Jacques Whitford AXYS

Environmental
Engineering
Scientific
Management
Consultants

4370 Dominion Street
5th Floor
Burnaby BC
Canada V5G 4L7

Bus 604 436 3014
Fax 604 436 3752

www.jacqueswhitford.com
www.axys.net

Review of the Diavik and EKATI Diamond Mines

ADAPTIVE MANAGEMENT PLANS

FINAL REPORT

Prepared for:
Environmental Monitoring Advisory Board
Independent Environmental Monitoring Agency
Yellowknife, NWT

Prepared by:
Jacques Whitford AXYS Ltd.
Yellowknife, NT

June 2008

PROJECT NO. 1037316.

Jacques
Whitford
AXYS

PROJECT NO.	**1037316.**
REPORT TO	**Environmental Monitoring Advisory Board** Yellowknife, NWT Attention: Mr. John McCullum, Executive Director
FOR	**Final Report**
ON	**Review of the Diavik and EKATI Diamond Mines' Adaptive Management Plans**

May 27, 2008

Jacques Whitford AXYS Ltd.
5103-51st Avenue (P.O. Box1680)
Yellowknife, Northwest Territories
X1A 2P3

Phone: 867.920.2216
Fax: 867.920.2278

Executive Summary

The Environmental Monitoring Advisory Board (EMAB) and the Independent Environmental Monitoring Agency (IEMA) have requested assistance from Jacques Whitford AXYS Ltd. (JWA) in the review of the Diavik and EKATI Diamond Mines' Adaptive Management Plans, respectively. These plans have been submitted to the Wek'èezhìi Land and Water Board as a condition of each company's Water Licence.

JWA was tasked to present a framework and elements of an effective adaptive management plan, assess the Diavik and EKATI mines Adaptive Management Plans against the framework, present initial reviews, facilitate a workshop May 14-15, 2008 to discuss adaptive management and the mines' Adaptive Management Plans, and provide final reviews of the Adaptive Management Plans.

Given the uncertainty associated with initial predictions about mine operations identified in the environmental assessment process, with effectiveness of some of the mitigations incorporated in the mine operation, and with natural variability or change in the environment unrelated to mine operations, a mine needs to have an adaptable flexible management plan that can identify whether there are negative effects (beyond those predicted as acceptable) and an ability to adjust operations to reverse the negative trends in a timely manner.

The Adaptive Management Plans for the Diavik and EKATI mines were evaluated from three perspectives:

- Does it meet the directive provided by the WLWB?
- Does it follow the framework for adaptive management as described in current literature?
- Does it provide good links between monitoring results and management options?

Both plans appear to address the WLWB directives to provide adaptive management plans. For Diavik, this was to prepare a plan that describes "how data from the AEMP will be used to identify the need for additional mitigation strategies to minimize the impacts of the project on the aquatic environment." For EKATI, the directive was to provide "a management plan that describes a way of managing risks associated with uncertainty and provides a flexible framework for the mitigation measures to be implemented."

However, both plans did not follow the accepted framework for adaptive management, which is a rigorous approach to investigate uncertainty in management options by treating the management itself as an experiment. Within the cyclical framework of "assess, design, implement, monitor, evaluate, adjust", the plans do not contain all the elements of adaptive management. They are not set up with a clearly described experiment for management of the mine or for specific activities. They both appear to start with a hypothesis that the current management plans are optimal for protection of the aquatic environment, and that results of the ongoing aquatic effects monitoring programs will be used to identify whether the hypothesis is true. The plans also do not provide sufficient detail to evaluate the effectiveness of available or potential management options. In part, this is because any new mitigations will emerge from the specific issues identified in monitoring. However, more information about effectiveness of options or ongoing research will help the interested parties (stakeholders, i.e., governments, regulators, communities, advisors) have confidence that there are options that can be put in place in a timely manner. Importantly, neither plan identifies how stakeholders are or can be involved, for example at the problem assessment, evaluation and adjustment stages.

Both the Diavik and EKATI plans have well developed scientific frameworks and show how the results of the aquatic effects monitoring programs would be used to determine management actions. However, the management considerations are not as well developed as the scientific aspects. The plans identify triggers or thresholds for action, but many of the identified actions simply call for intensified study or

monitoring. Also, the timelines for action are not clearly identified and there is concern that there may be too much time between identification of a negative effect and implementation of a new mitigation. As noted above, both plans lack clear processes for stakeholder involvement. This is a critical point. The value placed on environmental resources is a societal judgement, and stakeholders need to be involved in evaluating the importance and implication of monitoring results, and in making decisions on management options.

Given that the mines did not prepare adaptive management plans in the defined sense of experimental management, it is relevant to discuss whether these should even be adaptive management plans or whether it is more suitable for the Wek'èezhìi Land and Water Board to require "adaptable" management plans. No examples of adaptive management plans for aquatic effects of mine operations have been identified. Metals mines subject to Metal Mining Effluent Regulations typically do not prepare adaptive management plans.

Table of Contents

List of Tables

List of Figures

List of Acronyms

AdM	Adaptive Management
AdMP	Adaptive Management Plan
AEMP	Aquatic Effects Monitoring Program
CCME	Canadian Council of Ministers of Environment
EMAB	Environmental Monitoring Advisory Board
IEMA	Independent Environmental Monitoring Agency
WLWB	Wek'èezhìi Land and Water Board

1 Introduction

The Environmental Monitoring Advisory Board (EMAB) and the Independent Environmental Monitoring Agency (IEMA) requested assistance from Jacques Whitford AXYS Ltd. (JWA) in the review of the Adaptive Management Plans (AdMP) for the Diavik and EKATI diamond mines, respectively. Diavik Diamond Mines Inc. prepared the *Diavik Diamond Mine Adaptive Management Plan for Aquatic Effects* (Diavik Diamond Mines Inc. (Diavik 2007) and BHP Billiton prepared the *EKATI Diamond Mine Watershed Adaptive Management Plan* (Rescan 2008). These plans were submitted to the Wek'èezhìi Land and Water Board (WLWB) as a condition of each company's Water Licence. This final report of JWA incorporates feedback from the initial report submitted April 28 and the May 14-15, 2008 workshop with the monitoring boards, stakeholders and consultants.

