SUFFICIENCY REVIEW OF LAKE PRODUCTIVITY INFORMATION CONTAINED IN THE ENVIRONMENTAL IMPACT STATEMENT FOR THE NEW PROSPERITY GOLD-COPPER MINE PROJECT

Context

Taseko Mines Limited (The Proponent) has proposed the development and operation of a gold and copper mine (New Prosperity Mine), located on the Fraser plateau, approximately 125 km southwest of Williams Lake, British Columbia. The project has a 20 year estimated operating life, and would employ conventional copper porphyry floatation processing. Development of the mine would involve new construction of an open pit, an onsite mill and support infrastructure capable of processing 70,000 tonnes of ore per day, a 125km power transmission line, a 2.8km mine access road, a tailings storage facility and ore and waste rock storage areas.

The proposed mine would be located within the Fish Creek watershed, which hosts several fish-bearing creeks and lakes, including Fish Lake, that are likely to be impacted by the development. A previous project submission to the Canadian Environmental Assessment Agency (CEAA) occurred in 2009-2010, but was deemed by a federal review panel to have significant adverse environmental effects. The Government of Canada agreed with the federal review panel and the project was not approved for development. The current New Prosperity project is a modification of the former development proposal, and the subject of an ongoing Canadian Environmental Assessment Act (CEAA) review (CEAA Registry 11-05-63928).

In October, 2012, Fisheries and Oceans Canada's Pacific Region Ecosystem Management Branch (Environmental Assessment and Major Projects Unit - EAMP) requested Pacific Region Science Branch to conduct a review of the New Prosperity Gold-Copper Mine Project Environmental Impact Statement (hereafter referred to as the EIS; submitted September 27, 2012) for information adequacy and completeness necessary to the proper evaluation of potential effects of mining activities on the productivity of Fish Lake.

Specifically,

1. Is the information referenced both sufficient and recent enough for Science to assess future productivity of Fish Lake and its tributaries?
2. If not, what other information would be reasonable to request to infer future productivity?
3. Is there enough information to make reasonably informed inferences, or to identify risks associated with data gaps?
4. Are the methods used to assess the potential effects on future productivity of Fish Lake appropriate and executed properly.

The current EIS review updates an earlier Science Branch review of the draft New Prosperity EIS (DFO 2012), as part of the Agency-led screening concluded on June 27, 2012, and is referenced throughout this document as DFO 2012 (available from http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm)

This Science Special Response is from the October 22, 2012 Science Special Response review process considering the sufficiency of the lake productivity information submitted in relation to the New Prosperity Gold-Copper Mine project.

Background

Fish Lake is a 112 ha, biologically-productive and shallow lake ecosystem located in the Fish Creek drainage of the Fraser plateau. As outlined in the Environmental Impact Statement (EIS), the proposed New Prosperity mine will impact the catchment hydrology supplying Fish Lake, the hydrological and hydrochemical properties of its tributaries, as well as the limnological characteristics of the lake itself. Concern exists over the potential impacts to a non-anadromous *Oncorhynchus mykiss* (rainbow trout) population harvested in both aboriginal and recreational fisheries.

As outlined in the EIS, > 50% of the upstream catchment area for Fish Lake would be cut off from Fish Lake during the life of the mine. Discharge from the outlet of Fish Lake would be actively captured and pumped up to the remaining reaches of headwater streams to retain inflow to the lake. This arrangement is likely to impact the trophic status and ecosystem structure and functioning of Fish Lake, and is a concern for the future biological productivity of Fish Lake in terms of lake habitat and fisheries productivity.

Lake productivity is governed by numerous abiotic and biotic factors, both internal and external to lake ecosystems (Wetzel 2001). In a trophic ecology (food web) context, important regulators of productivity include the availability and proportions of limiting nutrients (i.e., phosphorus and nitrogen) and light for autotrophic production, the efficiency of trophic energy transfers (i.e. algae→zooplankton or benthos→fish; governed by the abundance and species composition of prey items at each trophic level), and water quality parameters (i.e. temperature, pH, oxygen, contaminants) important to the persistence of fish species (Wetzel 2001, Kalff 2002). Other direct and indirect habitat limitations on fisheries productivity, include factors that influence reproductive success and the survival of individuals and populations, such as the quantity of suitable spawning habitat (i.e. substrate, pore-water quality), dissolved oxygen availability (i.e. winterkills, hypoxia), sub-lethal and lethal contaminant levels in water and/or sediments, and predation rates (Hartman and Miles 2001).

