining industry.

Periodic meetings should be held, under the auspices of Environment Canada, to review the results of EEM of metal mining in Canada. These meetings should be regional or national in scope and should take place at reasonable intervals (for instance, 3 years (regional) and 5 years (national)). Participants should be drawn from the mining industry; federal, provincial, and aboriginal governments or agencies involved in the regulation or review of mining operations; and stakeholders with an interest in the conservation of aquatic resources likely to be affected by mining operations.

The purpose of the meetings would be to provide an opportunity to conduct a comprehensive review and critique of EEM programs and environmental protection measures. The EEM coordination group should be directly involved in the preparation of documentation used in the periodic review meeting. The directorate should also report recommendations from the meeting to the industry, governments, and other stakeholders.

➥ ***It is recommended that Environment Canada establish a central registry of reports and data generated through EEM in the mining industry.***

Of particular potential importance is the compilation of reference site data that could be used by mining companies to augment information from their local reference sites.

➥ ***It is recommended that Environment Canada institute an independent and periodic peer review of the EEM program to provide recommendations on revisions to the environmental protection framework.***

➥ ***It is recommended that an informal resource group of individuals from government, industry, and academia be established to review and make recommendations regarding site-specific EEM programs.***

➥ ***It is recommended that an EEM coordination group be formed as an umbrella organization to oversee and monitor the progress of EEM, and to act as a clearing house for information. National in scope, it would include representation from affected stakeholders — government, industry, aboriginal groups, and environmental nongovernmental organizations.***

8 Revisions to the Environmental Code of Practice for Mines

8.1 Introduction

Accompanying the current MMLER is an Environmental Code of Practice for Mines. The code is intended “to be a guide for professionals in meeting their environmental control responsibilities and emphasizes pollution control practices that should be considered at all stages of mine–mill development, from initial planning through to abandonment.”

Since 1977, there have been significant advances in environmental practices at mine sites. For example, management of acid-generating wastes has changed considerably as a result of the Mine Environment Neutral Drainage program and the British Columbia Acid Rock Drainage Task Force. In addition, there have been significant changes in societal expectations regarding the environmental impacts of industrial activity, disclosure of information, and public involvement in decision-making. Furthermore, there have been significant advances in the state of knowledge regarding the effects of mining on the environment.

➥ ***It is recommended that the Environmental Code of Practice for Mines be updated.***

➥ ***It is recommended that the updated Environmental Code of Practice for Mines continue to have a significant focus on issues related to water management and water pollution prevention.***

➥ ***It is recommended that the updated Environmental Code of Practice for Mines also address other issues, such as stakeholder involvement.***

The updated code should:

- emphasize the principles of pollution prevention
- be applicable to all phases of mining activities from exploration, mine development, ore stockpiling, operations, and close out and transfer of ownership to the appropriate Crown agency
- provide references to address the production, prevention, control, treatment, and monitoring of acidic drainage from waste rock, tailings, ore stockpiles, and exposed ore

in mines; the handling/treatment of sludge from acid mine drainage/acid rock drainage (AMD/ARD) treatment; site management of fuels, reagents, solvents, and refuse; power generation; and site close out

- address and recommend measures to involve communities and aboriginal groups dependent upon local natural resources for sustenance, employment, and quality of life

8.2 Scope of Revisions

➥ ***It is recommended that the current Environmental Code of Practice for Mines be revised in two ways:***

- ***update material in the current code***
- ***add additional sections to address other aspects of environmental management and monitoring***

The scope of revisions is summarized in Table 8, which compares the Table of Contents of the current code with a proposed outline for the updated code.

8.3 Revisions Regarding Stakeholder Involvement

Stakeholder involvement would be difficult to require under the MMLER, but the updated code could be amended to include the following:

- Mine operators should identify stakeholder groups and be prepared to form public liaison committees, made up of community representatives and mine managers and regulators, to deal with the exchange of information and decision-making regarding the practices of the mine. These committees would advise the mine operator and regulators.

- In reporting the effects of effluent on the environment, mine operators should provide an accurate interpretation of the data that the public can understand. Operators should provide this information in the language of the community.

- It should be the responsibility of the mine operator to make potential risks clear to the public.

Table 8: Table of Contents of current Environmental Code of Practice for Mines and proposed outline of revised code.

Current Environmental Code of Practice for Mines	Proposed Updated Environmental Code of Practice for Mines
Water-borne Wastes • mill process effluent • mine drainage • surface drainage including seepage • wastes from exploration and development activities **Minimization of Water Volumes** • reuse of water in the mine • reuse of water in the mill **Waste Treatment** • tailings impoundment systems • other metal removal systems • removal of radionuclides • thiosalt removal **Rehabilitation** • long-term control of contaminated effluents • rehabilitation of open pits and mine workings • rehabilitation of tailings areas **Disposal of Waste Rock and Mill Tailings** **Fail-safe Design** • in-plant contingencies • site contingencies **Monitoring**	**Preproduction** • baseline environmental surveys • pollution-prevention planning • water use, protection planning, and diversion, etc. • conceptual close-out planning • waste characterization • opportunities for waste minimization • AMD/ARD prediction and modelling • dewatering of inactive pits or underground workings • protection of fish habitats • consultation with local communities **Production** • water use minimization, recycling and diversion • AMD/ARD prevention • AMD/ARD collection and treatment, sludge disposal • tailings impoundments • mill and tailings effluent treatment • use, recycling, and disposal of solvents, reagents, fuels, industrial and domestic wastes • prevention of air pollution • monitoring and prevention of fugitive dust emissions • protection of fish habitat • energy conservation • ongoing or progressive reclamation • blasting agents and residues • continued consultation with local communities **Site Close Out** • removal of infrastructure, e.g., storage areas, buildings, roads, load-out areas, power lines, parking lots • reclamation, and site enhancement with respect to environmental condition, economically or socially acceptable use • maintenance of consultation with local communities • effluent, seepage, runoff, and point discharge monitoring and downstream EEM until an environmentally steady or improved state is achieved and the closure plan has been fully implemented to the satisfaction of the relevant regulatory agencies

9 Information Gaps and Research Needs

A number of information gaps and research needs were identified during preparation of the case studies and Regional Syntheses. Further information gaps and research needs were also identified during preparation of this Final Report. These research needs are summarized below.

- ➢ Examine approaches to cumulative and chronic effects monitoring.

- ➢ Improve the understanding of chronic and sublethal toxicity effects of metal contaminants

- ➢ Validate the application of methods such as mesocosms and the use of metallothionein to assess sublethal and chronic effects.

- ➢ Examine the application of the following approach to assessing the efficacy of effluent treatment and to evaluating chronic effects on organisms in receiving waters caused by contaminants discharged in mining and milling effluents.

  1) Use information on contaminant concentrations in treated effluents, and on volumes of treated effluents discharged, to calculate actual contaminant loadings to receiving waters.

  2) Determine the bioavailability of these contaminants by analysing a statistically appropriate number of fish species and benthic organisms per site.

  3) Evaluate whether these contaminants are producing chronic adverse effects on the health of these organisms.

  4) Determine the significance of these chronic adverse effects on the viability of the overall receiving watershed ecosystem.

  5) Investigate the significance of measurable environmental effects (sediments, water quality, benthos, and bioaccumulation) on the overall health of the receiving environment.

- ➢ Improve the understanding of the fate and effects of metals:
  - to determine the relationship between metal levels in sediments and the bioavailability and potential impacts of these metals
  - to determine the bioavailability and toxicity of chromium and molybdenum in sediments
  - to determine the bioaccumulation of metals in periphyton
  - to understand the movement of metals within the food chain
  - to determine sublethal effects of metals
  - to better understand sources of mercury in the environment and to determine whether or not mercury release from metal mines is causing environmental effects
  - to determine the advantages and disadvantages of measuring total metal concentrations versus dissolved metal concentrations
  - to determine the validity of using metal concentrations in fish tissue (muscle, liver), as fish health indicators

- ➢ Determine elemental threshold values for aquatic species above which the health and survival of individuals and/or populations of these species would be significantly affected.

- ➢ Assess and validate relevant statistical procedures for study design and data analysis.

- ➢ Identify means of predicting and avoiding thiosalt production.

- ➢ Determine whether or not flotation reagents, such as xanthates, are causing effects in receiving environments.

- ➢ Continue government/industry research programs to identify and develop cost-effective pollution prevention and control technologies for total ammonia and nitrogen compounds.