From its work order, the primary tasks of JWA are to:

1. Present a framework and/or elements of an effective AdMP
2. Assess each AdMP against the Framework (a detailed assessment of the specific contents such as validity of threshold levels selected is not expected, rather the review is to address overall adequacy in relation to the ideal framework)
3. Present initial reviews and facilitate workshop discussions of the objectives and elements of adaptive management and of the mines' Adaptive Management Plans.
4. Submit final reviews of the Diavik and EKATI Adaptive Management Plans.

In addition to providing a general overview of adaptive management, this review evaluates the mines' Adaptive Management Plans from three perspectives:

- Do the AdMPs meet the directives provided by the WLWB?
- Do the plans follow the framework for adaptive management as described in current literature?
- If not AdMP, do they provide good links between monitoring results and management options if changes to mitigation measures and water management are indicated?

The report is organized into seven sections: (Section 1) introduction; (Section 2) a general discussion of adaptive management and environmental planning and monitoring at mines; (Section 3) a review of the Diavik AdMP; (Section 4) a review of the EKATI AdMP; (Section 5), closure; and (Section 6) literature cited.

1.1 Overview

The Diavik and EKATI Diamond Mines, like any large projects, have potential for significant effects on the environment. Many negative effects can be predicted in advance, and the mines include mitigation measures to reduce the size of such effects. However, even with the best design and the best knowledge available, there is often uncertainty about how well the mitigations will work and whether there will be a negative effect on the environment.

To deal with such uncertainty, mine management needs a system to identify whether there are negative effects (using triggers, thresholds or other tools to identify the changes) and an ability to adjust operations to reverse the negative trends. There can be challenges for scientists conducting environmental monitoring programs in distinguishing real change from natural variability, and identifying implications of the change. There can also be challenges for mine managers in identifying options to change the operations in a timely manner. Communication with and involvement of stakeholders (regulators, governments, review boards, and affected communities) about the monitoring results and any proposed alterations to mine management is vital.

There are several tools government agencies, review boards, and mine operators can use to minimize negative effects on the aquatic environment. Good management includes the following elements:

- clearly defined management objectives for operating conditions (e.g., effluent quality standards) described in the mine permits
- design features and operating procedures incorporated to minimize negative effects
- monitoring programs to assess environmental conditions, effectiveness of mitigations, and compliance with permits during operation
- clearly defined triggers for management response and
- workable options for adjusting the operations to reverse any negative trends.

One of the tools required of the Diavik and EKATI mines is Adaptive Management Plans for the aquatic environment. The WLWB (2007 directive) requested Diavik to develop an AdMP that "should describe, in sufficient detail, how data in the AEMP will be used to identify the need for additional mitigation strategies to minimize the impacts of the project on the aquatic environment." Diavik responded with the 2007 *Diavik Diamond Mine Adaptive Management Plan for Aquatic Effects* (Diavik Diamond Mines Inc. 2007). Similarly, the WLWB requested an AdMP for the EKATI mine which responded with the 2008 *EKATI Diamond Mine Watershed Adaptive Management Plan* (BHP Billiton Diamonds Inc. 2008).

2 Adaptive Management – a learning process

2.1 Defining Adaptive Management

The term "adaptive management" was developed in the 1970's by C.S. Holling and C. Walters to describe a rigorous approach for learning by deliberately designing and applying management actions as experiments. Uncertainty about the most appropriate management options to use is addressed by treating the management itself as an experiment. Over the years, the term has been used loosely to describe plans that adapt management strategies to the results of environmental monitoring programs. This can lead to confusion, with proponents making commitments in environmental assessments to prepare AdMPs, or with regulators requiring AdMPs to be developed, when what was meant may be more correctly termed "adaptable management".

To supplement the available literature on adaptive management and provide greater direction, Fisheries and Oceans Canada tasked ESSA Technologies to develop a guide for preparation of AdMPs (Greig, Marmorek and Murray 2008). This guide (which summarizes the principles and elements of adaptive management, its uses and limitations), was not available when the Diavik and EKATI AdMPs were developed. This review drew upon the summary of the adaptive management process prepared for Fisheries and Oceans Canada and also a second summary prepared for the U.S. Department of the Interior (Williams *et. al* 2007). The discussion below presents the commonly accepted view of the framework and the six elements of the adaptive management process

The adaptive management approach involves:

- clearly defined management objectives to guide decision-making
- exploring alternative ways to meet management objectives
- predicting the outcomes of alternatives based on the current state of knowledge
- implementing one or more of these alternatives
- monitoring to learn about the impacts of management actions
- using the results to update knowledge and adjust management actions

The adaptive management process provides a systematic means for maximizing learning and making adjustments that improve project implementation and management of overall project effects. The process has six steps, which are repeated over time as needed: (1) Assessment, (2) Design, (3) Implementation, (4) Monitoring, (5) Evaluation, and (6) Adjustments/revisions. Monitoring of effects is a critical element as it provides information for the second cycle of assessment, leading to adjustments in project design and implementation.

The adaptive management process needs to involve all stakeholders, not just the technical experts, and the commitment of the management team to carry out the plan. This ensures that social or value-based judgements about what is negative, positive, or inconsequential, and what are tolerable levels of risk are incorporated in the objectives and considered when evaluating project effects and making adjustments to the management plans.

Both adaptive management and other management approaches deal with the uncertainty, permit conditions, mitigations, monitoring, triggers, options for changing operations, and social decisions. However, adaptive management differs in that it acknowledges the uncertainty by treating the management itself as an experiment. An adaptive management approach is not appropriate or possible when an activity is likely to result in irreversible consequences, or where there are no viable options for changes to management.