Lake and river habitats are inherently integrated features of the watersheds from which they originate. Modifications to terrestrial catchment attributes can have important impacts on abiotic and biotic conditions in downstream aquatic habitats, such as lakes, with commensurate impacts on habitat and fisheries productivity. This connectivity necessitates the consideration of lake productivity in a watershed context.

In this review of the sufficiency of information, the New Prosperity Mine EIS was reviewed with a focus on aspects of lake habitat productivity and habitat quality that pertain to the trophic ecology of fish, particularly rainbow trout, and to the coupling of the watershed to lake habitat productivity and water quality. Fisheries and Oceans Canada’s Ecosystems Management Branch has deemed the aspects of fish survival and reproductive success related to contaminant loading and fish contaminant burdens to be the jurisdiction of Environment Canada. Therefore, any potential contaminant influences on lake productivity (i.e., food web impacts), although potentially important, have not been considered here.

Analysis and Responses

The following are Science Branch responses to the questions posed by DFO EAMP regarding the Taseko Mines Ltd. New Prosperity Mine EIS submitted September 27, 2012.

Is the information referenced both sufficient and recent enough for Science to assess future productivity of Fish Lake and its tributaries?

Information Sufficiency and Recentness

As noted previously in DFO (2012), predictive modeling has been conducted to characterize many of the anticipated impacts of the New Prosperity Mine on habitat and fisheries productivity in Fish Lake and its tributaries. These predictions include changes in catchment area, altered flow volumes, changes in the nutrient chemistry of Fish Lake and its tributaries, and changes in lake biological productivity. This review finds several key aspects of the EIS, however, to remain insufficient in detail to fully assess future changes in the habitat and fisheries productivity of Fish Lake and its tributaries. These insufficiencies are highlighted in detail in the responses to Question 2 below.

1. ***If not, what other information would be reasonable to request to infer future productivity?***

Climate Change

Climate change and increasing climate variability are likely to be the primary large-scale drivers of future water distribution and quality (IPCC 2007), and principal controls on aquatic ecosystem structure and functioning both in western Canada (Selbie et al. 2011) and around the globe (Walther et al. 2002).

In their climate change assessment, the Proponent has negated any impacts of climate change on the Fish Lake watershed throughout the past century, referencing purportedly complacent temperature and precipitation time series from the meteorological records at Barkerville, British Columbia. The representativeness of the Barkerville station for characterizing the climatic conditions at Fish Lake, however, is highly questionable, as it is located approximately 230 km northeast of Fish Lake, BC. Moreover, the Government of British Columbia includes the Barkerville station within the Sub-Boreal Ecoprovince, a biogeoclimatically-distinct region from the Central Interior Ecoprovince, where Fish Lake is situated (BCMWLAP 2006). As ecoprovinces are inherently defined by distinct climates, topographies, and geological histories (BCMWLAP 2006), the biogeoclimatic settings at Barkerville and Fish Lake are fundamentally different. To illustrate this contrast, the temperature and precipitation trends in the Sub-Boreal and Central Interior ecoprovinces over the past century are summarized in Table 1 from the Government of British Columbia's *Indicators of Climate Change for British Columbia 2002* (BCMWLAP 2006).

The BCMWLAP (2006) data indicate that the Central Interior Ecoprovince (containing the Fish Lake watershed) has experienced substantial climatic change over the past century. The rate of warming in the Central Interior Ecoprovince (Fish Lake) has been greater than that for the Sub-Boreal Interior Ecoprovince (Barkerville) for all seasonal measures of temperature, except summer minimum temperatures (Table 1). In particular, the BCMWLAP (2006) reports significant warming in spring and summer (Table 1). The Proponent, however, did not consider changes in seasonal temperature patterns in their analysis, despite the critical influence of changing seasonality on lake stratification and ice cover, key drivers of lake and fisheries productivity in northern-temperate lakes (Hostetler and Small 1999; Selbie et al. 2011). It should be noted that the range of warming reported in both the Central Interior and Sub-Boreal Interior ecoprovinces have elicited major impacts on freshwater lakes in British Columbia (i.e. changes in lake stratification and ice cover; BCMWLAP 2006; Selbie et al. 2011).