- ➢ Assess impacts of airborne contaminants from tailings and metallurgical facilities on aquatic ecosystems.

- ➢ Assess and validate sample collection techniques, quality assurance/quality control measures, statistical and laboratory methods, and other study components. The Aquatic Effects Technology Evaluation program is meant to provide guidance on these matters.

- ➢ Develop regional or site-specific water quality and sediment quality objectives for any future programs to evaluate the aquatic effects of mining in Canada. In place of site-specific water quality and sediment quality guidelines, it is appropriate to have a provision in the effects evaluation process to utilize background concentrations and related biological conditions as reference criteria.

Appendix 1: Other Influences and Initiatives

In developing and implementing an overall framework to protect the aquatic environment, in revising the MMLER, and in designing and implementing an environmental effects monitoring program, Environment Canada and other stakeholders will have to take into consideration several policies and initiatives, in addition to the recommendations of AQUAMIN. These policies and initiatives are summarized below.

Toxic Substances Management Policy

This federal policy puts forward a preventive and precautionary approach to deal with substances that enter the environment and that could harm the environment or human health. This policy underscores the need to apply pollution-prevention principles to existing federal programs to reduce or eliminate the risks associated with toxic substances. At the same time, the policy recognizes the need to sustain jobs and a healthy economy by implementing cost-effective measures to prevent environmental degradation.

Pollution Prevention — A Federal Strategy for Action

This strategy reflects a major shift in emphasis from "control" to "prevention." It encourages changes that are likely to lead to lower production costs, increased efficiencies, and more effective protection of the environment. The strategy focuses on five goals, including the achievement of a climate in which pollution prevention becomes a major consideration in private sector activities by:

- promoting pollution prevention through research, development, and demonstration initiatives
- promoting the adoption of sustainable production in industrial and manufacturing processes
- implementing economic instruments that will result in pollution prevention
- helping small and medium-sized enterprises improve their environmental performance

Canadian Environmental Assessment Act

The *Canadian Environmental Assessment Act* identifies the responsibilities and procedures for environmental assessments of projects in which the federal government has decision-making authority in its role as proponent, land manager, the source of funding, or regulator (i.e., responsible authority). The objectives of the act are:

- to ensure that the environmental effects of a project are carefully considered before responsible authorities take action
- to encourage responsible authorities to take actions that promote sustainable development
- to ensure that projects that are to be carried out in Canada or on federal land do not cause significant environmental effects beyond the jurisdictions in which they are to be undertaken

- to ensure that the public has an opportunity to participate in the process

Pulp and Paper Environmental Effects Monitoring Program

The pulp and paper environmental effects monitoring program became a legal requirement in Canada for pulp and paper mills in 1992. Since then, mills have developed and conducted monitoring programs. Mills were required to report the results of their monitoring programs by April 1, 1996. As the first program of its kind, there are several key lessons to be learned from the pulp and paper EEM experience:

- the goals of EEM should be clearly defined and agreed to by participants
- participants in EEM should be well informed about the nature of the program
- the roles of stakeholders involved in EEM should be clearly defined
- the degree of national consistency required regarding monitoring should be agreed upon at the outset
- program design should be sufficiently flexible to allow adaptation to the unique conditions of each study site
- the development of laboratory and analytical guidelines/protocols is valuable
- consultation with relevant stakeholders is important to the success of EEM

Treasury Board Policy

Treasury Board policy applies to all federal regulatory agencies, and for existing regulatory programs and new or substantively amended regulations, departments must demonstrate that:

- a problem or risk exists, government intervention is justified, and regulation is the best alternative
- Canadians have been consulted and have had an opportunity to participate in developing or modifying regulations and regulatory programs
- the benefits of the regulatory activity outweigh the costs
- steps have been taken to ensure that the regulatory activity impedes Canada’s competitiveness as little as possible
- the regulatory burden on Canadians has been minimized
- systems are in place to manage regulatory resources effectively

Whitehorse Mining Initiative (WMI)

This initiative was a multistakeholder consultation initiated in September 1992 to address several key issues of importance to the mining industry in Canada. The process was completed in September 1994. It outlined principles, goals, and recommendations pertinent to the various issues, including environmental protection, science-based environmental decision-making, aboriginal lands and resources, aboriginal involvement in the mining industry, and overlap and duplication. Some relevant recommendations of the initiative follow:

- Proponents should plan their public involvement mechanisms and processes carefully and as early as possible.
- Follow-up on environmental assessment predictions and commitments should be monitored by multistakeholder public liaison committees. Results of environmental effects monitoring should be made public and compared with predictions made in the environmental assessment so that recommendations for improvement of future projects can be made when needed.
- Environmental effects monitoring should satisfy several objectives: verification of compliance with environmental standards, validation of predictive models and confirmation of environmental assessment, and assessment of the adequacy of pollution prevention and control systems in protecting ecosystem health, with particular regard to key environmental indicators.
- Monitoring should be targeted, effective, and efficient; include a program to ensure the accuracy of data; be conducted with a frequency that is reduced when environmental objectives are consistently met; track potentially significant mine-related effects; and be based chiefly on self-monitoring with adequate verification by regulatory agencies.

Aquatic Effects Technology Evaluation

The mandate of the Aquatic Effects Technology Evaluation (AETE) program is to evaluate environmental monitoring technologies to be used by the mining industry and regulatory agencies in assessing the impacts of mine effluents on the aquatic environment and to recommend specific methods or groups of methods that will permit accurate characterization of environmental impacts in receiving waters in as cost-effective a manner as possible. The program includes three areas: acute and chronic toxicity testing, biological monitoring in receiving waters, and water and sediment monitoring.

The program has two main objectives:
1) to assist the Canadian mining industry in meeting its environmental effects monitoring and related requirements in as cost-effective a manner as possible
2) to benefit the Canadian environment by evaluating new and existing monitoring technologies for the assessment of environmental impacts, and indicating the benefits and weaknesses of each technology

Aquatic Effects Technology Evaluation started on April 1, 1994 and will conclude on March 31, 1998. The deliverable from the program will be a series of reports on appropriate, cost-effective methods of determining the biological and nonbiological impacts of mine effluents on Canada’s lakes, rivers, and streams:

- bioassay alternatives to rainbow trout and *Daphnia magna*
- preferred methods of determining the sublethal toxicity impacts of mining effluents
- preferred methods of determining the impacts of mining effluents on biota in receiving waters
- preferred methods of determining the impacts of mining effluents on receiving waters and sediments
- recommended technologies for environmentally effective and cost-effective monitoring of the impact of mine effluent in Canada

AQUAMIN and AETE interacted in several ways. Firstly, a number of individuals participated in both programs. In addition, there was ongoing communication between the secretariats of the two programs. Information from the database prepared for AQUAMIN has been considered by AETE in the selection of study sites. The suite of monitoring tools developed by AETE will be useful to mining companies and regulators in establishing monitoring requirements at mine sites.

Mine Environment Neutral Drainage (MEND) Program

Generation of acidic drainage (called acid mine drainage) is a chemical oxidation process that occurs when sulphide minerals, such as pyrite and pyrrhotite, in ore, waste rock, tailings, and the walls of mines are exposed to air, water, and certain bacteria (the chemistry of the process is described in some detail in Supporting Document I). The acidic waters resulting from these oxidation reactions can dissolve metals in tailings, rocks, minerals, and soils. This water can contaminate both surface and ground water. The cost of ameliorating or preventing the generation of acid mine drainage at active and inactive Canadian mine sites is estimated to be $5.2 to $6.9 billion. Acid mine drainage is the most serious environmental problem facing the Canadian metal mining industry.

The Mine Environment Neutral Drainage program was established in 1989 as a cooperative program, jointly funded, directed, and managed by federal and provincial government agencies and members of the metal and the eastern Canadian coal mining industries. The purpose of the program is to develop cost-effective technologies to predict, monitor, prevent, control, and treat acid mine drainage. The program has a budget of $18.0 million to carry out its research over an 8 year period ending in 1997.

MEND research programs have been developed by technical committees tasked to address prediction and monitoring, prevention and control treatment, and technology transfer. The program has generated an extensive body of scientific and technical information, available in published reports. The research has included demonstration projects at a number of Canadian mine sites. Restricting the access of sulphide minerals in tailings and waste rock piles to oxygen is an essential element in preventing the acid-generating reaction from starting. A number of prevention and control research and demonstration projects have focussed on the use of underwater disposal techniques for waste rock and tailings and the use of dry covers on the surface of tailings disposal sites.