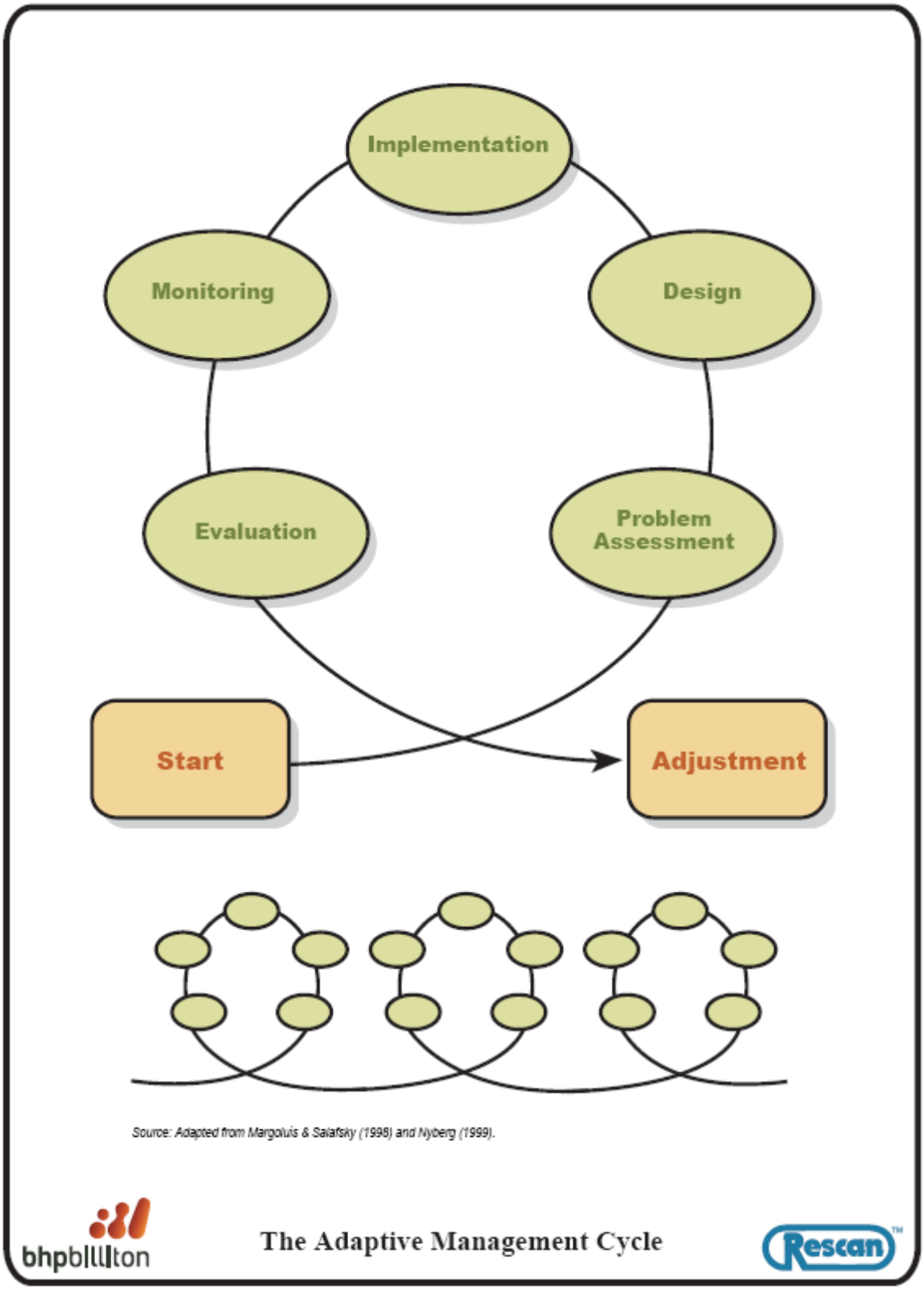
2.2 Framework and Elements of Adaptive Management

Table 1 describes the six stages or steps in adaptive management and the criteria used to evaluate the Diavik and EKATI mines' AdMPs. The cyclical nature of adaptive management is shown in Figure 1, which is reproduced from a diagram in the EKATI plan.

Table 1: Stages/Elements of Adaptive Management

Stages/Elements of Adaptive Management	
1. Assess	Engage Stakeholders Assess existing knowledge Identify management goals Identify uncertainties
2. Design	Develop models/hypotheses Determine management action(s) to be applied Define measurable indicators Develop monitoring and data analysis plan
3. Implement	Implement Plan
4. Monitor	Monitor results
5. Evaluate	Compare results against model prediction
6. Adjust	Adjust model/hypothesis and management plan Adjust management implementation

Figure 1: The Adaptive Management Cycle



1. Assess

The first element is taking stock of the available knowledge and data to identify potential project impacts, positive and negative, and areas of uncertainty. This information is used to develop clear, measurable, and agreed-upon management objectives to guide decision-making and evaluate how effective the management is over time. The objectives also need to allow for suitable timeframes for action, to allow adjustments to be made before adverse effects can occur. An adaptive management approach is not appropriate or possible when an activity is likely to result in irreversible consequences.

Objectives need to incorporate the social and economic interests of stakeholders. Engagement of stakeholders from the beginning and throughout is, therefore, essential to inform and guide the adaptive management process.

The assessment stage should result in a clear understanding of current knowledge and the identification of objectives and issues that the management plan is to address.

2. Design

The experimental design for the adaptive management plan is developed. Scenarios or models are created that incorporate different ideas and uncertainties about how the natural system functions and ideas or hypotheses about what will happen as a result of alternative management actions. Management alternatives are then designed to test the identified uncertainties. These are tested in subsequent stages, to provide information about which management actions will be most suitable. A key component to the design stage is the establishment of measureable indicators and a sound monitoring plan.

Adaptive management can be either “active” or “passive”. Either approach uses the same six steps. With active management, alternative management actions with explicitly different predicted outcomes are tested simultaneously as different treatments in an experiment and the results are compared. With passive adaptive management, there is one management alternative that is believed to be the best, and actual results are tested against the predicted results. Passive management does not provide as robust an experimental design and the learning is slower as one alternative is tested at a time. However, active management is not an option when the testing of different alternative management actions is too costly or not feasible, or the resource being managed is so vulnerable that only the best judged practice should be applied.

3. Implement

Implementation is a straightforward element in adaptive management; however, its success depends on the commitment of the required resources (staff, equipment, etc.) to conduct the plan as designed. In an active approach, the various alternatives are tested at the same time, whereas in a passive approach, a single option is tested. For either active or passive approaches, the response time for adjusting management practices that is build into the cycle should be relevant to the anticipated severity and reversibility of any detected effects.

4. Monitor

Monitoring programs are designed to provide data on the status of the natural resources of interest, the success in meeting management objectives, and the different effects among the alternative management actions tested. The success of the subsequent evaluation and adjustment stages depends on the quality of the monitoring data and the timeliness with which they are provided. The AdMP monitoring programs for Diavik and EKATI use the existing aquatic monitoring programs; these need to ensure there are adequate baseline data for comparison of trends over time, an appropriate design for measuring effects, studies of effectiveness of mitigation measures, compliance monitoring for all regulated parameters, and evaluation of actual versus predicted effects.

