A review of the effects assessment for the Morrison Copper/Gold Project

for:

BC Environmental Assessment Office
Victoria, British Columbia

by:

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1. CONTEXT

The proposed Morrison Copper Gold Mine Project (the Project) is a Copper and Gold Mine located 65 kilometres northeast of Smithers, British Columbia adjacent to Morrison Lake (Figure 1). The Project proposes an open pit mine with a tailings storage facility, waste rock dump, a plant site, warehouse, assay lab and other facilities, and a 25 km, 138 kV transmission line that will bring power to the site. Pacific Booker Minerals (the Proponent) has submitted an application to the BC Environmental Assessment Office (EAO) for an Environmental Assessment Certificate, and the application is currently under review. Mining of the open pit will employ conventional truck and shovel methods over a 19-year period, preceded by a 2.5 year construction period, and followed by a 5 year closure and reclamation period, for a total mine life of 26.5 years. The proposed treatment process is a conventional crushing, grinding and flotation system resulting in the production of approximately 120,000 tonnes of concentrate per year containing copper and gold. The Project is designed as a zero-surface-discharge facility during operations, with a water treatment plant and discharge to the environment commencing in the closure phase and continuing in perpetuity.

An assessment of the effects of the mine development on water flow, water quality and fish and aquatic resources has been carried out by the Proponent as part of its application for an Environmental Assessment Certificate. (I refer to the suite of baseline and assessment reports and the EAC Application as the Project EA.) During the course of the Project EA review, the EAO has been advised of concerns from the various regulatory agencies and First Nations with respect to potential effects on fish and aquatic resources and water quality and quantity, primarily with a focus on impacts to Morrison Lake. Specific concerns relate to:

- the sufficiency of the available baseline data
- whether or not the modeling and analysis assessment is appropriate
- level of uncertainty of the water quality and water balance predictions, and
- the resulting effects assessment predictions.

These concerns could not be resolved to EAO's satisfaction during the review process, so the EAO has contracted an independent, expert, third party technical review of the hydrogeology, hydrology, water balance, water quality, and related aquatic resources and fisheries components of the Project EA, with a focus on the assessments of potential effects of the proposed Project on Morrison Lake, Morrison Creek and, if required, Babine Lake. Robertson GeoConsultants Inc. (RGC) was contracted to review the hydrogeology, hydrology, water balance, and water quality predictions. Solander Ecological Research Ltd. has been contracted to review the assessment of aquatic resources and fisheries components of the Project EA.

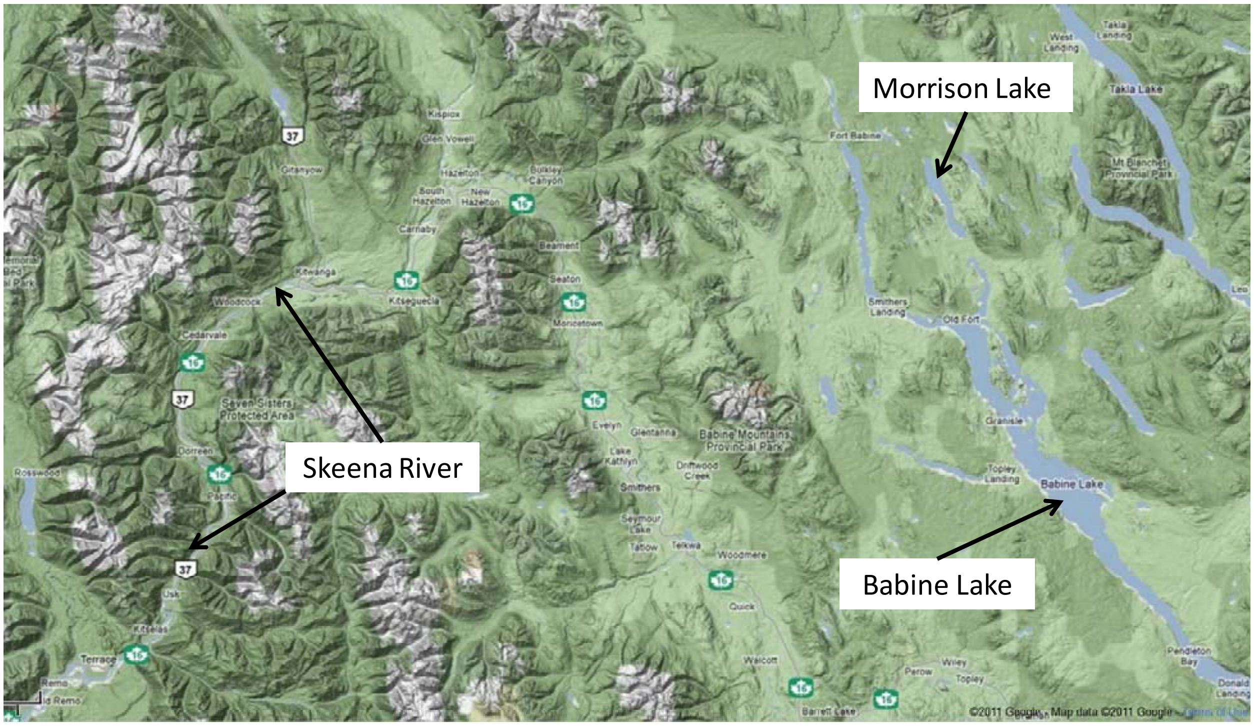

Figure 1. Location of Morrison Lake in British Columbia. Morrison Lake is part of the Babine Lake system, a major sub-basin within the Skeena watershed.

2. SCOPE, ASSUMPTIONS AND KEY QUESTIONS

Morrison Lake is approximately 15 km long and up to 1.5 km wide, with a perimeter of ~37 km and maximum depth of ~60 m. The lake flows into Babine Lake, which in turn flows to the Babine River and ultimately into the Skeena River. Morrison Lake is a valued ecological component with a high significance rating due to the unique salmon population and its value to First Nations. The main potential effects to the lake from the Project are associated with the following three sources:

- Seepage from the tailings storage facility (TSF), which is located approximately 2 km uphill of the lake.
- Interaction with the open pit, which is located approximately 100 meters from Morrison Lake and will be developed to a level approximately 250 m below lake level.
- On closure, contaminated water from exposed pit walls will be collected and treated, and the treated water will be discharged via a pipeline and diffuser in the deepest part of Morrison Lake.

The primary concerns expressed by regulatory agencies and First Nations have been the effects of water quality and water quantity on fish and aquatic resources.

The scope of the review as presented by EAO is as follows.

> "Conduct an independent, expert, technical review of the: aquatic resources and fisheries components, as they relate to potential water quality impacts, of the Application for an Environmental Assessment Certificate for the proposed Morrison

Copper/Gold project (proposed Project), in particular with a focus on the assessments of the potential effects of the Project on Morrison Lake, Morrison River and, if required, Babine Lake.

The contractor must:

- Assess the relevant baseline data provided by the Proponent for the effects assessment
- Assess the measures, including the Adaptive Management Plans, proposed by Pacific Booker Minerals Ltd (the Proponent) to mitigate the potential effects
- Determine if the data and assessment support the Proponent's conclusions that the proposed Project will not have a significant adverse effect on the health of aquatic resources and fisheries in Morrison Lake and Morrison River. If the data and assessment do not support the determination of effects, the contractor will specifically define for the Environmental Assessment Office what data and assessment is required for the environmental assessment."