Report on the Assessment of Metal Mine Submarine Tailings Discharge to Marine Environments

Although AQUAMIN included two case studies at sites that indirectly discharged mine effluents to marine environments (Nanisivik and Hope Brook), the focus of AQUAMIN was on freshwater environments. In particular, unconfined disposal of tailings in marine environments was not examined in AQUAMIN, although reports documenting the effects of such activity were collected. Environment Canada has contracted a review of the effects of mining effluents on the marine environments. The report will examine data from published and unpublished reports and will:

- evaluate the effects of metal mine effluents, including unconfined tailings, on Canadian coastal marine environments

- identify information gaps and research needs in marine EEM and recommend a national EEM program for marine environments
- propose possible approaches for regulating, monitoring, and assessing future mine effluent discharges to marine environments

Appendix 2: Participants in AQUAMIN[38]

Nardia Ali, Environment Canada, Ontario Region	WG4
Wayne Barchard, Environment Canada, Atlantic Region	WG1
Charlotte Bastien, AQUAMIN Secretariat, Environment Canada	SEC (SG, WG7)
Brian Bell, Sudbury Operations, Inco Limited	WGs 1 & 8
Bill Blakeman, Industrial Sectors Branch, Environment Canada	SG, WGs 2 & 8
Dan Boyle, Geological Survey of Canada, Natural Resources Canada	WG1
Neil Brody, New Brunswick Ministry of the Environment	SG
Victor Chapados, Noranda Minerals, Division Mines Gaspé	WG4
Marc Charette, AQUAMIN Secretariat, Environment Canada	SEC (SG, WGs 7 & 8)
Murray Clamen, Ecohealth Branch, Environment Canada	SG
Al Colodey, Environment Canada, Pacific and Yukon Region	WG7
Ron Connell, Dome Mine, Placer Dome Canada	WG7
Leslie Cooper, Ontario Ministry of Northern Development and Mines	SG, UG, WG4
Peter Davenport, Geological Survey Branch, Newfoundland Department of Mines and Energy	WG3
Bruce Downing, Teck Exploration Ltd.	WG6
Charles Dumaresq, AQUAMIN Secretariat, Environment Canada	SEC (SG, UG, WGs 1, 2, 4, 5, 7 & 8)
Bill Duncan, Trail Operations, Cominco Limited	WG7
Jacques Duval, Quebec Cartier Mining	WG4
Wayne Fairchild, Department of Fisheries and Oceans	WG3
Bruce Fallis, Department of Fisheries and Oceans	WG5
Gordon Ford, British Columbia Ministry of Environment, Lands and Parks	SG
Sheila Forsyth, AQUAMIN Secretariat, Environment Canada	SEC (SG, UG, WGs 1 & 2)
Wayne Fraser, Hudson Bay Mining & Smelting Company	WG5
Elizabeth Gardiner, Ontario Mining Association/Mining Association of Canada	SG
Tom Gates, Saskatchewan Environment and Resource Management	UG, WG5
Claude Gignac, Ministère de l'Environnement et de la Faune du Québec	UG, WG4
Jacques Giguère, Mines d'Or Kiena	WG4
Benoit Godin, Environment Canada, Pacific and Yukon Region	WGs 1 & 6
David Good, Greenfyre	WG4
Bob Hallam, Hallam, Knight, Piésold Ltd.	WG6
Steve Harbicht, Environment Canada, Prairie and Northern Region	WG5
John Hawley, Ontario Ministry of the Environment and Energy	SG, WGs 1 & 2
Jenifer Hill, Hallam, Knight, Piésold Ltd.	WG6
Doug Hyde, Rawson Academy of Aquatic Science	SG, WG1
Tom Hynes, CANMET, Natural Resources Canada	SG
Henri Jacob, La Reve	WG4
Genia Kedney, Pro Faune	WG4
Jack Klaverkamp, Freshwater Institute, Department of Fisheries and Oceans	WGs 4 & 7
Wayne Knapp, Department of Fisheries and Oceans, Pacific Region	WGs 6 & 8
Jamie Kneen, Inuit Tapirisat of Canada	SG, WG2

[38] Some participants joined their respective group (Steering Group, Working Group, or Secretariat) after the group had started its deliberations; others left before the group had completed its work. Hence, participants were not necessarily involved in all activities and decisions of their respective group in relation to AQUAMIN.

Elaine Koren, Industrial Sectors Branch, Environment Canada	WGs 4, 5 & 6
Vaclav Kresta, New Brunswick Environment	SG
Tiina Kurvits, AQUAMIN Secretariat, Environment Canada	SEC (SG, UG, WG3)
John Kwong, National Hydrology Research Institute, Environment Canada	WG6
Marc Lefèbvre, Enviréo Conseil Inc.	WG4
Joseph LeJeune, New Brunswick Environment	SG
Kim Lemky, AQUAMIN Secretariat, Environment Canada	SEC (SG, UG, WG6)
Brennain Lloyd, Northwatch	WG8
Connie MacDonald, Evaluation and Interpretation Branch, Environment Canada	SG
Eric Madsen, Department of Indian Affairs and Northern Development, Yellowknife	WG5
Barney Masazumi, Dene Nation	WG5
Bernard Matlock, Nova Scotia Department of Environment	WG8
Kevin McDonell, Department of Indian Affairs and Northern Development, Yellowknife	WG5
Harlan Meade, Westmin Resources	SG
Bob Michelutti, Falconbridge Limited	WGs 1 & 7
David Milburn, Department of Indian Affairs and Northern Development	SG
Chris Mills, East Kootenay Environmental Society	UG, WG6
Alena Mudroch, National Water Research Institute, Environment Canada	WG3
Richard Mudry, AQUAMIN Secretariat, Environment Canada	SEC (SG)
William Napier, Homestake Canada	WG4
Mil Nickerson, Tusket River Environmental Protection Association	WG3
Irené Novaczek, Environmental Coalition of Prince Edward Island	SG, UG, WGs 2, 3 & 7
Roy Parker, Environment Canada, Atlantic Region	UG, WGs 3 & 7
Judy Parkman, Recycling Organization Against Rubbish	SG, WGs 6 & 7
Michael Patterson, Heath Steele Mines	WG3
Alan Penn, Cree Regional Authority	WGs 4 & 7
Ed Porter, AQUAMIN Secretariat, Environment Canada	SEC (SG, WG3)
Robert Prairie, Noranda Technology Centre	SG, UG, WG1
Peter Prebble, Saskatchewan Environmental Society	WG5
Gary Rawn, National Programs Division, Department of Fisheries and Oceans	SG, WGs 1 & 2
Sankar Ray, Department of Fisheries and Oceans	WG3
Trefor Reynoldson, National Water Research Institute, Environment Canada	WG6
David Robinson, Habitat Management, Department of Fisheries and Oceans	SG
Danielle Rodrigue, CANMET, Natural Resources Canada	WG4
Fernando Rosa, National Water Research Institute, Environment Canada	WG5
Normand Rousseau, Ministère de l'Environnement et de la Faune du Québec	WG4
Richard Schwenger, Brunswick Mining and Smelting, Mining Division	WG3
Bill Shilts, Geological Survey of Canada, Natural Resources Canada	WG2
Marc Sinotte, Ministère de l'Environnement et de la Faune du Québec	SG
Harm Sloterdijk, Environment Canada, Centre St. Laurent	WG4
Michael Sprague, New Brunswick Department of the Environment	WG3
Angela Stadel, Inuit Tapirisat of Canada	SG, WG8
Larry Strachan, Manitoba Environment	SG
Michael Sudbury, Falconbridge Limited	WG4
Leonard Surges, Brunswick Mining and Smelting	SG, WGs 2 & 8
David Sutherland, British Columbia Ministry of Environment, Lands and Parks	SG, WGs 1, 2 & 8
Guy Theberge, Action St. Francois	WGs 4 & 8
Shelley Thibedeau, Department of Indian Affairs and Northern Development	WG5
Yves Thomassin, Groupe Environnement Shooner, Inc.	WG4

Patsy Thompson, Atomic Energy Control Board of Canada	WG5
Mark Thorpe, Placer Dome Inc.	WGs 1 & 6
Lise Trudel, AQUAMIN Secretariat, Environment Canada	SEC (SG, UG, WGs 1, 4, 7 & 8)
Claire Villeneuve, AQUAMIN Secretariat, Environment Canada	SEC (SG, WGs 7 & 8)
Neville Ward, Ontario Ministry of Natural Resources	SG
Gary Westlake, Ontario Ministry of the Environment and Energy	WG4
Gerry Whitley, Department of Indian Affairs and Northern Development	WG7
Maxine Wiber, Rio Algom Limited	WG7
Anne Wilson, Environment Canada, Prairie and Northern Region	WG5
Hugh Wilson, Metall Mining	WG5

Abbreviations: SEC, Secretariat; SG, Steering Group; UG, Umbrella Group; and WG, Working Group.