5. Evaluate

Evaluation is the learning stage of adaptive management. Monitoring results are compared against management objectives and the predicted results for each of the tested alternative management actions. The evaluation process needs to involve all stakeholders, for the significance of the results will vary depending on the value placed on the resources, differences in the level of risk that is tolerable, and other subjective issues.

6. Adjust

Based on findings of the evaluation, hypotheses, models, and management actions can be revisited and adjusted. This may include adjustments to water treatment, materials handing or other processes. Stakeholder understanding of the adjustments to management is important.

2.3 Limitations of Adaptive Management

Adaptive Management is not appropriate or possible in all cases. If management decisions cannot be revisited and adjusted, or if there are no alternatives, then adaptive management is not possible. A one-time decision such as whether or not to dam a river, fill in a lake, or clear cut a forest are examples of irreversible effects. Adaptive management is also not possible if reliable monitoring information cannot be obtained within a timeframe that allows adjustments to be made before irreversible or unacceptable changes to the resources occurs. Adaptive management is also not possible if an understanding of the resource system is so poor that reasonable models and hypotheses cannot be designed. This can be the case when there are too many factors to be considered and their relationship is too poorly understood to allow for meaningful experimentation.

2.4 Adaptive Management and the Diavik and EKATI Plans

The Diavik and EKATI AdMPs both describe the aquatic effects monitoring programs, triggers or thresholds for management action and, in a general way, options for management. While they contain many of the elements of adaptive management described in Section 2.2, they are not AdMPs as defined in the literature or by Greig *et al.* 2008. There are two key areas in both plans where links with adaptive management are not clear:

- in the design step, the hypothesis about the management experiment is not stated (the plans appear to be “passive” approaches for the entire operation, based on a hypothesis that the current management plans are optimal for protection of the aquatic environment) and
- in the adjust step, there is not enough information to evaluate whether there will be management options that would be successful in addressing any significant negative effects identified in the monitoring programs (enough detail to allow the WLWB and monitoring boards to have confidence that any negative effects can be addressed).

Also, the role and extent of stakeholder involvement are not described; there may be technical considerations about appropriateness of the thresholds or triggers for action and about whether to include triggers for aquatic organisms in the EKATI plan; and timeliness of management responses is difficult to evaluate.

The reviews provided by JWA in Sections 3 and 4 for the individual mines, as well as those provided at the May 15 workshop by JWA, ESSA Technologies (for Fisheries and Oceans Canada), Zajdlik Associates (for Indian and Northern Affairs Canada) and MacDonald Environmental Services (for the Tlicho Government) all concluded that the Diavik and EKATI AdMPs do not fit the framework of adaptive management. The reviewers concluded that the plans do not include the “experimental management” element inherent in adaptive management.

A brief search of literature and the internet for AdMPs for mines, and canvassing of scientists and some operating metal mines did not yield examples of AdMPs for aquatic effects. However, the Environmental Effects Monitoring (EEM) programs required under the Metal Mine Effluent Regulations for metal mines

(Environment Canada 2002) do include cycles of investigation similar to those identified in the Diavik and EKATI plans. However, the EEM programs do not apply to diamond mines at this time.

The formal stages of metal mine EEM include several years of study (each stage taking two to three years):

- Initial Monitoring (to identify whether there is an effect)
- Periodic Monitoring (to confirm if there is an effect and whether it is mine related)
- Focussed Monitoring (to identify magnitude and geographic extent of the effect)
- Investigation of Cause (within the mine)
- Additional studies outside of EEM, including research and studies into potential corrective actions

2.5 Links between Environmental Assessment, Environmental Monitoring and Management Plans

From the initial concept for a mine to full operation, there are several steps and processes in place to manage the potential for negative effects on the aquatic environment. There are permits, monitoring requirements, and ongoing regulatory and stakeholder review. The planning phase includes an environmental assessment, which includes predictions about potential effects that could occur and commitments to environmental management to mitigate effects. The construction, operation and closure phases include environmental monitoring programs to evaluate whether there are predicted or unexpected adverse effects on the environment. It makes sense that if the monitoring results indicate conditions are worse than predicted, the company changes their management plan and adopts new mitigation strategies in a timely manner. This latter aspect is the core function of the AdMPs reviewed here.

The following sections describe the environmental assessment, monitoring and management processes as a context for the discussion of the AdMPs.

2.5.1 The Environmental Assessment

The Environmental Assessment is a planning document that:

- describes baseline conditions
- identifies potential effects of the project on the environment
- describes mitigation measures to reduce the potential for adverse effects
- assesses the residual (or remaining) effects on the environment
- determines whether these residual effects will be significant
- considers whether there will be any cumulative effects or interactions with other projects in the area
- includes commitments by the proponent to certain environmental and other management plans, monitoring programs and other requirements associated with a water license and other permits

Since the environmental assessment is a planning document, it needs to be “ground truthed” when operations begin. There can be uncertainty about the effects that can occur, how effective certain mitigation measures will be, or how much better or worse than predicted water quality may be. High natural variability or global processes such as climate change may influence the outcomes.

2.5.2 The Environmental Monitoring Programs

Typically, the mine is built as described in the Project Description, using environmental management plans committed to in the Environmental Assessment, although there may be changes to incorporate newer technology. The mine develops environmental monitoring plans (e.g., Aquatic Effects Monitoring Programs for Diavik and EKATI) and conducts monitoring to evaluate how well its operations meet standards to protect the environment. These plans need to include a statistically and ecologically sound

approach to answering the question "Does the mine have an effect on the environment?" The science of Environmental Effects Monitoring is well developed in Canada, based on requirements of Environment Canada for metal mines (not diamond or coal mines) and pulp mills. Considerable effort is spent conducting these programs, which include both physico-chemical (water and sediment) and biological (fish, plankton, benthic organisms) components.

There may also be monitoring programs to assess effectiveness of mitigation measures and compliance for regulated parameters. Ultimately, monitoring should be used to evaluate whether the observed effects are similar to those predicted in the Environmental Assessment and lead to operational changes if negative effects are greater than predicted. Federal or territorial governments may have additional monitoring requirements.

There is a degree of uncertainty about monitoring results, due to natural variability and statistical considerations. An experiment (or monitoring program) is set up to test a hypothesis or idea, for example, "there is no effect of mine discharges on the aquatic environment and all the current mitigation strategies are working as designed." Statistical experts have shown that even the best-designed studies have a chance of error. There is a possibility that monitoring will incorrectly detect a change in the environment (false negative) or incorrectly detect no change (false positive). The probability of such errors can be reduced by putting additional efforts into the monitoring program.