It is important to clarify what this report does and does not do. This report provides a review of the Project EA materials with a focus on fish and fish habitat; resources such as wildlife, socioeconomics, etc. are not considered. I reviewed all Project EA materials on fish, fish habitat and aquatic resources in the context of assessing potential effects on fish and fish habitat. The review does not assess physical and chemical modeling conducted for the Project EA, and instead relies on the results of RGC's analysis and review (Robertson Geoconsultants Inc. 2011). It is also important to state that this is an overview to aid EAO in coming to conclusions and making potential recommendations to Ministers. My review is qualitative in that I have conducted no additional analyses nor have I checked calculations of any of the Project material I have read. This approach is nevertheless reasonable for a review at this stage of the EAC application process.

My review focuses on four main questions:

1. What resources are present in the study area?
2. What impacts will occur to these resources?
3. What measures will be taken to reduce or offset these impacts?
4. What monitoring will be used to assess whether impacts are as expected and mitigation is effective?

For presentation purposes I have divided the Project into three main phases, Construction, Operations, and Closure. The construction phase includes all site preparation activities including construction of the TSF, facilities, access roads and transmission corridors. The Operations phase includes all activities during typical operations of the Project. The Closure phase includes all activities associated with decommissioning the mine, reclaiming disturbed areas and long-term treatment and export of waste water. Under each phase I consider three geographic areas, the transmission corridor, the mine site (mainly this includes open pit, waste rock dumps and stockpiles, and the TSF), and the adjacent receiving environment (mainly this is Morrison Lake).

A primary aim of the review is the identification of "significant residual impacts," which are defined as impacts remaining after all mitigation is applied. The term residual impact derives from an accounting exercise whereby impacts are quantified, after considering mitigation and compensation. To properly quantify impacts, the assessment should consider extent, duration, frequency, magnitude and reversibility of impacts. Definitions for these and other terms are provided at the end of this document, but I define significance and residual impact here because they are central to the assessment.

> **Residual Impact.—** The impact remaining after all mitigation is applied. The assessment should consider extent, duration, frequency and magnitude of impacts.
>
> **Significant Impact.—** A high probability of occurrence of residual effect that cannot be avoided or mitigated, having a combination of characteristics that render it unacceptable to the public, regulators, other interests, or that exceeds standards or contravenes legal requirements.

Water Quality Guidelines as standards for determining significance.— A critical and difficult aspect of environmental impact assessment is the determination of "significance." As noted above, key attributes that define a significant effect are magnitude, geographic extent, duration and frequency, and the degree to which the effects are reversible. Yet despite general definitions, difficulties still arise because there are few truly objective means to unambiguously define a significant adverse effect — definitions vary within and among stakeholders, agencies, and the general public because significance is related in part to individual or collective values. All regulators and most stakeholders would agree that a loss of 50% of the only spawning habitat available for a highly valued fish stock is significant; however, fewer may agree that a 5% loss was of concern.

We live in a complex society surrounded by standards and guidelines—speed limits, health and safety guidelines, financial principles, production standards, etc. Guidelines and standards are essentially a set of rules (not necessarily embedded in a legal framework), which guide collective decisions to reflect collective values. A "standard" is defined as follows:

> Quantifiable and measurable thresholds that are typically defined in law or regulation, and are mandatory. A statement that outlines how well something should be done, rather than how it should be done. A standard does not necessarily imply fairness or equity, nor an absolute knowledge of cause-and-effect linkages. Standards are typically established using a combination of best available scientific knowledge, tempered by cautious use of an established safety factor. (Dunster and Dunster 1996)

The primary difference between a standard and guideline is whether it is enshrined in law or regulation. When done properly, standards and guidelines can have tremendous value: they indicate whether a product or decision meets specific criteria. As a result, we can judge whether that product or decision is acceptable without first having to become an expert on that topic. So for example, a consumer can purchase an electric appliance with a CSA label and be assured that it is safe to use. In most cases, guidelines and standards like these have margins of safety built in. Guidelines and standards are often adjusted through time as new information becomes available, or values change.

The BC Water Quality Guidelines provide a gauge for assessing impacts to water quality and aquatic biota. They have been developed after considering the available scientific literature and the typical receiving environment in British Columbia. Like most guidelines they include safety factors to account for uncertainties, like sensitivities of organisms not yet tested, or chronic sublethal effects. However, the safety factors do not typically build in potential interactions with other toxins, so in this sense they do not incorporate other reasonable uncertainties. In the absence of carefully developed site-specific water guidelines I will use the BC Water Quality Guidelines as a determinant of significance. Water quality that meets the guidelines is assumed to have no significant biological impact. Water with stressor concentrations that exceed the guidelines is assumed to have a significant impact. The appropriateness of the guidelines is assumed to have occurred during their development, and a critical review of the guidelines is considered well beyond the scope of this contract.

Scale.— The assessment of biological significance depends crucially on the selection of an appropriate scale of investigation. I have chosen to examine the evidence while considering a geographic scale of Morrison Lake for most of the effects, which I believe is appropriate for the Morrison Project.

Uncertainty.— There are many excellent discussions on the effect of uncertainties on the predictive capacity of ecological models (Hilborn and Mangel 1997), and it is a given that impact assessment incorporates many subjective decisions. To impart rigour to the assessment process, it is reasonable to expect all conclusions to be supported with uncertainty analysis, to the extent feasible, including sensitivity analyses (either qualitative or quantitative) and statistical power analyses.

3. INFORMATION SOURCES

The main information sources used for this review are reports and files associated with the Morrison Copper Gold Mine Project Application for an Environmental Assessment Certificate (Project EA). These are technical documents that present project design details and discuss the likely or assumed interactions between the Project and a set of natural resources. The documents are posted on the EAO Project Information Centre website, under the Morrison Copper Gold Project. Copies of some of these reports were made available by EAO staff. The materials reviewed include:

Morrison Copper/Gold Project Application Chapter 7. [7.9 Aquatic Resources and 7.10 Fish and Fish Habitat]

Morrison Copper/Gold Project Application Chapter 8. [8.9 Aquatic Resources and 8.10 Fish and Fish Habitat]

Morrison Copper/Gold Project Application – Review comments

Morrison Copper/Gold Project Application Review Response Report Rev 2

Rescan. 2009. *Morrison Copper/Gold Project: Aquatics Baseline Report, 2006–2007*. Prepared for Pacific Booker Minerals Inc. by Rescan Environmental Services Ltd. March 2009. [Appendix 26]

Rescan. 2008. *Morrison Copper/Gold Project Aquatics Baseline Report, 2008*. Prepared for Pacific Booker Minerals Inc. by Rescan Environmental Services Ltd. December, 2008. [Appendix 27]

Rescan Environmental Services Ltd. (Rescan). 2008. *Morrison Copper/Gold Project Fisheries Baseline Report (2006-2008)*. Prepared for Pacific Booker Minerals Inc. December 2008. [Appendix 28]