Appendix 3: Detailed Justifications Regarding Parameters

This material accompanies recommendations regarding parameters presented in Section 4.3.[39]

Aluminum

Aluminum is one of the most common elements in many rock-forming minerals that can contain, in addition to aluminum, mixtures of cadmium, magnesium, potassium, iron, silicon, and oxygen. Igneous and metamorphic rocks containing alumino-silicate minerals are the predominant hosts and gangue (waste) rocks associated with many metallic ore bodies. As a consequence, aluminum, silicon, and oxygen are the predominant elements present in metal mine tailings.

Aluminum is relatively soluble in water, especially under acidic conditions. Accordingly, tailings pond effluents may contain dissolved aluminum ions as well as chemically bound aluminum in the form of clays and other alumino-silicate mineral particles.

- Aluminum is not regulated by the MMLER.
- The report of Working Group 3 states that elevated levels of fluoride and aluminum in effluents, and observed receiving water impacts downstream of the closed East Kemptville Tin Mine are of concern. Accordingly, the report states that site-specific controls could include limits for these parameters.
- The Canadian Water Quality Guidelines for Freshwater Aquatic Life also state that aluminum toxicity in fish increases under alkaline conditions, and they cite experiments involving rainbow trout that indicated that the toxicity of dissolved aluminum was more severe, but that suspended aluminum was also toxic.
- The MISA draft development document states that aluminum was present in 70% of the Ontario metal mining effluents sampled, with an average concentration of 0.20 mg/L.
- The MISA document also states that:
  - ➢ Dissolved aluminum is not a significant component of most metal mining effluents.
  - ➢ Aluminum in Ontario metal mining effluents can be controlled, in most cases, by controlling levels of suspended solids.
  - ➢ Aluminum is regulated in British Columbia within the range (guidelines) of 0.5 to 1.0 mg/L (the lower limit is for new plants; the high limit is for older plants). In addition, Italy regulates aluminum at 2 mg/L and Spain regulates aluminum between 1 and 2 mg/L. As far as is known, aluminum is not regulated in any other mining jurisdiction in the world.
- Aluminum is not regulated in the Ontario *Metal Mining Effluent Limits Regulation.*

---

[39] Note that Working Group 5 identified uranium and salinity as additional parameters of concern. However, the recommendations of Working Group 5 were not available to Working Group 8 at the time of writing. Therefore, uranium and salinity are not addressed in this appendix.

Arsenic

Arsenic generally occurs in combination with iron and sulphur (arsenopyrite) and, in most cases, is found in the dissolved portion of effluent.

- The maximum MMLER authorized monthly mean concentration for arsenic in effluent is 0.5 mg/L and the maximum concentration for arsenic in a single “grab sample” is 1.0 mg/L.
- The reports of Working Groups 3, 4, 5, and 6 indicate that arsenic can bioaccumulate in fish and that it is known to be toxic to aquatic organisms.
- The Canadian Water Quality Guidelines for Freshwater Aquatic Life state that the concentration of total arsenic in natural receiving water should not exceed 50 µg/L.
- The MISA draft development document states that arsenic was found in 26% of the metal mine effluents sampled, with an average concentration of 0.036 mg/L.
- The Ontario *Metal Mining Effluent Limits Regulation* limits the monthly average total concentration to 0.5 mg/L and the daily sample concentration to 1.0 mg/L.

Cadmium

Cadmium is almost always associated with sphalerite (a common ore mineral of zinc). It can be found in either solid or dissolved form. Cadmium is designated toxic under the *Canadian Environmental Protection Act* and is recognized as a contaminant of mine-related effluents. Also identified by Working Group 6 as a parameter of concern, cadmium is recognized as being toxic to fish and causing reductions in the growth and survival of fish.

- The reports of Working Groups 3, 4, 5, and 6 state that cadmium contributed to impacts at two mine sites — Myra Falls, which in 1993 achieved compliance with cadmium and toxicity, and the Samatosum Mine, which reduced cadmium to very low levels using treatment technology that exceeded BATEA.
- The Canadian Water Quality Guidelines for Freshwater Aquatic Life state that the concentration of total cadmium in natural receiving water should not exceed 0.017 µg/L. However, water hardness can modify the toxicity of cadmium, and the guidelines should be corrected for that parameter using the following relationship:

  $$WQG = 10^{\{0.86\,[\log 10\ (\text{hardness})] - 3.2\}}$$

  where hardness is measured as calcium carbonate ($CaCO_3$) equivalents in milligrams per litre and the water quality guideline (WQG) is given in micrograms per litre.
- The MISA draft development document states that cadmium was found in 12% of the metal mine effluents sampled, with an average concentration of 0.003 mg/L.

Calcium

Calcium was identified as a parameter in only one case study, where its discharge from a mine in liquid effluent caused the depletion of dissolved oxygen in a lake. Because calcium is commonly used as an effluent treatment reagent, it has the potential to indirectly impact on receiving streams. Its concentration in final effluent would be difficult to control for this reason. Its potential impact is site dependent and, therefore, it is not included as a regulated parameter.

Copper

As an element, copper is present in several minerals, the most common ore minerals being native copper, chalcopyrite, chalcocite, bornite, malachite, azurite, and chrysocolla ($CuFeS_2$). Copper is commonly present in metal mine effluent as particulates, as dissolved copper, or as copper–cyanide or copper–iron–cyanide complexes.

- The Canadian Water Quality Guidelines for Freshwater Aquatic Life recommend concentrations of total copper in natural water as listed below:

Hardness (mg/L as $CaCO_3$)	Concentration of Total Copper (µg/L)
0 - 60 (soft)	2
60 - 120 (medium)	2
120 - 180 (hard)	4
> 180 (very hard)	6

- The MISA draft development document reports that for 39 Ontario effluent streams sampled for 12 months, the average copper concentration was 0.07 mg/L.
- Existing BATEA is capable of achieving copper concentrations in effluents in the range of 0.3 to 0.6 mg/L.
- The *Metal Mining Liquid Effluent Regulations* maximum monthly mean concentration and “grab sample” limits for copper in effluents are 0.3 and 0.6 mg/L respectively.
- The Ontario *Metal Mining Effluent Limits Regulation* requirement for the monthly average total copper concentration is 0.3 mg/L.
- The Environment Canada report on the status of compliance of Canadian metal mines for 1990 indicates that average copper concentration limits were exceeded twice by the 49 metal mines subject to the MMLER and three times by the 53 mines subject to the concentrations prescribed in the MMLEG.

Cyanide

Base metal operations typically use small amounts of cyanide (21 tons/day), whereas gold operations generally use much larger quantities (88 tons/day).

- Cyanide is commonly used as a depressant of pyrite in the milling process and as a reagent in the recovery of gold and silver.
- Cyanide is extremely toxic to aquatic organisms and has been recognized by Working Groups 3, 4, and 6 as a parameter of concern. Extensive technology exists to treat cyanide.
- The Canadian Water Quality Guidelines for Freshwater Aquatic Life state that the concentration of total cyanide in natural receiving water should not exceed 0.005 mg/L of free cyanide.
- The MISA draft development document states that cyanide was found in 54% of the metal mine effluents sampled, with an average concentration of 0.084 mg/L in gold mining effluent and 0.006 mg/L in base metal mining effluent.

Fluoride

Fluorine is present in two fluorine-bearing minerals, fluorite and cryolite. These minerals are rare in Canadian metallic mineral deposits and crystalline rocks. Fluorite and cryolite are commercially recovered for use as fluxes in the steel making and aluminum smelting industries.