There are implications to either type of error. A false negative error can be considered as, "you think you have a problem but you don't." In this case, a mine would invest in additional infrastructure and new mitigations that don't make a difference in environmental conditions. A false positive error can be considered as, "you don't think you have a problem, but you do." In this case, a mine would continue operating according to current plans and standards, but because ongoing changes in the aquatic environment are not recognized, the adverse effects can get bigger.

Study designs for monitoring programs use both ecological and statistical tools to define how much effort goes into determining if there are significant effects on the environment. The challenges include:

- distinguishing natural variability from any effects resulting from mine operations
- deciding how many samples should be collected, how often, and at how many sites (with fish, for example, it is important to not over-sample so that natural populations decline due to the monitoring program)
- defining what thresholds or guidelines should be used to recognize an effect (approaches such as weight-of-evidence are useful in dealing with the many interrelated studies and data from the monitoring programs)
- understanding the ecological implications of potential effects (tools such as weight-of-evidence and risk assessment can be useful in understanding how organisms can be affected, and to what extent)

2.5.3 The Management Plan

The management plan should make sure results of the monitoring programs are incorporated into ongoing management of the mine, to respond to any negative changes identified by monitoring. The plan also allows the mine operator to restate or refine any commitments for environmental management.

The key questions to consider in evaluating the management plan include:

- Are there clear management objectives – are the values to be protected defined and does the plan describe how to identify whether the current strategy is or is not working as predicted?
- Are there clear triggers for management action and is there a way of determining if the effects are related to mining operations and not to some other cause?
- Are there realistic management options to address identified problems and can they be implemented in a suitable timeframe, to limit the extent of any negative effects?

The management plan should integrate the existing monitoring programs into an overall framework for decision-making. Although the management plan may deal with uncertainty and the possibility of errors (false positives, false negatives) by including additional studies to verify trends, assess ecological risks and identify potential causes within the mine, it is important to distinguish these studies from the management actions themselves (i.e., changes in operations). The time required for additional study should fit into an appropriate timeline for implementing the solutions to avoid irreversible damage.

As discussed in Section 2.3, the Diavik and EKATI AdMPs are not adaptive management in the formal sense. However, the mines may be able to include experimental management approaches on a smaller scale (i.e., as an outcome of the monitoring, to evaluate specific mitigation options), rather than for management of the entire mine, as is currently presented.

3 Evaluation of the Diavik Diamond Mine Adaptive Management Plan for Aquatic Effects

Diavik submitted the *Diavik Diamond Mine Adaptive Management Plan for Aquatic Effects* to the WLWB in August 2007. This was in response to a WLWB directive to prepare an AdMP for the Aquatic Effects Monitoring Program (AEMP) that describes "how data from the AEMP will be used to identify the need for additional mitigation strategies to minimize the impacts of the project on the aquatic environment."

The Diavik property is located on East Island in Lac de Gras, NWT and has operated under the terms and conditions of a Class A Water License since 2000. An AEMP is conducted annually to "determine the short and long-term effects on the aquatic environment resulting from the project, test impact predictions, measure the performance of operations and evaluate the effectiveness of impact mitigation" (Part K (6) of Water License). There are five monitoring programs within the AEMP: effluent, dust and snow, seepage and runoff, special effects studies (e.g., dikes) and traditional knowledge monitoring activities.

3.1 Review of Diavik Adaptive Management Plan

The evaluation of the Diavik plan in terms of the formal elements of an adaptive management plan is summarized in Table 2 and discussed below.

Table 2: Summary of Review of Diavik Mine Aquatic Effects Adaptive Management Plan

Stages/Elements of Adaptive Management	Diavik Diamond Mine Aquatic Effects Adaptive Management Plan
1. Assess	
• Engage Stakeholders	? Amount and effectiveness of engagement is unclear (e.g., meetings, workshops, opportunities to comment on draft reports, inclusion of stakeholder comments in the Plan) Environmental Monitoring Advisory Board and Wek'èezhìi Land and Water Board
• Assess existing knowledge	✓ Aquatic Effects Monitoring Program considers baseline data and describes monitoring programs to detect change (effects sizes, study design) ? use of traditional knowledge
• Identify management goals	✓ Water License provides Environmental Quality Criteria (EQC) for discharges (end of pipe), reporting commitments
• Identify uncertainties	✓ Aquatic Effects Monitoring Program (AEMP)

Stages/Elements of Adaptive Management	Diavik Diamond Mine Aquatic Effects Adaptive Management Plan
2. Design	
• Models/hypotheses	? Some are described in Section 2 of AdMP, but they are related more to the AEMP than to adaptive management. The main hypothesis of the AdMP is not explicitly stated, making it difficult to evaluate this aspect. There appears to be a passive approach, with a hypothesis that the existing environmental management is adequate to protect the aquatic environment
• Management action(s) to be applied	? Assume this is to follow current standard operating procedures (e.g., are these described in environmental management plans?)
• Measurable indicators	✓ Described in Section 3 of AdMP for water quality and biota
• Monitoring and data analysis plan	✓ Described in Sections 2 and 3 of AdMP
3. Implement	
• Implement Plan	✓ Annual commitment to AEMP and AdMP
4. **Monitor**	
• Monitor Results	✓ Annual commitment to AEMP and AdMP
5. Evaluate	
• Compare results against model prediction	✓ Method described in Section 3 of AdMP
• Include stakeholders in the evaluation	? not described
6. **Adjust**	
• Adjust model/hypothesis and management plan	? Some management strategy options are described in Section 4 of AdMP, but details about how effective they are likely to be are not provided. For example, there should be sufficient detail to allow a reviewer to evaluate whether there are technological options available and to have confidence that proposed strategies would work (i.e., a discussion of successful use elsewhere, ongoing research at the mine to assess possibilities for emerging trends).
• Include stakeholders in the discussion of options	? not described
• Adjust Management implementation	? Implicit in the AdMP, but success would be linked to the availability of realistic management options

Diavik's Adaptive Management Plan includes the four components below.

1. **Strong links to the AEMP**, so that results of the AEMP are evaluated in terms of their effectiveness in meeting the management objectives (standards, guidelines or other clear indicators):
   - The AEMP includes water and sediment chemistry, and lake communities (phytoplankton, zooplankton, benthic invertebrates) of Lac de Gras.