Table 1: Comparison of select historical climate change parameters between the Central Interior and Sub-Boreal ecoprovinces

Climate Change Parameter	Period of Record	Central Interior Ecoprovince (Fish Lake, BC)	Sub-Boreal Interior Ecoprovince (Barkerville, BC)
Annual Mean Temperature	1895-1995	+ 1.1°C/century	+ 1.1°C/century
Spring Mean Temperature	1895-1995	**+ 1.9°C/century**	**+ 1.7°C/century**
Summer Mean Temperature	1895-1995	**+ 0.8°C/century**	**No Trend**
Fall Mean Temperature	1895-1995	Not Trend	No Trend
Winter Mean Temperature	1895-1995	No Trend	No Trend
Annual Max Temperature	1895-1995	No Trend	No Trend
Spring Max Temperature	1895-1995	**+ 1.7°C/century**	**+ 1.3°C/century**
Summer Max Temperature	1895-1995	No Trend	No Trend
Fall Max Temperature	1895-1995	No Trend	No Trend
Winter Max Temperature	1895-1995	No Trend	No Trend
Annual Min Temperature	1895-1995	+ 1.7°C/century	+ 1.7°C/century
Spring Min Temperature	1895-1995	**+ 2.2°C/century**	**+ 2.1°C/century**
Summer Min Temperature	1895-1995	**+ 1.5°C/century**	**+ 1.7°C/century**
Fall Min Temperature	1895-1995	**+ 2.6°C/century**	**+ 2.2°C/century**
Winter Min Temperature	1895-1995	No Trend	No Trend
Annual Mean Precipitation	1929-1998	**+ 2%/decade**	Insufficient Data
Spring Mean Precipitation	1929-1998	**+ 3%/decade**	Insufficient Data
Summer Mean Precipitation	1929-1998	No Trend	Insufficient Data
Fall Mean Precipitation	1929-1998	No Trend	Insufficient Data
Winter Mean Precipitation	1929-1998	No Trend	Insufficient Data
Snow Depth	1935-2000	**- 9%/decade**	Insufficient Data

Data summarized from BCMWLAP (2006).

Similarly, precipitation in the Central Interior Ecoprovince has increased at a rate of +2% per decade, with the greatest increases in spring precipitation (+ 3% per decade; Table 1; BCMWLAP 2006). These statistically-significant trends contradict the assertion of the Proponent that there have been limited changes in precipitation at Fish Lake. Moreover, they span a much longer record (1929-1998) than the post-1950's period that the Proponent has suggested BCMWLAP (2006) reports. Despite increasing spring and summer precipitation, a pronounced rate of snowpack decline of 9%/decade has been observed since 1935 in the Central Interior Ecoprovince.

Cumulatively, the climate data reported in BCMLAP (2006) highlight the substantial meteorological changes that have occurred within the Central Interior Ecoprovince. While heterogeneity can exist in local climate responses, arising from unique landscape and atmospheric features, it is probable that the Fish Lake watershed has experienced similar climatic patterns, and will continue to experience the influences of directional climate change into the future.

Total and seasonal water availability, evaporation, inflows and discharge, lake thermal structure and seasonal productivity patterns are all closely linked to changes in temperature, precipitation, and snowpack conditions. As such, further information on the current and future impacts of climate change and increased seasonal variability on the hydrology and hydrochemistry of the Fish Lake watershed are required to fully assess the adequacy of the EIS modeling efforts. Regional climate models may be incorporated into the estimations of water quantity and quality, and projected, at a minimum, over the next century (i.e. not just the 20 year life of the mine), to assess additive and interactive effects on lake and fisheries productivity. (e.g. ClimateBC http://www.genetics.forestry.ubc.ca/cfcg/ClimateBC/ClimateBC.html). Similarly, estimates of seasonal climate variability in response to climate cycles (i.e. Pacific Decadal Oscillation; El Niño Southern Oscillation) can be incorporated into projections for future lake and watershed hydrologic conditions (e.g. NRCAN Indicators of Climate Variability and Change; http://www.nrcan.gc.ca/earth-sciences/climate-change/community-adaptation/assessments/259).