Rescan. 2009. *Morrison Copper/Gold Project Proposed Transmission Line Fisheries Baseline Report*. Prepared by Rescan Environmental Services Ltd. for Pacific Booker Minerals Inc. March 2009. [Appendix 29]

Rescan. 2010. Morrison Copper/Gold Project: 2009 Fish and Fish Habitat and Aquatic Resources Report. Prepared by Rescan Environmental Services Ltd. for Pacific Booker Minerals Inc. March 2009. [Appendix AE]

Klohn Crippen Berger. 2010. Morrison Copper/Gold Project Lake Effects Assessment. [Appendix AB]

David Bustard and Associates Ltd. 2005. 2004 Fisheries Studies Morrison Watershed. Prepared for Pacific Booker Minerals Inc. July [Appendix AD]

David Bustard and Associates Ltd. 2004. Fisheries background studies Morrison Watershed. Prepared for Pacific Booker Minerals Inc. May 2004

Pacific Booker Minerals Inc. 2010. Morrison Copper/Gold Project Toxicity Tests (LC50 and IC25) and Water Chemistry. Prepared by Pacific Booker Minerals Inc. April, 2010 [Appendix AW]

LBN Spawning Report (2010)

In addition to these sources, I have queried other on-line sources to search for relevant primary literature on the Morrison Lake watershed.

I visited the site on 19 October 2011 to get a general overview of the topography and proposed layout of the Project, but I did not conduct any field work to corroborate information presented in the Project EA or any other reports. All conclusions are therefore based on inference from existing information made available during this review.

I have not assessed the Project EA's predictions of water quantity and water quality, but this has been done by RGC as part of their scope of work for a third-party review. RGC's review indicates that the predictions presented in the EA may be too optimistic; that is, seepage flows may be greater and water quality may be worse than predicted. I expect there to be ongoing discussions regarding these predictions and additional information and modeling may lead to further changes to predicted flows and water quality conditions. Regardless of the outcome of this discussion, I believe it is essential to include in the assessment some form of sensitivity analysis and statements of a range of effect, particularly for outcomes that are difficult to predict or have potentially large consequences.

4. What resources are present in the study area?

4.1 Fish Habitat

The *Fisheries Act* (Section 34) defines fish habitat as:

> "spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes."

Interpreted broadly this means areas where fish live, along with other areas that provide food or other essential functions like streambank stability or temperature amelioration. In this interpretation fish habitat would potentially include aquatic habitat without fish and terrestrial habitats such as riparian areas. There are many precedents for the inclusion of such habitats in the assessment of impacts to fish and fish habitat and DFO regularly requires compensation for impacts to riparian habitats. Whether project effects have been sufficiently compensated is a decision for DFO.

4.1.1 Transmission Corridor

All streams in the transmission corridor appear to have been assessed with a combination of existing information, map-based data, and site-specific assessment, although fish sampling was apparently limited to only a subset of streams on the transmission route. The baseline document contains a good discussion of data requirements for assigning fish-bearing and non-fish-bearing status, including sufficient upstream and downstream assessment and sampling in more than one season or year.

Knowledge Gaps

I believe the data and assessment are sufficient to support the Proponent's conclusions regarding the presence or absence of fish (i.e., the extent of fish habitat) in the transmission corridor; however, additional sampling should occur during the permitting stage, should the Project be issued an EAC. Specific and general deficiencies are described as follows.

The final designation and presentation of fish-bearing and non-fish-bearing status is somewhat unclear. It is not apparent whether all stream crossings were assigned a default fish-bearing status and then revised based on pre-existing, mapped or site-specific data, but the rationale presented in the document would argue for this approach. Given a preference for this approach, there appears to be a need for follow up work to finalize the assignment of fish-bearing status and to support calculations for compensation, and to corroborate findings with follow up studies in additional years or seasons. More context for assessing construction-related impacts and the need for mitigation could also be provided by discussing the proximity to downstream fish-bearing habitats.

Reliance on a single year or season of data.— This topic is given additional discussion here because it is an issue addressed at several points in the review and is considered to different extents in different parts of the Project EA.

If sampling occurs at only a single time, there is no evidence with which to judge whether data were collected in a good, bad or normal year. Such data provide the context for judging whether impacts are significant and compensation targets are reasonable. This context can be best provided by undertaking similar sampling in additional seasons or years. It may be possible to use regional data (i.e., population estimates from nearby lakes and streams) to assess typical population variance in similar systems, or simply to assume a certain coefficient of variation and plan accordingly in a risk-averse manner. However, it should be noted that fish production may not be correlated among sites, so care should be exercised before adoption of reference sites outside the area of interest.

Current RISC standards (Forest Practices Code of British Columbia 1998) provide an excellent discussion of relevant sampling methods, their relative merits, and the level of effort required to determine non-fish bearing status. The generally accepted standard is electrofishing of all available habitat over at least 100 m linear length of stream. If no fish are observed, there is a requirement to assess the need for additional effort, usually in the form of one or more repeat visits and/or assessment of additional stream length. It is unclear whether the methods used for the Project EA have satisfied these criteria, particularly in the assignment of fish-bearing or non-fish bearing status. The primary relevance of this assessment work is the need to determine adequate compensation for lost fish habitat.

It may be argued that compensation ratios greater than 1:1 are sufficient to account for annual variability in habitat use or abundance. It is my understanding that the primary purpose of the 2:1 ratio is to account for uncertainty in the efficacy of compensation (i.e., the compensation habitat may not perform as expected), rather than uncertainty in the estimate of lost production. An accurate estimate of lost habitat therefore remains an essential component of successful compensation. This criticism is most germane to those estimates of compensation habitat that are highly dependent on fish presence or abundance estimates.

It seems unlikely that more sampling would detect additional species in most places, but it is reasonable to think that there is variation among seasons and years in use of different habitats. In my experience, it is common for additional sampling to extend the areas of use and occupation. Additional sampling should occur during the permitting stage, should the Project be issued an EAC, to clarify impacts and compensation requirements. Sampling should be done at times that fish are most likely to occur.

4.1.2 Mine Site

All lakes, ponds and streams in the mine site appear to have been assessed with a combination of existing information, map-based data, and site-specific assessments. There appears to have been a greater level of effort conducted on fish sampling in the mine site than on streams in the transmission corridor, and effort has been spread among the waterbodies and across the most relevant parts of each waterbody. The sampling information is summarized and presented well.

Knowledge Gaps

I believe the data collected to date are sufficient to support the Proponent's conclusions regarding the current presence or absence of fish (i.e., the extent of fish habitat) within the mine site; however, additional sampling should occur during the permitting stage, should the Project be issued an EAC, to clarify impacts and compensation requirements.

The greatest deficiency is the reliance on a single sampling event within a single year or season. A detailed discussion of the importance of additional sampling is presented in Section 4.1.1.

4.1.3 Morrison Lake

Fish and aquatic habitat in Morrison Lake has been described in several baseline reports that summarize existing information, and present results of on-site assessments. On-site assessments have included habitat mapping of potential shoreline spawning areas, and general documentation of habitat use by sampling for fish using gill nets and minnow traps at various locations around the lake.