- The AEMP includes a commonly accepted scientific and statistical framework to identify whether there is an effect – this includes sampling effort, frequency, investigation of cause, distinguishing of sites in the "near field", "mid field" and "far field".
- A "weight of evidence" approach is used to evaluate the various lines of evidence about environmental conditions and considers both statistical and environmental relevance of the findings.

2. **Environmental management practices** at the mine and potential sources of effects to Lac de Gras, discussed in Section 2 of the AdMP:
   - A perimeter collection system around the island collects and contains mine source waters prior to treatment.
   - A water treatment plant treats water from various mine sources (including country rock piles, pit and plant site and processed kimberlite containment area) prior to discharge to Lac de Gras. This is the main discharge to the lake.
   - Environmental protection practices are described for water, dust, waste and hazardous materials.
   - Potential issues identified include nutrient enrichment (nitrate and ammonia from blast residues), increased suspended sediment levels, introduction of metals from leaching of country rock used in the dike or in mine effluent, fish mortality, alteration of fish habitat, or changes in fish tissue.

   The Environmental Assessment and the AEMP consider what effect the proposed mine will have on water quality, water supply and fish. A complex system of pathways and linkage charts describes potential project-environment interactions. Significance of the potential effects were assessed and classified (Level I, Level II, Level III, depending on spatial extent and other characteristics).

3. **Identifiable triggers or drivers** for decisions and actions within the AEMP that would lead to changes in environmental management, described in Table 1-1 and Section 3 of the Adaptive Management Plan:
   - Defined early warning, moderate or high effects levels
   - A process to follow when an effect level is exceeded—the cause is evaluated and, if found to be caused by mine operations, Intensive Monitoring occurs
   - Intensive monitoring, which will be conducted to better define the nature, magnitude and extent of the effect, and can also include additional sampling to link environmental implications of the change (i.e., implications of a change in a water quality parameter would be assessed in terms of the biological community that could be affected)
   - An ecological risk assessment, which will be conducted in the event of a moderate or high level effect or of an early warning effect that is mine-related, with information used for adaptive management (Ecological risk assessment considers whether lake organisms are being exposed to contaminants or habitat alteration. Indicators of nutrient enrichment (eutrophication) in the lake will be examined using a weight of evidence approach to integrate the various indicators.)
   - Changes to environmental management lead to additional monitoring

4. **Actions** to be taken if an effect is recognized, discussed in Section 4 of the AdMP. These include:
   - Assessing the need for additional mitigation strategies
   - Identifying the source of the effect (e.g., one or more constituents of the effluent, a compound leaching through the dike, dust fall)
   - Implementing mitigation strategies (only discussed generally; although the AdMP states Diavik has studied several mitigations and will be able to use the results in a timely review of options)
   - Analyzing benefits versus costs and impacts for moderate and high level effects

3.2 Conclusions and Recommendations for Diavik Plan

Diavik's AdMP was evaluated from three perspectives:

- Does it meet the directive provided by the WLWB?
- Does it follow the framework for adaptive management as described in current literature?
- Does it provide good links between monitoring results and management options?

Diavik's AdMP appears to address the WLWB directive to provide a plan that describes, "how data from the AEMP will be used to identify the need for additional mitigation strategies to minimize the impacts of the project on the aquatic environment." However, it is not an AdMP in the defined sense, as it does not identify the management experiment and does not contain all the elements of AdMP (sufficient stakeholder involvement, clear hypothesis to test, description of viable management options). The lack of clarity about stakeholder involvement and description of viable management options are relevant to the Plan's ability to provide good links between monitoring results and decisions about management options.

Management considerations are not as well developed as scientific considerations. Table 3 contains observations and recommendations EMAB may wish to consider regarding revision of the Diavik AdMP. Several similar observations and recommendations were made about the EKATI mine.

Table 3: Observations and Recommendations for the Diavik Adaptive Management Plan

Observation	Recommendation
The role and involvement of stakeholders (governments, affected communities, EMAB, etc.) with respect to the plan is not discussed.	1. Identify opportunities for stakeholder involvement, for example: • in defining / refining the management goals • direct involvement in some monitoring programs (e.g., fish palatability) • reviewing and evaluating the results of monitoring programs • considering adjustments to management options. In addition to promoting good communication, this involvement will allow exchange of information, and will likely identify additional or new ways in which traditional knowledge can be incorporated.
Some possible management strategies are discussed, but not in detail.	2. Provide additional details about potential management strategies and a short discussion about their effectiveness in other situations or about ongoing studies at Diavik, as this will allow EMAB and WLWB to have more confidence in their potential success. • Examples discussed briefly in the AdMP are source control of specific contaminants through material substitution or management, increased recycling and reuse, reduction in source loading, water treatment, or changes to performance or location of the diffuser. • The AdMP mentions that Diavik has conducted studies into possible additional mitigations, which should be helpful in timely decision-making; however, details are not provided.
Timeliness of response may be an issue, and there is concern that negative effects may become more	3. Clarify the anticipated timelines for identifying an effect (trigger) and making adjustments to the mine operations: • There may be a long lag between identifying low level (early warning), moderate level and high level effects, then conducting an

Observation	Recommendation
pronounced if there is a long lag time before implementation.	environmental risk characterization, followed by looking into cause and determining new mitigation strategies, and then conducting a cost/benefit analysis before making changes to operations.
There are concerns that the triggers, as defined, may not lead to adjustments to management strategies	4. Clarify the links among effects levels, triggers and action. • triggers should be better defined to show how they protect the environment and how this improves the timeliness of management response. • trigger levels should take into account how long it would take to mitigate or reverse the effect and how long it would take for the environment to recover.
The term "adaptive management" has led to some confusion	5. For the WLWB, determine whether adaptive management or the more general management approach discussed at the May 14-15 workshop by presenters and participants should be used, and convey that direction to Diavik for plan revision.

It is important for the mine and the regulator to convey to stakeholders that they are confident in the options available to reverse any negative trends and prevent irreversible damage to the environment, in a timely manner. A discussion of how easy and timely it is to assess results of the complex monitoring programs, work through risk assessments and implement new mitigation strategies would also be useful to include in the management plan.

4 Evaluation of the EKATI Diamond Mine Adaptive Management Plan for Aquatic Effects

BHP Billiton has developed a Watershed Adaptive Management Plan for its EKATI mine (Rescan, 2008) as a condition of its Water Licence. As requested by the WLWB, the plan includes numerical thresholds and triggers, and is linked with the Aquatic Effects Monitoring Program (AEMP).