- Fluoride as a compound or as fluorine is not regulated by the MMLER nor was it considered as a candidate for control limits by the Ontario MISA program for metal mines.
- The Canadian Water Quality Guidelines for Freshwater Aquatic Life do not contain a reference to, or concentration limits for, fluoride in natural receiving water.
- The report of Working Group 3 states that effluent from the East Kemptville (Nova Scotia) Tin Mine (closed) contained significant concentrations of fluoride and that although it was shown to be accumulating in the bones of fish, pathological effects of the bioaccumulation were not detected. Fluoride was also detected at the St. Lawrence Mine in Newfoundland and the Mount Pleasant Mine in New Brunswick.

Iron

Iron is found in association with most ore mineral deposits and in combination with sulphur as iron sulphides. As a result, iron is found in most metal mining effluent.

- The reports of Working Groups 3, 4, 5, and 6 indicate that concerns were primarily limited to precipitates that form in receiving streams as a result of the oxidation of other dissolved metals.
- The Canadian Water Quality Guidelines for Freshwater Aquatic Life state that the concentration of total iron in natural receiving water should not exceed 0.3 mg/L.
- The MISA draft development document states that iron was found in 100% of the metal mine effluents sampled, with an average concentration of 0.45 mg/L.

Lead

Lead is one of the most common metallic elements mined and smelted in Canada. It most commonly occurs as the sulphide galena, either alone or in association with sulphides of zinc (sphalerite), copper (chalcopyrite), and silver (argentite). Lead can be present in mine effluent in the form of galena particulates or particulates containing sphalerite and/or chalcopyrite. It may also infrequently occur in solution as lead ion.

- The maximum MMLER authorized monthly mean concentration for total lead in effluents is 0.2 mg/L and the maximum concentration for total lead in a single "grab sample" is 0.4 mg/L.
- The Status Report on Water Pollution Control in the Canadian Metal Mining Industry (1990/91) (EPS-1/MM/4 December 1992) indicates that none of the 49 mines regulated under the MMLER exceeded the annual average lead concentration limit of 0.2 mg/L and that two of the 53 mines under the MMLEG exceeded the specified 0.2 mg/L annual average lead concentration.
- The reports of Working Groups 3, 4, 5, and 6 note that elevated levels of lead and zinc have been identified in water receiving mine/mill effluents. As well, elevated levels of copper, lead, zinc, cadmium, and nickel have been identified in receiving water sediments downstream from mines/mills that produce or recover copper, lead, zinc, or nickel, either singly or in combination, depending on the nature of the respective ore bodies.
- The Canadian Water Quality Guidelines for Freshwater Aquatic Life recommend that the concentration of total lead in natural receiving water should not exceed the levels listed below:

Hardness (mg/L as $CaCO_3$)	**Concentration of Total Lead (µg/L)**
0 - 60 (soft)	1
60 - 120 (medium)	2
120 - 180 (hard)	4
> 180 (very hard)	7

- The MISA draft development document states that lead was found in 20% of the metal mining effluents sampled. The average lead concentration in the sampled effluent was 0.02 mg/L.
- The MISA document also states that:
  - ➛ "The weathering products of galena are only sparingly soluble in water. In Ontario metal mining effluents, lead is normally found in the form of suspended solids. Soluble lead readily reacts with many common components of metal mining effluents to form precipitates."
  - ➛ "Lead is regulated in almost all metal mining jurisdictions worldwide. The common range of regulation is from 0.2 to 0.6 mg/L."
  - ➛ Although average lead levels in Ontario metal mining effluent are low, tailings areas associated with lead mining operations often contain quantities of lead that were not recovered by the milling process. As a consequence, failure of a tailings area, erosion of a tailings area,

and storm events, including high winds over a tailings area, can result in lead losses to the environment.

➢ The Ontario *Metal Mining Effluent Limits Regulation* limit for a monthly average total lead concentration is 0.2 mg/L and for a daily sample is 0.4 mg/L.

Although the MISA draft development document is silent with respect to lead removal technologies, the Kilborn Engineering best available treatment technologies for mine effluents study carried out for the MISA program identifies the current practice of pH control and settling as the best available technology economically achievable.

Mercury

Mercury is considered toxic under the *Canadian Environmental Protection Act*. It commonly occurs in solid solution with native gold and silver and less commonly as a sulphide mineral or in solid solution in major sulphide ore minerals.

- Insufficient data are available concerning mercury concentrations in mine effluents.
- The Canadian Water Quality Guidelines for Freshwater Aquatic Life state that the concentration of total mercury in natural receiving water should not exceed 0.0001 mg/L.
- The MISA draft development document states that mercury was found in 14% of the metal mine effluents sampled, with an average concentration of 0.0002 mg/L.

Molybdenum

Molybdenum occurs predominantly in porphyry copper deposits in the western provinces. It also occurs at the Cluff Lake uranium mine in Saskatchewan. Therefore, molybdenum is not a contaminant of national concern. Although it can affect drinking water quality and cause molybdenosis in cattle, it was not demonstrated to have produced clear effects on fish habitat.

Nickel

Nickel is commonly found in combination with iron and sulphur (pentlandite) and occurs in most metal mining effluent in solid or dissolved form. Several sulphide ores are host to nickel. Nickel species are soluble at a range of pHs and concentrations are high where sulphate concentrations are high.

- The maximum MMLER authorized monthly mean concentration for nickel in effluent is 0.5 mg/L and the maximum concentration for nickel in a “grab sample” is 1.0 mg/L.
- The reports of Working Groups 3, 4, 5, and 6 indicate that nickel can accumulate in fish and is known to be toxic. It is also known to cause chronic adverse effects in fish.
- The Canadian Water Quality Guidelines for Freshwater Aquatic Life state that the concentration of total nickel in natural receiving water should not exceed the levels listed below:

Hardness (mg/L as $CaCO_3$)	Concentration of Total Nickel (µg/L)
0 - 60 (soft)	25
60 - 120 (medium)	65
120 - 180 (hard)	110
> 180 (very hard)	150

- The MISA draft development document states that nickel was found in 68% of the metal mine effluents sampled, with an average concentration of 0.14 mg/L.
- The Ontario *Metal Mining Effluent Limits Regulation* limit for a monthly average total nickel concentration is 0.5 mg/L and for a daily sample is 1.0 mg/L.

Nitrogen Compounds

Ammonia (NH_3) is a ubiquitous naturally occurring inorganic compound. Ammonium nitrate (NH_4NO^{3-}) is the most significant component (60–95%) of ammonium nitrate/fuel oil (ANFO), the most common blasting agent used at Canadian metal mines. Nitroglycerine-based explosives, which contain 40% ammonium nitrate, are also used for a variety of blasting activities at metal mines. Ammonia can also be formed during cyanide destruction processes employed in the gold mining sector.

- Nitrogen compounds are not regulated by the MMLER.
- The Canadian Water Quality Guidelines for Freshwater Aquatic Life recommend following U.S. Environmental Protection Agency total ammonia concentration limits, based on pH and water temperature, as listed below:

pH	Ammonia Concentration (mg/L) at the Following Water Temperatures (°C)						
	0	5	10	15	20	25	30
6.50	2.5	2.4	2.2	2.2	1.49	1.04	0.73
6.75	2.5	2.4	2.2	2.2	1.49	1.04	0.73
7.00	2.5	2.4	2.2	2.2	1.49	1.04	0.74
7.25	2.5	2.4	2.2	2.2	1.50	1.04	0.74
7.50	2.5	2.4	2.2	2.2	1.50	1.05	0.74
7.75	2.3	2.2	2.1	2.0	1.40	0.99	0.71
8.00	1.53	1.44	1.37	1.33	0.93	0.66	0.47
8.25	0.87	0.82	0.78	0.76	0.54	0.39	0.28
8.50	0.49	0.47	0.45	0.44	0.32	0.23	0.17
8.75	0.28	0.27	0.26	0.27	0.19	0.16	0.11
9.00	0.16	0.16	0.16	0.16	0.13	0.10	0.08

The guidelines also state that:

> "The concentrations of total ammonia should not exceed those shown in the table above. Although un-ionized ammonia is the toxic component, note that the table shows the equivalent concentration of total ammonia for each combination of temperature and pH. Thus, calculation of un-ionized ammonia is unnecessary. The toxicity of un-ionized ammonia varies with pH and temperature, and the portion of total ammonia that is un-ionized also varies with pH and temperature. The total ammonia guidelines recommended in the table reflect both of these variations."