Knowledge Gaps

I believe the data presented as part of the Project EA are insufficient to support a rigorous assessment of project effects on fish and fish habitat in Morrison Lake, particularly with respect to potential changes in water quality in littoral and deepwater areas. These deficiencies would exist whether one relied on water quality predictions from the Project EA or revised predictions from RGC, because both predict exceedence of BC Water Quality Guidelines for several constituents in seepage and effluent discharges, and insufficient information has been collected to understand potential exposures of fish and other organisms. Considerable additional information is required to make a confident assessment of effects on the receiving environment. Some excellent work on fish presence and distribution has been completed, but it is likely that the current data gaps would require collection of new data, or similar data in additional seasons or years. Additional data and analyses would reduce uncertainty in estimates of abundance, distribution and productivity, and provide important context for discussion of effects and compensation. These are significant gaps that should be addressed as part of the EA process, not during permitting. Specific and general deficiencies are described as follows.

There is exceedingly little data available to describe habitat use for many of the species known to occur in Morrison Lake. The Project EA indicates the following species occur: rainbow trout (*Oncorhynchus mykiss)*, cutthroat trout (*O. clarkii clarkii*), kokanee (*O. nerka*), sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), Chinook salmon (*O. tshawytscha*), lake trout (*Salvelinus naymaycush*), lake whitefish (*Coregonus clupeoformis*), mountain whitefish (*Prosopium williamsoni*), longnose sucker (*Catostomus catostomus*), largescale sucker (*Catostomus macrocheilus*), northern pikeminnow (*Ptychocheilus oregonensis*), burbot (*Lota lota*), redside shiner (*Richardsonius balteatus*), prickly sculpin (*Cottus asper*), and peamouth chub (*Mylocheilus caurinus*). General habitat use patterns are known from the scientific literature on many of these species, but apparently very little is known about habitat use within Morrison Lake. From work completed elsewhere, many of the species are known to spawn and rear in littoral areas, and several commonly use deepwater habitats. Of particular concern for the environmental assessment is the relative use of areas that may be affected by seepage from the mine site or effluent discharges, if those discharges are to exceed BC Water Quality Guidelines.

Baseline studies completed by Bustard (Application Appendix AD) describe the distribution of shoreline spawning habitats, particularly for lake trout, kokanee and sockeye salmon. Although this work seems to have been done well, there are several methodological issues that are not discussed and therefore cast doubt on the utility of the results. One issue is that of physical conditions for observation. The only areas apparently examined were relatively shallow zones that could be observed from a boat or the shoreline. This method would typically restrict observations to shallow areas, but visibility is restricted by the heavily stained nature of water in Morrison Lake – Secchi disk readings were 4 m during Bustard's study and only 3 m during studies by Shortreed et al. (1998), suggesting visibility is limited. McPhail (2007) notes that shoreline spawning for kokanee usually occurs at depths less than 10 m, but it seems unlikely that visibility would allow good observations from the surface of depths anywhere close to this range. We know that shoreline spawning occurs in other BC lakes (e.g., Seton and Anderson lakes) at depths greater than can be observed from the surface.

Five shoreline areas were identified as good shoreline spawning sites for sockeye and kokanee, however, only one of these was actively used by sockeye, and none by kokanee. It is difficult to tell whether this apparently low intensity of habitat use is because littoral habitats are rarely used for spawning or whether conditions impeded observations of other high quality sites. Bustard's review of historical information noted that the lack of kokanee spawners observed in streams associated with Morrison Lake suggests that kokanee in the lake are primarily shoreline spawners. Since kokanee have represented a substantial portion of Morrison Lake fish caught in gill nets and trawls (e.g., Shortreed et al. 1998), it seems reasonable to question whether spawning sites were simply not visible during the surveys. Several other species that occur in Morrison Lake use shoreline areas for spawning, feeding and shelter yet there is little information presented on the local habitat use among species or across seasons. In the absence of such information it seems the most parsimonious approach for the impact assessment is to assume habitat is evenly distributed around the littoral areas of the lake. This admittedly could over-represent or under-represent the amount of habitat that might be affected by the Project.

Fish habitat use of the deep pelagic areas is also poorly known. Although there may be some relevant data (e.g., deepwater trawls) in historic and baseline data, there is no presentation of this in relation to siting of the effluent discharge diffuser. The application states that the concentration of toxins in the effluent will rapidly be diluted such that it meets BC Water Quality Guidelines a fairly short distance away from the diffuser, but there is no analysis of habitat use within the proposed plume. Notwithstanding that RGC's review indicates that considerably greater concentrations of certain contaminants may occur, conclusions of significance should be based on an understanding of the importance of the affected habitat, not just its size. For example, lake trout are a piscivorous species in which juveniles and adults preferentially use cool, deepwater habitats. Daily vertical migrations by sockeye and kokanee juveniles and kokanee adults mean these fish also frequent deepwater habitats. Other species such as burbot and lake whitefish also use deepwater habitats extensively. The extent to which these fish would be exposed to potentially high concentrations within the mixing zone appears to be unanswerable with the information presented to date. The notion presented by the Proponent that fish would avoid these areas is unsubstantiated and does not address uncertainties related to present habitat use.

The potentially serious implications of relying on a single year of data has been discussed in greater detail in Section 4.1.1, and it is a problem repeated for fish habitat assessment of Morrison Lake. The most important implication is in determining the significance of potential impacts. In the absence of reliable information on habitat use it is exceedingly difficult to predict the ecological outcome of project effects, especially the potential effect of exposure to toxins in effluents and seepage.

4.2 Fish Populations

The Project EA indicates the following species occur in Morrison Lake and its tributaries: rainbow trout (*Oncorhynchus mykiss)*, cutthroat trout (*O. clarkii clarkii*), kokanee (*O. nerka*), sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), Chinook salmon (*O. tshawytscha*), lake trout (*Salvelinus naymaycush*), lake whitefish (*Coregonus clupeoformis*), mountain whitefish (*Prosopium williamsoni*), longnose sucker (*Catostomus catostomus*), largescale sucker (*Catostomus macrocheilus*), northern pikeminnow (*Ptychocheilus oregonensis*), burbot (*Lota lota*), redside shiner (*Richardsonius balteatus*), prickly sculpin (*Cottus asper*), and peamouth chub (*Mylocheilus caurinus*).

There are no SARA-listed species in the Morrison watershed. Coastal cutthroat trout (*clarkii* subspecies) are a provincially blue-listed species and thus are a species of special concern in British Columbia. They are ranked as a priority 2 species within the provincial Conservation Framework. A COSEWIC status report has not been completed, but the species is on COSEWIC's mid-priority list for status assessment.

4.2.1 Transmission Corridor

The assessment of streams in the transmission corridor is reviewed generally in Section 4.1.1.

Knowledge Gaps

I believe the data and assessment are sufficient to support the Proponent's conclusions regarding fish populations in the transmission corridor; however, additional sampling should occur during the permitting stage. As noted in Section 4.1.1, the greatest deficiency in the transmission corridor is the reliance on a single sampling event within a single year or season. This deficiency exists also for describing fish populations in this area of the project. It seems unlikely that more sampling would detect additional species in most places, but it is reasonable to think that there is variation among seasons and years in use of different habitats and local abundance. A detailed discussion of the importance of additional sampling is presented in Section 4.1.1.