The EKATI mine includes open pits and facilities in the Koala Watershed and King-Cujo Watershed. This assessment of EKATI's AdMP focuses mainly on the Koala Watershed (Beartooth, Koala, Koala North and Panda pits), as activities at the Misery pit in the King-Cujo watershed were suspended in 2005. It is assumed that the same management approaches and potential issues apply to both watersheds.

Although the AdMP focuses on water quality in the receiving environment, and does not include evaluation of the biological communities, the AEMP does assess environmental effects of the effluent discharges on biological characteristics of the lakes, which provides ecological relevance.

4.1 Review of EKATI Adaptive Management Plan

The overall evaluation of the EKATI Plan in terms of the formal elements of an adaptive management plan is summarized in Table 4 and discussed below.

Table 4: Summary of Review of EKATI Mine Aquatic Effects Adaptive Management Plan

Stages/Elements of Adaptive Management	EKATI Diamond Mine Watershed Adaptive Management Plan
1. Assess	
• Engage Stakeholders	? Amount and effectiveness of engagement? (e.g., meetings, workshops, opportunities to comment on draft reports, inclusion of stakeholder comments in the Plan) IEMA and Wek'èezhìi Land and Water Board
• Assess existing knowledge	✓ Aquatic Effects Monitoring Program considers baseline data and describes monitoring programs to detect change (effects sizes, study design)
• Identify management goals	✓ Water License provides Environmental Quality Criteria (EQC) for discharges (end of pipe), reporting commitments
• Identify uncertainties	✓ Aquatic Effects Monitoring Program (AEMP)
2. Design	
• Models/hypotheses	? Some are described in Section 2 of AdMP, but they are related more to the AEMP than to the adaptive management. The main hypothesis of the AdMP is not explicitly stated, making it difficult to evaluate this aspect. There appears to be a passive approach, with the hypothesis that the existing environmental management is adequate to protect the aquatic environment
• Management action(s) to be applied	? Assume that this is to follow current standard operating procedures (e.g., are these described in environmental management plans?)
• Measurable indicators	✓ Described in Section 3.3 of AdMP for water quality but lacks triggers or thresholds for aquatic organisms. The AEMP describes monitoring programs for biota, which could be incorporated in the thresholds. The water quality guidelines used for thresholds do provide some biological relevance, in that they are based on toxicity responses of sensitive organisms.
• Monitoring and data analysis plan	✓ Described in Section 3 of AdMP
3. Implement	
• Implement Plan	✓ Annual commitment to AEMP and AdMP
4. Monitor	
• Monitor Results	✓ Annual commitment to AEMP and AdMP
5. Evaluate	
• Compare results against model prediction	✓ Method described in Section 3 of AdMP
• Include stakeholders in the evaluation	? not discussed

Stages/Elements of Adaptive Management	EKATI Diamond Mine Watershed Adaptive Management Plan
6. Adjust	
• Adjust model/hypothesis and management plan	**?** The AdMP provides only a generic toolbox, with few details. Some management strategy options are described in Section 4 of AdMP, but details about how effective they are likely to be are not provided. For example, there should be sufficient detail to allow a reviewer to evaluate whether there are technological options available and to have confidence that proposed strategies would work (e.g., a discussion of successful use elsewhere, ongoing research at the mine to assess possibilities for emerging trends).
• Include stakeholders in the discussion of options	**?** not discussed
• Adjust Management implementation	**?** Implicit in the AdMP, but success would be linked to the availability of realistic management options. The three year timeline for management responses may be too long if there are indications of a potentially severe or irreversible effect.

The EKATI Adaptive Management Plan contains the following six components:

1. **Description of water management practices** for its facilities in the Koala Watershed and King-Cujo Watershed, including clean water diversion, waste rock storage areas, containment facilities for seepage water, mine processing wastes and sanitary wastes, and interactions of mine water with the receiving waters. Principal elements of the practices are:
   - clean water diversion of 5.41 Mm^3/year (2006), entering Kodiak, Little and Moose Lakes, mixing in Moose Lake with the outflow from Leslie Lake and the mine
   - recirculation and re-use of water wherever feasible
   - a series of treatment cells in the Long Lake Containment Facility that provide areas for settling of particulate matter and movement of cleaner water to downstream treatment cells prior to release to the receiving environment
   - discharge from Long Lake Containment Facility to Leslie Lake (first receiving waterbody) of 10.1 Mm^3/year (2006), with passage through various lakes to ultimately discharge to Lac De Gras
   - discharge from King Pond Settling Facility to Cujo Lake of 0.33 Mm^3/year, through various lakes to ultimately discharge to Lac Du Sauvage
2. **Description of current water quality monitoring results and potential issues**:
   - the AEMP monitors quality of effluent from the containment facility, and water quality and aquatic life in several lakes and streams downstream of the discharges, including Lac De Gras and Lac Du Sauvage. The AEMP considers both statistical and ecological relevance in detecting changes to characteristics of the receiving environment. There is a defined methodology for evaluating long-term changes in the downstream watersheds (based on statistical tools and best professional judgment).
3. **Identification of the main potential trends and concerns for water quality**:
   - chloride increase in lakes due to the addition of saline groundwater (pit dewatering); a Tier I ecological risk assessment and additional toxicology tests have been done

- hardness increase in lakes, mainly from groundwater (pit dewatering); the lakes are low in hardness, and the increased hardness provides protection from metal toxicity (many water quality guidelines increase with increasing hardness)
- nitrate increase in lakes, presumably related to blast residues (nitrate is a primary nutrient for aquatic plant growth, can lead to eutrophication)
- overall increase in total dissolved solids due mainly to groundwater (pit dewatering)
- increases in some metals in the lakes, which to date are well below the thresholds. These include copper (temporary situation related to slope instability at one stream, addressed through site remediation and a Tier I ecological risk assessment), molybdenum (due to elevated concentrations in kimberlite ore from Misery Pit, addressed through a Tier I ecological risk assessment), and nickel