- Natural Resources Canada and several mining companies are currently engaged in a jointly funded research program directed toward developing cost-effective technologies that can be used to remove ammonia from or reduce ammonia in the low (10–50 mg/L) concentrations that can be common in high volume mine effluent.
- AQUAMIN Working Groups 3, 4, 5, and 6 report high concentrations of ammonia as a "substance of concern" in receiving waters downstream from certain mining operations in Ontario, and ammonia and nitrates in receiving waters in British Columbia.

The MISA draft development document states that:

Ammonia plus Ammonium

- "Ammonia plus ammonium" were found in all 50 (100%) of the metal mining effluents sampled.
- The average concentration of "ammonia plus ammonium" measured in the metal mining sector was 1.4 mg/L in base metal mining effluents and 6.3 mg/L in gold mining effluents. At the time of the MISA effluent monitoring program for the metal mining sector, there were two base metal mines and four gold mines with "ammonia plus ammonium" concentrations above 10 mg/L.
- In the metal mining sector, the use of ammonia for pH control or for metal precipitation has been largely discontinued. All metal mines normally use explosives. Explosives commonly in use all contain ammonium nitrate. The most common explosive in use in Ontario is ANFO, which is 95% ammonium nitrate. Water gel explosives contain 60 to 80% ammonium nitrate and nitroglycerine-based explosives contain 40% ammonium nitrate. Minor amounts of explosives are spilled during use or do not take part in an explosion. Ammonium nitrate is highly soluble in water. The geology, mining method and conditions in a mine determine the type of explosive that can be used in any particular circumstance. Safety is always a factor. Explosives containing smaller amounts of ammonium nitrate can sometimes be substituted for explosives containing higher amounts of ammonium nitrate. In many cases, however, substitution is simply not practicable or is not possible due to wet conditions underground.
- In Canada, guidelines for ammonia in metal mining effluents exist in Ontario (10 mg/L) and in British Columbia (1 mg/L for new plants and 10 mg/L for older plants). In the United States, ammonia is regulated only in the uranium sector at a level of 100 mg/L. In Spain, ammonia is regulated between 15 and 50 mg/L and in Tasmania, regulated levels of 0.5 mg/L are stated.
- Specific practicable demonstrated technology for the removal of the low levels of ammonia found in the high volume discharges that characterize the Ontario metal mining sector could not be found.
- Ammonia is not regulated in the Ontario metal mining sector effluent limits.

Total Kjeldahl Nitrogen

- "Total kjeldahl nitrogen" was found in 96% of the metal mining effluents sampled.
- The average concentration of "total kjeldahl nitrogen" measured in the metal mining sector was 8 mg/L.
- "Total kjeldahl nitrogen" is not regulated in the metal mining sector worldwide.
- Specific practicable demonstrated technology for the removal of "total kjeldahl nitrogen" from metal mining sector effluent could not be found.
- "Total kjeldahl nitrogen" is not regulated in the Ontario metal mining sector effluent limits.

Nitrate plus Nitrite

- "Nitrate plus nitrite" was found in 90% of the metal mining effluents sampled.
- The average concentration of "nitrate plus nitrite" measured in the metal mining sector was 8.8 mg/L.

- ➛ Nitrate is a major nutrient for aquatic vegetation. Because nitrates may stimulate plant growth, excessive amounts of nitrate may result in prolific growth. As a result, oxygen depletion may result and lead to fish kills.
- ➛ A concentration of 6000 mg/L is acutely toxic to rainbow trout and a concentration of 10 mg/L is toxic to rainbow trout eggs.
- ➛ A guideline for "nitrate plus nitrite" exists in British Columbia (10 mg/L for new plants; 25 mg/L for older plants). In Spain, nitrate by itself is regulated within the range of 0.5 to 1 mg/L.
- ➛ Specific practicable demonstrated technology for the removal of "nitrate plus nitrite" from metal mining sector effluent could not be found.
- ➛ "Nitrate plus nitrite" is not regulated in the Ontario metal mining sector effluent limits.

pH

The concentration of hydrogen ions is one of the most important components of aquatic ecosystems. The equilibrium between these ions is influenced by reactions with acids and bases that occur naturally or that are introduced into an ecosystem. The concentration of hydrogen ions often determines the solubility of metal species and, therefore, is linked to the toxicity of the effluent.

Acid mine drainage resulting from natural chemical oxidation of metal sulphide-bearing ore and waste generated from mining/milling and waste management processes is a frequent occurrence at mine sites. Acids and bases are widely applied in both the milling of concentrates and the treatment of effluent.

- The minimum MMLER authorized monthly mean pH of effluent is 6.0 and the minimum pH of a single "grab sample" is 5.0.
- The reports of Working Groups 3, 4, 5, and 6 state that both low and high pHs have been recognized as being potentially toxic to fish. An upper pH limit was clearly identified as an issue of concern by AQUAMIN.
- The Canadian Water Quality Guidelines for Freshwater Aquatic Life state that a pH range of 6.5 to 9.0 should be maintained to protect aquatic life.
- The Ontario *Metal Mining Effluent Limits Regulation* states that a plant must not discharge a process effluent that has a pH below 6.0 or above 9.5 at any time.

Radium-226

- The maximum MMLER authorized monthly mean concentration for radium-226 in effluent is 10 pCi/L and the maximum concentration for radium-226 in a single "grab sample" is 30 pCi/L.
- The reports of Working Groups 3, 4, 5, and 6 state that the AQUAMIN process identified radium-226 as a parameter of concern for both uranium mines and other mines that could possibly generate radioactive species (e.g., silver mines with uranium minerals). The technology exists to treat radium-226 to maintain levels within previously established limits.

Thiosalts

Thiosalts are a group of metastable oxysulphur anions formed by partial oxidation of sulphide minerals during processing. Thiosalts is the term generally used to refer to polythionates, which include dithionate, trithionate, tetrathionate, and pentathionate. Trithionate and tetrathionate are generally the dominant species formed under alkaline conditions typical of grinding and flotation processes.

- The reports of Working Groups 3, 4, 5, and 6 indicate that thiosalts have relatively low toxicity. The main environmental impact associated with thiosalts is the generation of sulphuric acid when thiosalts are oxidized in aerobic water. Thiosalts have been documented as being the indirect cause of significant impairment to the benthic community for a distance of 35 kilometres downstream of Brunswick No. 12.

Total Suspended Matter

Total suspended matter is commonly found in most metal mining effluent and usually consists of a mixture of silicates, oxides, carbonates, and sulphates. Total suspended matter can kill fish by clogging their gills, smothering fish habitat, contaminating sediments, or reducing light penetration in receiving waters.

The concentration of total suspended matter in liquid effluent has generally been recognized as a good indicator of pollution and controlling suspended matter can be a means of controlling a variety of potential contaminants, such as metal precipitates. Available technology to remove suspended matter has been widely applied by the mining industry and strong evidence exists to demonstrate that established limits can be achieved universally.

- The maximum MMLER authorized monthly mean concentration for total suspended matter in effluent is 25.0 mg/L and the maximum concentration for total suspended matter in a single “grab sample” is 50.0 mg/L.
- The reports of Working Groups 3, 4, 5, and 6 state that total suspended matter is commonly associated with metal mining contaminants that have been found in sediments of water bodies receiving mine effluent.
- The Canadian Water Quality Guidelines for Freshwater Aquatic Life state that the concentration of total suspended matter in natural receiving water should not exceed the levels listed below:

Background Total Suspended Matter (mg/L)	Increase in Total Suspended Matter
$\leq$ 100.0	10.0 mg/L
> 100.0	10% above background

- The MISA draft development document states that total suspended matter was found in 80% of the metal mine effluents sampled, with an average concentration of 7 mg/L.
- The Ontario *Metal Mining Effluent Limits Regulation* limit for a monthly average total concentration is 15.0 mg/L and for a daily sample is 30.0 mg/L.

Zinc

Zinc sulphide (sphalerite) is a common zinc mineral. Zinc sulphate, an oxidation product, is soluble in water. Therefore, zinc is usually found in most metal mining effluent.

- The maximum MMLER authorized monthly mean concentration for zinc in effluent is 0.5 mg/L and the maximum concentration for zinc in a single “grab sample” is 1.0 mg/L.
- The reports of Working Groups 3, 4, 5, and 6 indicate that zinc can accumulate in the tissue of aquatic organisms and that it is known to be toxic. Much of the noncompliance with the MMLER can be attributed to elevated zinc concentrations in liquid effluent from base metal mines.
- The Canadian Water Quality Guidelines for Freshwater Aquatic Life state that the concentration of total zinc in natural receiving water should not exceed 0.03 mg/L.
- The MISA draft development document states that zinc was found in 76% of the metal mine effluents sampled, with an average concentration of 0.07 mg/L.
- The Ontario *Metal Mining Effluent Limits Regulation* limit for a monthly average total concentration is 0.5 mg/L and for a daily sample is 1.0 mg/L.