4.2.2 Mine Site

The species occurring in lakes, ponds and streams in the mine site appear to have been assessed with a combination of existing information, map-based data, and on-site assessment.

Knowledge Gaps

I believe the data and assessment are sufficient to support the Proponent's conclusions regarding fish populations on the mine site; however, additional sampling should occur during the permitting stage. Like fish sampling conducted for the transmission corridor, fish sampling of waterbodies on the mine site relies on a single sampling event within a single year or season. A detailed discussion of the importance of additional sampling is presented in Section 4.1.1.

4.2.3 Morrison Lake

General surveys of fish in Morrison Lake have been completed in the past, as have specific studies of certain species like sockeye. This information has been reviewed for the Project EA and complemented by additional survey work. It provides a description of the fish species occurring in the lake, their general and relative abundance, and growth patterns for some species like lake trout.

Knowledge Gaps

I believe the data are sufficient to support the Proponent's conclusions regarding which species occur and general life history timing of fish populations in Morrison Lake; however, I believe additional species should be selected as Valued Ecosystem Components (VECs) for explicit assessment during the EA process.

The primary VECs selected for assessment in the Project EA are lake trout, sockeye salmon and rainbow trout, based on their importance to people and their different spawning periods. Although these are reasonable selections, I recommend adding a couple more species to represent different ecological roles. For example, kokanee would be a useful VEC as they are likely a substantial portion of the prey base for large piscivores, spawn on shorelines, forage in open water on zooplankton and use multiple open water habitats during daily vertical migrations. Another species like burbot, sculpins or lake whitefish could be selected to represent species that use littoral habitats for spawning, feeding and rearing. Sculpins may be sensitive to alterations in water quality (Maret and MacCoy 2002, Mebane et al. 2003), and should be reviewed as a possible sentinel species for monitoring. Maret and MacCoy (2002) noted that sculpins were absent from sites downstream of hard-rock mining areas in the Coeur d'Alene basin, Idaho, implying that they are sensitive to elevated metals concentrations.

Most of the substantial data gaps are related to fish habitat use and general patterns of fish movement, which are poorly known for Morrison Lake fish populations. As discussed in Section 4.1, where fish reside at key times like rearing, spawning, and overwintering, and the species-specific distribution of feeding and rearing areas, is poorly studied.

5. WHAT IMPACTS WOULD OCCUR TO RESOURCES IN THE STUDY AREA?

Sufficient information appears to have been collected and presented to allow general identification of the primary impact pathways and main areas of concern, but there is insufficient information to understand several important effects, particularly in relation to predicted water quality changes from seepage and effluent discharges.

5.1.1 Transmission Corridor

Construction, Operation and Closure.— Impacts to fish and fish habitat within the transmission corridor may occur from the construction of access roads and transmission lines. Possible impacts during construction that were identified in the Project EA include changes to water quality (e.g., runoff of sediment-laden water, introduction of nitrate waste from blasting, contaminant releases from construction machinery) and instream disturbances during clearing and construction. Construction-related impacts tend to be relatively short-term in nature, and most can be controlled with good management practices, on-site monitoring during construction and well-executed clean-up protocols at the end of construction. The corridor will need to be maintained in perpetuity to provide power to the site during all phases of the project, but most effects can likely be controlled with good management practices.

Knowledge Gaps

I believe the data and assessment are sufficient to support the Proponent's conclusions regarding effects to fish and fish habitat in the transmission corridor during all phases of the project; however, additional sampling is required to improve understanding of fish-bearing and non-fish-bearing status of streams. This work is primarily needed to clarify compensation needs, and can likely be deferred to the permitting stage.

5.1.2 Mine Site

Construction, Operation and Closure.— Impacts to fish and fish habitat on the mine site during construction may occur from a variety of land clearing, site preparation and construction activities. Possible impacts during construction that were identified in the Project EA include changes to water quality (e.g., runoff of sediment-laden water, introduction of nitrate waste from blasting, contaminant releases from construction machinery), altered flows, direct habitat losses, and instream disturbances. Some of these impacts may be relatively short-term in nature, but others will continue well past the construction phase. During the operation and closure phases the primary effects are associated with permanent habitat losses, altered flows, and water quality changes from seepage inflows to surface water on the site. Note that downstream effects will be discussed in Section 5.1.3 on Morrison Lake.

Knowledge Gaps

The baseline data are sufficient for the EA to describe the current extent and quality of fish habitats on the mine site. However, I believe the effects assessment is insufficient to support the Proponent's conclusions regarding effects on fish and fish habitat within the mine site. The deficiencies can likely be rectified with modest effort. Specific and general deficiencies are described as follows.

Flow reductions are insufficiently described for streams on the mine site. The EA materials indicate altered flows will occur in MCS 4 (34% reduction), MCS5 (90% reduction), MCS6 (60-90% reduction), MCS7 (50% reduction), MCS8 (negligible) and MCS10 (22% reduction), but the materials do not indicate how this reduction will be distributed across the flow regime. Since small streams are far more sensitive to flow reductions (Hatfield and Bruce 2000, Bradford and Heinonen 2008), it seems likely that most of these stream segments will become unusable for fish across much or all of the year. For the purposes of compensation calculations it is unclear whether flow affected stream segments were counted as partial habitat losses or complete habitat losses. The approach should be clarified and supported.

The Project EA indicates that seepage water from the TSF will flow into streams on the mine site, particularly MCS7, 8 and 10. Seepage inflow will result in ambient conditions in streams that exceed BC Water Quality Guidelines for several constituents, including sulphate, aluminum, arsenic, cadmium, cobalt and selenium, though the type and magnitude of exceedences differ among streams. This may affect habitat conditions within the streams and downstream habitat in Morrison Lake. The calculations completed by RGC indicate potentially higher ambient concentrations of these constituents than those indicated by the proponent in the Project EA, though both suggest ambient conditions will exceed the water quality guidelines for several constituents.

The Project EA provides very limited discussion regarding possible effects, but states that "site specific water quality objectives can be developed that are protective of aquatic habitat and fish." This statement along with several elements of the discussion imply that the BC Water Quality Guidelines are too stringent and that additional information (or a different interpretation of the same information) can be used to develop a less stringent guideline for this project. It is unclear what new information would be collected, what new interpretation might be used or what judgement criteria would be used in developing a site specific objective. Clarity on these matters are essential as part of the EA, and should not be deferred to the permitting stage for the simple reason that the outcome of any additional work is highly uncertain. In the meantime, I believe it is appropriate to use the existing water quality guidelines for defining significance of residual effect, for the reasons outlined in Section 2.

The supply of clean water to spawning and rearing fish habitats at the confluence of several small streams with Morrison Lake is also a concern, and this is discussed in greater detail in Section 5.1.3.

Additional sampling is required to improve understanding of fish-bearing and non-fish-bearing status of streams (the extent of fish habitat) and measures of fish abundance (the productivity of fish habitats). This work is primarily needed to clarify habitat losses for calculating compensation needs, and can likely be deferred to the permitting stage.