4. **Development of thresholds and triggers** for adaptive management strategies:
   - thresholds are selected to be protective of 95% to 100% of all aquatic plants and animals (depending on the statistical model used). They include CCME guidelines for protection of aquatic life; site-specific guidelines that modify CCME (based on hardness, baseline conditions, etc.); and site-specific thresholds that describe departure from baseline (a statistical definition of baseline: within 3 standard deviations of mean), to distinguish natural variability from mine-related changes
   - triggers are established to identify when action is needed to confirm the trend and take corrective action (adaptive management strategies). They give early warning of potential problems and use regression models to describe trends over time and predict conditions over the next three years
   - there are no thresholds identified for aquatic communities in the AdMP
5. **Monitoring** of the environment and assessment of conditions against the thresholds and triggers:
   - these monitoring programs are carried out as part of the Aquatic Effects Monitoring Program
6. **Identification of the response procedures and reporting**:
   - if conditions are not predicted to reach a threshold, there is no trigger and BHP Billiton will continue its existing monitoring programs without altering the mine or water management strategies (unless desired for other reasons)
   - if conditions are predicted to reach the threshold within three years, a trigger is activated and BHP Billiton will respond with management strategies; the response will be tailored to the magnitude, spatial extent and reversibility of potential effects

However, there is little information about the possible management options and their effectiveness. Section 4.1 of the EKATI Adaptive Management Plan states that, “The inherent nature of an adaptive management plan is that the most appropriate response can only be developed at the time, based on the information at hand. Nonetheless, there is a ‘toolbox’ of standard responses, many of which would likely be considered at EKATI.” The toolbox describes initial responses to verify the trigger (e.g., additional sampling, QA/QC checks, risk assessment, water quality criteria) and strategies to improve conditions (modifications of the management plans and practices, or of mitigation structures and facilities), but these strategies are not discussed in any detail, nor are their effectiveness or likelihood of success discussed.

4.2 Summary and Conclusions for the EKATI Plan

EKATI’s AdMP was evaluated from three perspectives:

- Does it meet the directive provided by the WLWB?
- Does it follow the framework for adaptive management as described in current literature?
- Does it provide good links between monitoring results and management options?

The EKATI AdMP appears to address the WLWB directive to provide, "a management plan that describes a way of managing risks associated with uncertainty and provides a flexible framework for the mitigation measures to be implemented." However, it is not an AdMP in the defined sense, as it does not identify the management experiment and does not contain all the elements of AdMP (description of stakeholder involvement, clear hypothesis to test, description of viable management options). The lack of clarity about stakeholder involvement and description of viable management options are also relevant to the Plan's ability to provide good links between monitoring results and decisions about management options.

Management considerations are not as well developed as scientific considerations. Table 5 contains observations and recommendations IEMA may wish to consider regarding revision of the EKATI AdMP. Many of the recommendations are consistent with those provided for the Diavik plan

Table 5: Observations and Recommendations for the EKATI Adaptive Management Plan

Observation	Recommendation
The role and involvement of stakeholders (governments, affected communities, IEMA, etc.) with respect to the plan is not discussed.	1. Identify opportunities for stakeholder involvement, for example: • in defining/refining the management goals • direct involvement in some monitoring programs (e.g., fish palatability) • reviewing and evaluating the results of monitoring programs • considering adjustments to management options. In addition to promoting good communication, this involvement will allow exchange of information, and will likely identify additional or new ways in which traditional knowledge can be incorporated.
Some possible management strategies (generic toolbox) are discussed, but not in detail.	2. Provide additional details about potential management strategies and a short discussion about their effectiveness in other situations, or about ongoing studies at EKATI, as this will allow IEMA and WLWB to have more confidence in their potential success. • It may be possible to use adaptive (experimental) management at a smaller scale (e.g., for evaluation of options to address specific salinity, cadmium or turbidity issues). • Examples of strategies discussed briefly in the AdMP are adjusting pumping rates or timing of pumping from the containment facility, designing new mitigation structures or facilities. • EKATI may have done some research into options, but these are not discussed in any detail.
Timeliness of response may be an issue, and there is concern that negative effects may become more pronounced if there is a long lag time before implementation.	3. Clarify the anticipated timelines for identifying an effect (trigger) and making adjustments to the mine operations: • There may be a long lag between identifying triggers, conducting additional studies (e.g., magnitude, extent, reversibility, updating water quality models or applying for site-specific water quality criteria), conducting an environmental risk assessment, and then looking into cause and determining new mitigation strategies before making operational changes.

Observation	Recommendation
There are no biological triggers identified	4. Include thresholds and triggers for biological indicators, based on organisms monitored for the AEMP, to improve biological relevance of the management plan.
There are concerns that the triggers, as defined, may not lead to adjustments to management strategies	5. Evaluate the triggers for their relevance to management objectives (e.g., preserving water and aquatic life characteristics of a pristine lake). • The CCME guidelines used as the triggers for most parameters are higher than baseline conditions. 6. Clarify the links between effects levels, triggers and action. • triggers should be better defined to show how they protect the environment and how this improves the timeliness of management response. • trigger levels should take into account how long it would take to mitigate or reverse the effect and how long it would take for the environment to recover.
The term “adaptive management” has led to some confusion	7. For the WLWB, determine whether adaptive management or the more general management approach discussed at the May 14-15 workshop by presenters and participants should be used, and convey that direction to EKATI for plan revision.

5 Closure

Respectfully submitted,

Jacques Whitford AXYS Ltd.

Reviewed by:

Original signed by:

Karen Munro, M.Sc., R.P.Bio.
Practice Lead, Aquatic Ecotoxicology,
Western Region

Original signed by:

Jeffrey Brokaw, Ph.D.
Senior Scientist, Fisheries Group

KM/JB/mp

[File Ref: P:_CMiC Projects\1037001_to_1038000\1037316 ESP - Diavik and BPH review Adaptive Management\report\1037316 Final Report-Diavik and Ekati AdM reviews FORMATTED.doc]

6 References

Greig, L, D. Marmorek, and C. Murray. 2008. Guidelines for Preparation of Adaptive Management Plans. Prepared by ESSA Technologies Ltd. Richmond Hill, ON for Fisheries and Oceans Canada, Western Arctic Area, Central and Arctic Regions, Yellowknife [NT] 8pp.

Williams, B. K., R.C. Szaro, and C. D. Shapiro. 2007. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

EKATI. February 2008. Ekati Diamond Mine Watershed Adaptive Management Plan. Prepared by Rescan Environmental Services Ltd, Vancouver, BC. For BHP Billiton Diamonds Inc, Yellowknife, NT

Diavik. August 2007. Diavik Diamond Mines Inc. Adaptive Management Plan for Aquatic Effects—Version 0. Yellowknife NT