Appendix 4: Monitoring Tools

In formulating recommendations for the design of EEM, Working Group 7 discussed a number of tools that could be used to monitor the effects of mining activity on the receiving environment. This is by no means an exhaustive list, but it does give an indication of the range of techniques available. Information in this appendix is drawn from material prepared by Working Group 7 members.

Benthic Invertebrates

Benthic invertebrates are organisms that live on the bottom of lakes, streams, or marine water bodies. They may live on or in sediment, or be attached to rocks. They are lower in the food chain than fish and frequently have shorter life cycles than fish. Furthermore, they are an important element in the food chain leading to game fish. Thus, they are an important component of fish habitat and can be used to monitor the effects of contamination on aquatic ecosystems. Populations and community structures of benthic invertebrates are often monitored because features such as the number of species present, dominant species, and population density may change in response to contamination. Several different techniques and invertebrate species may be used.

The advantages and disadvantages of using different taxonomic groups in biosurveys are well documented. Some advantages are summarized below, as well as some potential disadvantages.[40]

Macroinvertebrate communities are good indicators of localized conditions. Because many benthic macroinvertebrates have limited migration patterns or a sessile lifestyle, they are particularly well suited for assessing site-specific impacts (upstream-downstream studies). Macroinvertebrate communities integrate the effects of short-term environmental variations. Most species have a complex life cycle of approximately 1 year or more. Sensitive life stages will respond quickly to stress, but the overall community will respond more slowly. Degraded conditions can often be detected by an experienced biologist with only a cursory examination of the macroinvertebrate community. Macroinvertebrates are relatively easy to identify to lower taxonomic levels. Sampling is relatively easy, requires few people and inexpensive equipment, and has no detrimental effect on the resident biota. Benthic macroinvertebrates serve as a primary food source for many recreational and commercially important fish. Benthic macroinvertebrates are abundant in most streams. Many small streams (first and second order), which naturally support a diverse macroinvertebrate fauna, only support a limited fish fauna.

Problems associated with using some of the traditional approaches to sampling benthic invertebrates have also been described. These problems include: difficulties in finding unimpacted sites, difficulties in matching "clean" sites with contaminated sites with respect to habitat characteristics and physical and chemical attributes, and difficulties in interpreting natural variabilities in species composition and

[40] Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross and R.M. Hughs. 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. EPA/444/4-89-001.

abundance, the "ecological relevance" of results, and the financial cost. Subtle changes in communities may not be detected at an early stage. Assessing the effects of metals on stream benthic communities is also limited because of the inability to determine cause and effect relationships between the metals and the community structure; benthos respond to temperature, light, and particle size, which are confounding factors and may not be related to mine discharge.

If benthic invertebrate communities comprise only pollution-tolerant species, or if they are in a poor state of health, as evidenced by low diversities and altered abundances, efforts can be made to determine the magnitude and extent of the effects, and whether the source of the problem was disruption of the physical habitat or chemical contamination.

An alternative approach to field sampling involves the use of mesocosms. Mesocosms can be simple trough experiments, which allow for easy replication of benthic substrate exposed to mine effluent.[41] Benthic macroinvertebrate community responses (including diversity, abundance, emergence, and drift) and periphyton responses (species composition, chlorophyll *a*, etc.) can be obtained at relatively low cost. Such an approach may be a feasible alternative in locations where traditional benthos monitoring is not achievable.

Fish

Fish communities generally include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivorous). In addition to their relevance under the *Fisheries Act*, there are other advantages to using fish in environmental monitoring programs.[42] First, they are sensitive to a wide range of direct stressors. Second, fish integrate the adverse effects of complex and varied stresses on other components of the aquatic ecosystem, such as the food web, because fish are dependent upon these components for reproduction, growth, and survival; thus, the structure of the fish community is reflective of integrated environmental health. Third, fish are good indicators of long-term (several years) effects and broad habitat conditions because they are relatively long-lived and mobile, with long-lived populations showing effects such as reproductive failure and mortality through their age classes.[43] Fourth, the economic and cultural significance of fish make them useful indicators of the societal costs of environmental degradation (valued ecosystem components). In addition, fish can be at the top of the aquatic food chain and can be consumed by humans and wildlife, making them important subjects in assessing contamination.

---

[41] Limnotek Research and Development Inc. 1992. Stream Community Responses to a Gradient of Acid Mine Drainage Additions, Equity Silver Mine, Houston, B.C. Prepared for B.C. Acid Mine Drainage Task Force. 60 pp.

[42] Fausch, K.D., J. Lyons, J.R. Karr and P.L. Angermeier.1990. Fish Communities as Indicators of Environmental Degradation. *Am. Fish. Soc. Symp,*vol. 8, pp. 123-144.

[43] Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant and I.J. Schlosser. 1986. Assessing Biological Integrity in Running Waters: A Method and its Rationale. Special Publication 5. Illinois Natural History Survey.

Fish can be caught relatively easily and identified to the species level. Most specimens can be sorted and identified in the field and released unharmed. Environmental requirements of healthy fish are comparatively well known. Life history and distribution information is extensive for most recreational or commercially important species. Aquatic life uses (water quality guidelines or objectives) are typically characterized in terms of fisheries (cold water, cool water, warm water, sport, forage). Monitoring fish communities provides a direct evaluation of “fishability,” which emphasizes the importance of fish anglers and commercial fishermen.

Although large adult species, especially those consumed by humans, have obvious advantages, a major disadvantage in their use in environmental monitoring is their ability to migrate over large distances and areas. Consequently, their exposure history to industrial effluents, such as liquid effluents from mining, is frequently open to question. Fish communities respond to other stressors in addition to mine operations. Fishing measures can obviously distort community structure. Natural populations can vary cyclically and respond to a variety of environmental changes. This points to the potential advantage of using young-of-the-year and forage fish, which are not harvested and may not be as mobile as other species.[44]

The biological availability of metals to fish is also of importance. In some instances, exposure to metals through the gill membranes will be the issue of immediate concern, especially in the case of direct toxicity. In other instances, the accumulation of metals by benthic invertebrates from contaminated sediment and their subsequent assimilation by fish will the topic of interest.[45] It is not possible to generalize for all mine sites. In some cases, there may be grounds for suspecting that the mining operation influences mercury levels in fish muscle. In this case, fish may be collected to investigate mercury levels and to evaluate the risk to consumers. The issue of accumulation of metals in other tissues (gills, kidney, and liver) depends on the metal and question to be answered.

Metallothionein: Metallothioneins are low molecular weight proteins with a high binding affinity for certain metals, including arsenic, cadmium, copper, mercury, and zinc. They occur in a wide range of fish and invertebrates, and have been well studied in fish.[46] Increased synthesis of these proteins occurs following exposure to metals, and binding of the metals to proteins reduces their toxic effects. Thus, increased metallothionein concentrations in organs would indicate that the fish are acclimating to the toxicity of metals. Elevated metallothionein does not indicate impairment of fish health. However, there is considerable scientific literature to support the conclusion that metallothionein is a metal detoxification

---

[44] Gibbons, W. and K.R. Munkittrick. 1995. Suitability of Small Fish Species for Monitoring the Effects of Pulp Mill Effluents on Fish Populations. *In* Proceedings of the Second SETAC World Congress (16th Annual Meeting). November 5 to 9, 1995, Vancouver, British Columbia.

[45] Woodward, D.F., A.M. Farag, H.L. Bergman, A.J. DeLonay, E.E. Little, C.E. Smith and F.T. Barrows. 1995. Metals-contaminated Benthic Invertebrates in the Clark Fork River, Montana: Effects on Age-0 Brown Trout and Rainbow Trout. *Canadian Journal of Fisheries and Aquatic Science*, vol. 52, 1994–2004.

[46] Roesijadi, G. 1992. Metallothioneins in Metal Regulation and Toxicity in Aquatic Animals. *Aquatic Toxicology*, vol. 22, pp. 81–114.

response and that toxicity by the metal is believed to occur only after the binding capacity of metallothioneins is exceeded and metal "spillover" into the metal-sensitive enzyme pool.[47]

Metallothioneins can be measured using current analytical techniques, and their presence at elevated concentrations indicates that fish are being exposed to bioavailable metals.