5.1.3 Morrison Lake

Construction.— Impacts to Morrison Lake fish and fish habitat may occur from a variety of land clearing, site preparation and construction activities. Possible impacts during construction that were identified in the Project EA include changes to water quality (e.g., runoff of sediment-laden water, introduction of nitrate waste from blasting, contaminant releases from construction machinery) and altered flows. Direct effects on habitats in the lake appear to be limited, but changes to stream conditions on the mine site may affect downstream habitats in the lake. Some of the impacts may be relatively short-term in nature, but others may continue to occur well past the construction phase (e.g., nitrate waste from blasting).

Operation and Closure.— During the operation and closure phases the primary effects on fish and fish habitat in Morrison Lake are associated with altered flows in several tributaries, and water quality changes in the lake due to seepage and effluent discharges. Altered flows may affect input rates of terrestrial nutrients and energy, but probably more importantly it may affect the characteristics of shoreline spawning and rearing areas, such as groundwater flows in gravels at the mouth of creeks. Changes in water quality may affect rearing, spawning and incubation areas for fish, or areas of the lake that may be important for food production.

The Project EA predicts negligible changes in ambient water quality due to inputs from effluent discharge and seepage from the TSF. Calculations completed by RGC indicate that Morrison Lake may have considerably greater concentrations of some elements than are indicated in the EA materials. The RGC calculations suggest that inputs to Morrison Lake from seepage and effluent discharge may result in ambient conditions throughout the lake that exceed guidelines for sulphate, cadmium, copper and zinc, depending on model assumptions.

Knowledge Gaps

I believe the data and assessment are insufficient to support the Proponent's conclusions regarding effects on fish and fish habitat within Morrison Lake. Specific and general deficiencies are described as follows.

There are some substantial knowledge gaps that inhibit predicting ecological outcomes of seepage and effluent releases from the Project. Most of the data gaps relate to uncertainties in predicting exposures of fish to elevated metal and sulphate concentrations. Whether this assessment is done in a qualitative or quantitative manner, it should be completed within an ecological risk assessment framework so the logic is made transparent and the conclusions can be understood and properly peer-reviewed. At present, the logic underpinning the Proponent's significance determinations of effects on fish habitat within Morrison Lake is not presented clearly enough.

The Project EA makes a case that the size of the effluent plume and any seepage inflows are small and will be quickly diluted to ambient conditions that are within the water quality guidelines. Notwithstanding that RGC have reached very different conclusions about final ambient conditions, exposure to poor water quality is what should drive the assessment not the size of the plume per se. If few fish go near the effluent plume or seepage zones then it may be reasonable to assume no ecological effect, but at present there is little evidence (either way) that fish do not regularly occur in these areas. Known fish behaviour and life history (e.g., daily vertical migrations by kokanee and sockeye, use of deepwater habitats by lake trout and lake whitefish, shoreline spawning and littoral feeding by multiple fish species) raise enough questions to suggest that there may easily be considerable exposures for substantial parts of the population. For example, the only observed shoreline spawning site for sockeye in Morrison Lake is within an area that could be subject to moderate seepage from the TSF or stockpiles on the mine site. This means that spawning adults, and incubating eggs and embryos could be exposed to elevated levels of several potential toxins during highly sensitive life stages. Whether this is a significant residual impact depends in part on how intensive and widespread such exposures are, but the known distribution of shoreline spawning areas indicates there could be considerable concerns. For example, Shortreed et al. (1998) note that the Morrison sockeye stocks are likely limited by availability of spawning habitat, so virtually any reduction in spawning habitat would have an effect on recruitment and abundance.

Simplifying assumptions can be made to describe the likely proportion of different fish populations potentially exposed. For example, a quick estimate of shorelines subject to possible seepage suggests about 5.5 km. With a lake perimeter of about 37 km, this translates into roughly 15% of available shoreline. If we assume that littoral spawning and rearing areas are distributed evenly around the lake then this means about 15% of shoreline spawning fish or littoral-dwelling fish will be exposed to seepage inflow. Regardless of the length of affected shoreline, detailed information on fish habitat use would be required to assess the potential consequences for fish populations. Such information does not appear to exist, but is essential if there is reasonable likelihood that seepage discharges will exceed water quality guidelines.

The Project EA indicates that BC Water Quality Guidelines are expected to be exceeded in the effluent discharged to Morrison Lake and within the 'effluent mixing zone'. Calculations by RGC indicate that concentrations of several constituents may exceed the guidelines throughout the lake when the system reaches a steady state. If this occurs, all fish habitat in the lake would exceed the water quality guidelines, which would certainly constitute a significant impact, especially since there would be even higher concentration hot spots near the effluent diffuser, along shorelines subject to seepage, and during periods of thermal stratification when effluents are retained in the hypolimnion only. I concur with RGC's recommendation to have a physical limnologist review the conclusions of any new modeling of effluent dilution.

RGC's calculations indicate a possible outcome of the proposed management is to have ambient conditions in Morrison Lake exceed BC water quality guidelines for some constituents when the lake is fully mixed. If this occurs, water in Morrison Creek will de facto also exceed guidelines, since the lake outflow makes up the great majority of flow in the creek. How far downstream into Babine Lake these effects may travel will depend on inflows and mixing in that system. Additional physical modeling seems appropriate to bound this possible effect.

The issue of biomagnification of pollutants is insufficiently addressed in the Project EA. Evidence for biomagnification potential (e.g., Croteau et al. 2005) should be reviewed and assessed for the receiving environment, especially when water quality guidelines are exceeded for various constituents.

The lake effects assessment makes a number of predictions about the magnitude and duration of water quality guideline exceedences. I found the presentation obscured some of the duration estimates, and would prefer to see the results presented as a predicted time series so it is easier to judge when a guideline is exceeded and for how long. The presentation should include uncertainty bounds around the predictions.

The Project is expected to intercept on-site runoff and to withdraw water from Morrison Lake to use in processing the ore. A water balance is provided in Table 3.1 of the Lake Effects Assessment, but there should be an analysis of potential flow reductions in Morrison Creek, broken down by week or month, in wet, dry and normal years, and under different climate change scenarios. Flow reductions in Morrison Creek may not be a substantial issue at most times in most years, but it would be useful to address the issue directly, since this is an important spawning system for Morrison Lake fish stocks.

6. WHAT MEASURES WILL BE TAKEN TO REDUCE OR OFFSET IMPACTS?

6.1 Mitigation

Mitigation measures can be defined as actions taken to avoid project impacts. Mitigation is proposed for a number of project components and there is no single document that discusses all these measures. Rather, mitigation has been discussed in relation to individual project components. In some cases additional mitigation is discussed as a possible response to monitoring results. I review monitoring plans in Section 7 of this report.

Construction.— Mitigation is likely to take the form of standard management practices for many activities, particularly during construction. Most construction-related impacts tend to be relatively short-term in nature, and can be controlled with good management practices, on-site monitoring during construction and well-executed clean-up protocols at the end of construction. Details can generally be adequately developed during the permitting stage for these kinds of effects. A variety of best management practices and DFO operational statements would apply to most of these issues. Some construction-related effects may require additional attention, such as draining existing ponds, but I am confident that most construction-related impacts can be minimized without needing to resort to unproven technologies or approaches. The uncertainties seem to be considerably greater for other project phases.