Water Diversions, Limiting Nutrients Lake Trophic Status, Lake Ecology and Fish Productivity

The primary limiting nutrients to autotrophic productivity in lakes (and thus the basis for food web productivity for fish) are phosphorus (P) and nitrogen (N; Wetzel 2001; Kalff 2002). The Proponent has characterized Fish Lake as a P-limited system in the EIS and previous submissions, and fish biomass models have been applied that are based upon an underlying P-limitation assumption (i.e. Plante and Downing 1993). The characterization of Fish Lake as a P-limited system has been contended by DFO Science Branch during the 2009-2010 review process (documented in the testimony of D.T. Selbie in the CEAA hearing transcripts, Mainland, 2010), and the review of the draft EIS (DFO 2012). As the accuracy of fisheries productivity and lake habitat modeling (mainly TP-based) is contingent upon the true nutrient limitation in Fish Lake, the following discussion focuses on the nature of nutrient limitation in the system, to better aid in understanding the validity of the models presented in the EIS.

N- vs. P-limitation is most commonly determined through elemental stoichiometry, such as the comparison of total nitrogen to total phosphorus molar ratios ($TN:TP_{molar}$; Guildford and Hecky 2000; Davies et al. 2004). Guildford and Hecky (2000) define algal productivity as N-deficient at $TN:TP_{molar} < 20$, and P-deficient growth at $TN:TP_{molar} > 50$, with either N or P becoming deficient at ratio values between 20 and 50.

The most recent assessment of nutrient limitation in Fish Lake, to support the trophic status modeling in the EIS, was based upon TN:TP molar stoichiometry from new sampling conducted in 2011. In contrast to previous sampling (Taseko 2009), the summer water chemistry samples were obtained by integrating water throughout the water column in Fish Lake. It is unclear why existing data for the project, which were measured as discrete values retrieved at specific depths, were not incorporated in this analysis. While a water column-integrated approach may approximate the overall N to P availability for the lake, limitation of food webs (and thus fisheries productivity) typically occurs during the ice-free, stratified period, within the biologically-active euphotic layer (Wetzel 2001; Selbie et al. 2011). In Fish Lake, the euphotic zone is shallow, most of which is contained within the density-isolated epilimnion (Shortreed and Morton 2000). As Fish Lake strongly stratifies for an extended period, surface waters likely follow a progressive depletion of inorganic N (the N fraction readily biologically available) throughout the growing season, as do other lakes of varying trophic status in BC (Shortreed et al. 2001; Selbie et al. 2011). Shortreed and Morton (2000) observed severe epilimnetic N-limitation in Fish Lake in June 1999 ($TN:TP_{molar}$ = 7.87), and data collected by Taskeo Mines Ltd. In their 2006 July and October sampling demonstrate a range of N- to P-limitation throughout the water column in summer and fall ($TN:TP_{molar}$ = 7.39 – 91.1; data from Taseko 2009). These data would suggest Fish Lake experiences acute N-limitation throughout part of the growing season. Other lines of evidence support the seasonal development of food web N-limitation in Fish Lake through the stratified period, including the presence and bloom formation of N-fixing cyanobacteria (e.g. *Aphanizomenon flos-aquae, Anabaena* spp., *Anabaenopsis* spp.) in summer and fall (Morton and Shortreed 2000; Taseko 2009) and the low baseline chlorophyll *a* concentrations relative to existing TP levels (*see* EIS Trophic State Models). While the sampling conducted by The Proponent is of insufficient temporal resolution to ascertain the magnitude and timing of N-limitation in Fish Lake, it may be substantial, and could undermine the validity of the lake trophic status and fish productivity models, which are ultimately based upon the assumption of chronic P-limitation of biological production.

In order to understand future lake and fisheries changes in Fish Lake associated with the proposed altered hydrology (and associated variations in trophic status), it is necessary to use fish production and habitat models that accurately characterize and incorporate real food web limitation conditions in Fish Lake (either N- or P or both). Ultimately, it is unclear that the current limnological characterization of Fish Lake, and the predictions based upon chronic food web P-limitation are accurate. Moreover, it is unclear how the recirculation of Fish Lake will impact N cycling within the watershed and lake. As N is not readily internally-loaded from the sediments as P is in Fish Lake, predicting TN (particularly epilimnetic concentrations) in appropriate water quality models would allow an assessment of future food web limitation in Fish Lake, and the true impacts on lake and fish productivity to be assessed. It is important to note that enhanced N-limitation in Fish Lake could reduce fish productivity as a result of reduced food web productivity and/or trophic restructuring.