Histopathology: This is the measurement of changes in subcellular, cellular, tissue, and organ structures. Histological changes can occur prior to the occurrence of external effects, so histopathology can give an early indication of the effects of contamination.[48] Histopathology of the liver, kidney, and gill can provide an indication of contaminant-induced adverse effects on the structure and function of these organs. Histological analyses of eggs shortly before spawning provide information on the reproductive competence of individual fish. Direct relationships regarding the health of fish stocks cannot be made on the basis of changes in cellular, tissue, and organ structures. However, metals can produce changes in these structures, indicating that the fish are responding at the cellular, tissue, and organ levels of organization. The effects of these changes on processes or activities that occur at higher levels of biological organization, such as growth, reproduction, predator avoidance, and population stability, can be predicted based on the results of histopathology.[49]

Other

There are a number of reference measures to describe fish communities (e.g., Index of Biological Integrity (IBI) or benthic invertebrate communities. The Index of Biological Integrity concept has been implemented and interpreted differently in many locations (Europe, North America, and Australia/New Zealand). However, the concept, which also goes under various other names, including Rapid Bioassessment - Invertebrates (RBI), Hilsenhoff's Index, Trent Biotic Index, and the Stream Walk Approach, is similar in all cases. Under this concept, an integrated assessment is made by comparing habitat and biological measures of the potentially impacted site with reference areas. Once the relationship is developed, it is possible to discriminate water quality impacts from habitat effects and control efforts focussed at the most important source of impairment.

Laboratory toxicity testing has gained wide acceptance and has become an essential component of programs interested in establishing relationships between chemical contamination and ecological

---

[47] Cockerha, L.G. and B.S. Shane. 1994. Basic Environmental Toxicology. CRC Press. Boca Raton, Florida. 627 p.

[48] Hinton, D.E., M.W. Kendall and B.B. Silver. 1973. Use of Histologic and Histochemical Assessments in the Prognosis of the Effects of Aquatic Pollutants. ASTM STP 528. Amer. Soc. Testing and Materials. pp. 194-208.

[49] Hinton, D.E. and D.J. Lauren. 1990. Integrative Histopathological Approach to Detecting Effects of Environmental Stressors on Fishes. *Am. Fish. Soc. Symp.,* vol. 8, pp. 51-66.

effects.[50] By assessing the sublethal potential of effluents in laboratory tests, the potential for environmental impact of mine effluents can be evaluated. These results can aid in the interpretation of the field monitoring components.

[50] Swartz, R.C. 1987. Marine Sediment Toxicity Tests. Contaminated Sediments — Assessment and Remediation. Washington, D.C. National Academy Press.

Appendix 5: Implementation of EEM

Cooperative Approach Option

A cooperative approach to EEM would involve individual company commitments to conduct site-specific EEM programs within a specified period of time. The approach would provide for the participation of the general public, government, and industry in a structured consultative process.

Under the cooperative approach, mining companies would “sign on” and commit to their first EEM within 2 years, possibly with some flexibility given to companies with multiple sites, if considered necessary due to resource constraints, and if agreed to by the government regulator. Site-specific programs would be developed using an EEM guideline, proven and accepted tools and methodologies, and knowledge of the site requirements. The program design would include consultation with, and approval by, the responsible government regulator. Once agreed to, the plan description and date would be filed with an EEM coordination group.

The EEM coordination group would be formed as an umbrella organization to oversee the program, to monitor the progress of the EEM, and to act as a clearing house for information. National in scope, it would include representation from affected stakeholders — government, industry, aboriginal groups, and environmental NGOs. Among other responsibilities, the directorate would maintain and improve EEM guidelines and protocols, maintain a National Registry of program abstracts and references, generate an annual report on EEM activities, and identify information/research needs. Annual reports and abstracts would be made available to the government, stakeholders, and the general public upon request. Requests for site-specific reports would be directed to individual companies. A similar body would also be required in the case of a regulated EEM program.

After a predetermined, reasonable period of time has elapsed (perhaps 3 years), a formal review would take place under the guidance of the directorate. At this point, depending on the results of the review, the program could continue as is, other approaches or modifications could be implemented, or legislation could be put in place, if necessary.

A carefully focussed EEM program should lead to the development of a responsible, cost-effective approach to addressing local and regional aquatic ecosystem concerns on a national basis. The existence and role of the EEM coordination group would encourage establishment of successful, cooperative EEM programs implemented and monitored across the country. The program as a whole would provide for an open, transparent, and consultative process that meets local and national requirements to ensure the protection of aquatic environments downstream from mining facilities and that ensures the availability of pertinent information to interested parties.

Development of the program in accordance with federal guidelines would provide a degree of national consistency in the quality and interpretation of EEM data. There would be no attempt to incorporate EEM requirements directly into federal regulations used to control mining operations. No new governmental administrative structures would be required.

Supporters of the voluntary approach believe that it would foster greater trust and cooperation. Individual mines might be more likely to develop tailored EEM programs of optimal benefit to the receiving environment, and might also be willing to adopt innovative approaches that would advance the science of EEM. Through the Whitehorse Mining Initiative, many industry stakeholders have made a commitment to responsible environmental practices, including effective EEM. Under a regulated approach, on the other hand, mine operators might simply perform the minimum requirements and no more.

The concern frequently expressed about a cooperative approach is that individual companies may, or may not, subscribe to the principle of EEM. The reluctance to implement EEM might be most acute in the more problematic cases where the need to document ecological effects is greatest. In a world market that increasingly values sound environmental performance, the resultant shortcomings might not only interfere with timely mitigation but would also reflect badly on the Canadian industry and damage public trust.

Both consistency of standards and the avoidance of duplication of effort are important considerations. Regardless of whether EEM is implemented through guidelines or regulations, attainment of these objectives will require cooperation between federal and provincial authorities. Provinces can and sometimes do demand site-specific EEM as a requirement of operational approvals. The voluntary approach leaves discretionary control at the local level, in the hands of mining companies and provinces. Although some view this as desirable in that it allows maximum flexibility, others predict that such a system will result in continuation of the current pattern of variable, and sometimes inadequate, implementation standards. This would compromise the objective of having a reasonable minimum standard in place across the country.

Regulatory Approach Option

A regulatory approach could involve amending the MMLER (pursuant to Section 37(1) of the *Fisheries Act*) to include a requirement for an EEM program at all mine sites. Mandatory EEM would provide a degree of certainty for the public, consultants, industry, and governments. Defined standards lead to understood expectations for the generation, review, and use of data. This would help foster standardization and integration of various monitoring and assessment programs, from initial environmental assessment through to closure.

It can safely be assumed that a minimum standard (whether a guideline or a regulation) cannot be perfectly adequate for every receiving environment throughout our diverse country. However, if companies do not voluntarily tailor their programs in light of local sensitivities, provincial regulators have the option of writing more stringent EEM requirements into operating permits.

Federal regulation simply ensures that no site-specific plan can be less rigorous or accountable than a reasonable minimum requirement.

Resistance to a regulated approach to EEM stems partly from the concern that such an approach could be too rigid and inappropriate for specific problems posed by individual mine sites. Universal standards, if too prescriptive, could also limit the scope for initiative on the part of individual companies.

Because of these legitimate concerns, it has been agreed and is strongly recommended that any federally regulated EEM requirement be designed to encourage focussed, cost-effective, site-specific program development and include feedback loops that promote innovation by industry and continuous improvement by regulators.

In this regard, industry would view the regulatory approach as follows: “In a **regulatory** approach (i.e., EEM requirements under the MMLER), there should simply be a requirement in the regulation for the proponent to prepare and conduct EEM programs as directed by a government regulator (the department/agency/ministry responsible for issuing permits or approvals for effluent discharge and waste management). Because it is expected that the local government regulator would administer the EEM program, agreements would be required with the provinces and territories for administration of the regulation to avoid duplication of effort. No prescriptive detail would be outlined in the regulation; proponents would rely on an EEM guideline document that establishes goals and objectives, and specifies that the design of the site-specific programs should be based on proven and accepted methods.”

Another concern regarding regulated requirements is that depending on the history of the site, prospects for future development, and other sources of ecological disturbance, individual companies may perceive that they are bearing disproportionate responsibilities for EEM. A commitment to careful program development, including adequate reference sites, should allay these concerns.