Operation.— The primary mitigation measures are summarized in Table 10.14 of the Review Response Report. The main measures for TSF seepage include interception and diversion of inflows around the site, recycling of water for onsite processing of ore, monitoring of conductivity during detailed design, and lining sections as necessary. The measures will partially maintain flows in streams MCS7, 8 and 10 and reduce seepage to groundwater. Despite these measures, flows in the tributary streams are expected to be substantially reduced and water quality in surface water and groundwater is expected to exceed BC water quality guidelines. Seepage from the waste rock dump is to be mitigated in a similar manner, by reducing flow-through with interception and diversion of inflows.

Closure.— Mitigation during the closure phase primarily involves moving PAG waste rock into the pit, and treatment of pit water followed by discharge to Morrison Lake. Movement of waste rock into the pit appears to be contingent on results of monitoring runoff from the waste rock storage areas. Effluent discharges to Morrison Lake are expected to exceed BC water quality guidelines, even after treatment. Despite mitigation in the form of waste water treatment, RGC's calculations contradict the Project EA results, and indicate that steady state ambient concentrations of several constituents may exceed water quality guidelines throughout Morrison Lake. I could find no discussion of failure rate predictions for this technology (i.e., probability of going offline, or reduced efficacy of treatment and therefore worse effluent discharges), and what might be the predicted ecological risks if failure occurs.

In summary, mitigation of seepage and pit water may be insufficient to bring water borne discharges in line with BC water quality guidelines over the long-term.

6.2 Compensation

Compensation refers to actions taken to offset project impacts. Compensation for fish and fish habitat is described in a stand alone "Fish Habitat Compensation Plan" and is summarized in Table 10.14 of the Review Response Report. The rationale for compensation is described well and the plan proposes compensation for a number of direct and indirect effects, including loss of fish-bearing habitat and upstream non-fish-bearing reaches. DFO does not typically consider compensation for release of deleterious substances, and no compensation or other offsetting benefits have been proposed for effects arising from seepage and effluent discharges.

7. WHAT MONITORING WILL BE USED TO ASSESS WHETHER IMPACTS ARE AS EXPECTED AND MITIGATION IS EFFECTIVE?

Monitoring is a cornerstone of good resource management. Monitoring allows post-implementation assessment of management decisions and programs and provides direction on adjustments that may be necessary. There are essentially two types of monitoring, compliance monitoring and response monitoring. Compliance monitoring ensures compliance with permit conditions, or it may include monitoring of water quality, channel morphology, or other physical states where conditions have been articulated in regulations and permits. Compliance monitoring may also apply to habitat compensation works to ensure that they are physically stable and performing adequately.

Response monitoring (also known as environmental effects monitoring) is often more difficult to design and implement. It involves a test of whether management decisions result in the expected outcomes on the target ecological resources (e.g., fish populations, fish habitat, invertebrate production). Developing a biotic response monitoring program is like developing an experiment, and requires detailed consideration of experimental design and analysis to measure response relative to a baseline condition. Since biological responses are difficult to measure and variable in space and time, an effective monitoring program must be designed to address the complexity of relationships between biological responses and project-related environmental changes, and to account for external factors (i.e., non-project related) and natural temporal variations. The overriding argument for implementing a biotic response monitoring program is recognition of the current uncertainty in predictions of biological response (e.g., fish abundance) to changes in environmental conditions (Ludwig et al. 1993, Castleberry et al. 1996). Response monitoring may instead use a proxy measurement such as a habitat condition (e.g., water quality) under the assumption that if conditions remain within a certain range then any changes in an organism's distribution and abundance are unrelated to that factor.

Results from a well-designed monitoring program can highlight needs for changes to management strategies, or they may demonstrate that a decision led to acceptable outcomes. In the latter case, adjustments to management are unnecessary, or in some cases less stringent restrictions may be feasible. For this reason, monitoring is of keen interest to all stakeholders.

Adaptive management is the term used to describe a process for improving management decisions over time, using specific scientific procedures and rationale (Walters 1986, Walters and Holling 1990). The process is designed to help managers learn about complex ecological systems, by following a cycle of prediction, implementation, monitoring, evaluation (relative to predictions), and implementation adjustment. At its core, adaptive management implies a commitment to collecting good data and altering course from current management practice if data support doing so. The evaluation step requires good information on the status and trends of the resource, and objective criteria for judgements of whether resource status and trends are "on track," or not. Conclusions of the monitoring program will depend on the selection of management thresholds and the statistical properties of the data. All conclusions, therefore, should be supported with uncertainty analysis, to the extent feasible, including statistical power analyses.

Knowledge Gaps
I believe the Adaptive Management Plans as currently proposed are deficient in several respects. Insufficient detail is provided for response monitoring, including experimental design, level of effort to be applied, power of the program to detect effects, methods for comparing before and after conditions, target species to be used, triggers for decisions, and the actions to be considered should results indicate additional mitigation or compensation is required. These are essential elements that should be addressed in the EA process when risks are high and outcomes are uncertain. These standards should apply equally to all aspects of the proposed monitoring, including water quality monitoring, environmental effects monitoring, and testing of fish tissues for metals tainting.

The basic elements of an acceptable adaptive management plan are those of a good scientifically designed and executed experiment:

- A discussion of why an adaptive management approach is preferable and what components are adaptive,

- List of specific goals to be achieved in each of the components of the mitigation and compensation plans. These goals should be measurable and relevant to DFO policy objectives such as no net loss of fish production.
- A full range of scenarios that may affect achieving those goals. These scenarios would necessarily be based on a complete analysis of potential impacts to the aquatic resources.
- A full range of mitigation, compensation and contingency measures, demonstrated to be biologically sound, reasonable, and based on practical and proven techniques. The options should be able to address potentially long lag times, such as the predicted slow movement of TSF seepage water.
- A monitoring program with stated performance measures, criteria for measuring success, measurable benchmark criteria for implementing contingency plans and targets, and commitments that these plans would be undertaken if success is not achieved. The monitoring program should be based on good experimental design principles, including statements of experimental hypotheses, sampling procedures, data analysis, and intended statistical power of hypothesis tests.

Some aspects of compliance monitoring, such as monitoring of construction activities can reasonably be delayed until the permitting stage, because risks are relatively low and strategies tend to be consistent and well-proven.

8. CONCLUSION

The information I have reviewed is sufficient to allow general description of the major impact pathways for fish and fish habitat within the Project area. However, there are knowledge gaps that hinder the confident determination of residual effects and their significance for some elements of the Project, especially in relation to changes in water quality from seepage and treated effluent. Filling some of these knowledge gaps will likely require additional field work or modeling, some of which may require substantial effort. If the proponent is able to demonstrate with reasonable confidence that seepage and effluent discharges will not exceed BC Water Quality Guidelines, then only minimal fisheries work appears to be required for the EA, although additional work may be required for permitting.

There are several outstanding issues, which have not been given sufficient attention, and the rationale for some of the conclusions of significance in the Project EA has not been made transparently. Although the practice of impact assessment has elements of subjectivity there must be a transparent flow in logic to the conclusions, particularly when established guidelines may be exceeded, as is predicted for this Project. Whether the approach employed is qualitative or quantitative there must be a transparent way for all readers to judge whether the conclusions are reasonable and supported by good evidence. At present this logic is not clearly presented. Such presentations must include a clear representation of how uncertainty is incorporated into the findings, and an attempt to incorporate techniques such as sensitivity analysis wherever possible.

8.1.1 Transmission Corridor

I believe the data and assessment are sufficient to support the Proponent's conclusions regarding effects to fish and fish habitat in the transmission corridor for all phases of the project. Additional sampling should occur during the permitting stage to refine estimates of the extent and quality of fish habitat and the determination of compensation requirements. Specific and general deficiencies are discussed in Sections 4.1.1, 4.2.1 and 5.1.1.

8.1.2 Mine Site

I believe the data and assessment are insufficient to support the Proponent's conclusions regarding effects on fish and fish habitat within the mine site. The Project EA should include additional assessment of effects of flow reductions and effects of changes in water quality. This work should occur during the EA phase. Additional sampling should also occur during the permitting stage to refine estimates of the extent and quality of fish habitat and the determination of compensation requirements. Specific and general deficiencies are discussed in Sections 4.1.2, 4.2.2 and 5.1.2.

8.1.3 Morrison Lake

I believe the data and assessment are insufficient to support the Proponent's conclusions regarding effects on fish and fish habitat in Morrison Lake. Ultimately, all the deficiencies relate to predicting the ecological response to expected changes in water quality from seepage and effluent discharge. If the proponent cannot demonstrate, through enhanced modelling, analysis and/or design and mitigation that they can improve water quality of seepage and effluent discharge, considerably more information on habitat use by different fish species is required to understand the potential exposure of fish to high concentrations of some pollutants. Specific and general deficiencies in the Project EA are discussed in Sections 4.1.3, 4.2.3 and 5.1.3.

8.1.4 Adaptive Management Plans

I believe the Adaptive Management Plans as currently proposed are deficient in several respects. Insufficient detail is provided for response monitoring, including experimental design, level of effort to be applied, power of the program to detect effects, methods for comparing before and after conditions, target species to be used, triggers for decisions, and the actions to be implemented should results indicate additional mitigation or compensation is required. Specific and general deficiencies are discussed in Section 7.

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10. DEFINITIONS

There are no universally accepted or universally applicable definitions for all major projects. The following definitions were used in this review.

Mitigation.— Mitigation refers to measures taken to avoid or reduce the likelihood of negative impacts from construction and operation of physical works or an activity. The explicit purpose of mitigation is to avoid impacts.

Compensation.— Compensation refers to intentional activities undertaken to offset impacts after they occur, by providing benefits (e.g., habitat enhancements) elsewhere in the system.

Response Monitoring.— Biotic response monitoring involves a test of whether compliance results in the expected outcomes on the target ecological resources (e.g., fish populations, fish habitat, invertebrate production). Since biological responses are difficult to measure and variable in space and time an effective monitoring program must be designed to address the complexity of relationships between biological responses and physical states or factors (e.g., flow), and to account for external factors (e.g., non-flow related) and natural temporal variations. The overriding argument for implementing a biotic response monitoring program is recognition of the current uncertainty in predictions of biological response (e.g., fish abundance) to changes in environmental conditions.

Compliance Monitoring.— Compliance monitoring measures resource use (e.g., water use) or physical state (e.g., water quality) to ensure a user is complying with the conditions of permits. Compliance monitoring may also apply to habitat compensation works to ensure that they are physically stable and performing adequately.

Footprint Impact.— An impact associated with the project footprint, which is the land or water area directly disturbed by assessment, construction and clean-up activities, including associated physical works and activities. For example, habitat disturbed by structures, buildings, rights-of-way, construction workspace, or access routes.

Operational Impact.— An impact associated with operation of the project. Such impacts often vary temporally in association with water use (or use of another resource). For example, habitat quantity and quality associated with water flows in a diversion reach.

Residual Impact.— The impact remaining after all mitigation is applied. The assessment should consider extent, duration, frequency and magnitude of impacts.

Significant Impact.— A high probability of occurrence of residual effect that cannot be avoided or mitigated, having a combination of characteristics that render it unacceptable to the public, regulators, other interests, or that exceeds standards or contravenes legal requirements.

Less than Significant Impact.— All other impacts.

Frequency of Impact:

> **Accidental.—** Event occurs rarely over assessment period and does not occur under normal conditions.

Isolated.— Event is confined to a specific period (e.g., construction period; less than or equal to 10% of the assessment period).

Occasional.— Event occurs intermittently and sporadically (e.g., animal mortalities on road ways, and ground disturbance from unscheduled maintenance; estimated 10-15% of the assessment period).

Periodic.— Event occurs intermittently but repeatedly over the construction and operations period (e.g., mowing during routine maintenance activities; routine aerial patrols; estimated >15% but <80% of the assessment period).

Continuous.— Event occurs continually over the assessment period (e.g., noise at compressor station; estimated >80% of the assessment period).

Magnitude of Impact:

Negligible.— Residual effect is not detectable.

Low.— Potential residual effect is detectable but well below established or derived environmental standards or thresholds.

Medium.— Potential residual effect is detectable but within established or derived environmental and/or regulatory standards or thresholds.

High.— Potential residual effect is beyond established or derived environmental standards or thresholds, or causes a detectable change beyond range of natural variability, or management plans for the indicator being considered.

Extent of Impact:

Project Footprint.— The Project footprint (PF) for the project is the land area directly disturbed by assessment, construction and clean-up activities, including associated physical works and activities (*i.e.,* permanent right-of-way, temporary construction workspace, temporary access route, temporary stockpile site, temporary staging area, facility sites).

Local.— The Local Study Area (LSA) is defined as a 2 km buffer around the project footprint. The LSA is an 'indirect footprint' area and includes the zone of influence within which plants (50 m), animals (500 m), and humans (500 to 800 m) are most likely to be affected by project construction and operation. The width of this buffer will likely vary with project size and type.

Regional.— The Regional Study Area (RSA) extends beyond the LSA and may be broad enough to include those communities within the study region that may be affected economically (*e.g.*, jobs, accommodation) or socially (*e.g.*, hospitals, police).

Duration of Impact:

Immediate.— Event duration is limited to less than or equal to two days.

Short-term.— Event duration is longer than two days but less than or equal to one year.

Medium-term.— Event duration of is longer than one year but less than or equal to five years.

Long-term.— Event duration extends longer than five years.

Reversibility of Impact:

Immediate.— Residual effect is alleviated in less than or equal to two days.

Short-term.— Greater than two days but less than or equal to one year to reverse residual effect.

Medium-term.— Greater than one year but less than or equal to five years to reverse residual effect.

Long-term.— Greater than five years to reverse residual effect.

Permanent.— Residual effect is irreversible.

Probability of residual effect:

High.— Is expected to occur.

Low.— Is not expected to occur.

Level of confidence related to significance evaluation:

Low.— Determination of significance based on incomplete understanding of cause-effect relationships and or incomplete data pertinent to the project area.

Moderate.— Determination of significance based on good understanding of cause-effect relationships using data from outside the project area or incompletely understood cause-effect relationships using data pertinent to the project area.

High.— Determination of significance based on good understanding of cause-effect relationships and data pertinent to the project area.