Mitigation Measures to Protect Aquatic Ecology

The EIS indicates that mitigation measures will be undertaken for the protection of water quality to buffer any increases in lake phosphorus concentrations and impacts on Fish Lake productivity. In general, proposed mitigation methods (i.e. hypolimnetic aeration, addition of alum to precipitate P), are accepted lake management practices for culturally-eutrophied lakes. The Proponent refers to “trigger or alert” phosphorus levels that, once exceeded, would trigger active mitigation. Based upon a reported range in baseline P conditions (15-42µg/L P), the Proponent has calculated critical concentrations requiring mitigation to be in excess of 22-63 µg/L (~ 50% greater than baseline P levels). The reported “trigger” range, however, is broad, and transcends multiple trophic state classifications. As such, it is unclear what critical P concentration would precipitate mitigation actions, particularly as baseline conditions overlap with the predicted threshold range.

Moreover, it is not clear what fraction of P or if total phosphorus (TP) is the metric being considered. Lake P concentrations can vary in species (i.e. inorganic fractions, organic fractions), and both seasonally and spatially in lakes. Thus the timing (i.e. spring turnover concentrations) and location of "trigger" P samples must be clarified to evaluate the efficacy of the proposed techniques. More detail on the evaluation of trophic status and the threshold for initiating mitigation efforts is needed to accurately evaluate the efficacy of the proposed approaches to protect Fish Lake and its rainbow trout population from the anticipated effects of eutrophication.

As noted in DFO (2012), and in the previous discussion, Fish Lake likely experiences episodes of acute seasonal N-limitation in the surface waters. As N-limitation can cause deleterious blooms of cyanobacteria (blue-green algae) with impacts on water quality, food web productivity, and deepwater oxygen levels during stratification, decisions and cut-offs for implementation measures would be critical to Fish Lake habitat and fisheries productivity.

The general lack of specificity in the threshold P values that would trigger mitigation actions makes an assessment of the proposed mitigation plan problematic. Moreover, the current EIS contains limited information regarding other important lake water quality parameters that might be monitored to assess the need for mitigation against eutrophication (i.e. measures of nutrient limitation such as TN:TP, POC:PON). Further documentation on the proposed water chemistry monitoring program is required to evaluate the ability of The Proponent to detect and act upon water quality issues in Fish Lake.

While the proposed lake P targets are almost certainly not sufficiently sensitive to detect critical lake nutrient changes, and thus currently compromise the success of mitigation, the efficacy of the proposed mitigation measures in other lake systems suggest that in concept, mitigation, or at least minimization of eutrophication in Fish Lake may be able to be achieved. Failure to accurately monitor and implement mitigation measures in a timely fashion, however, could have strongly deleterious effects on the persistence of rainbow trout in Fish Lake (i.e. pervasive fish kills).

2. *Is there enough information to make reasonably informed inferences, or to identify risks associated with data gaps?*

As noted in Question 2 and in DFO 2012, there are critical information gaps surrounding the characterization of current and future conditions in Fish Lake (i.e. N-availability, oxygen-availability, lake physics and ecology associated with climate change), which unless accurately modeled, will compromise the ability to make reasonably informed decisions on the impacts to lake and fish productivity. Failure to produce this suite of information represents a critical data gap, and will necessarily result in a more conservative and precautionary approach to assessment of the potential impacts of mine development on the productivity of Fish Lake.

3. *Are the methods used to assess the potential effects on future productivity of Fish Lake appropriate and executed properly.*

Although the analyses presented are generally methodologically sound, in light of the omissions noted above, and the Proponent's characterization of the Fish Lake ecosystem, the approaches presented in the EIS are not sufficiently comprehensive to enable full environmental evaluation of impacts of the New Prosperity project on the productivity of the Fish Lake.

Conclusions

This EIS builds upon a former CEAA project submission that was deemed by a federal review panel and the Government of Canada to have significant adverse environmental affects, and was not approved for development. The New Prosperity Mine configuration was modified from the original plan to prevent the immediate destruction of Fish Lake to create a tailings pond. In the New Prosperity Mine configuration, the Fish Lake watershed would be extensively altered, requiring intensive engineering efforts to maintain flows and lake levels. While Fish Lake itself would not be directly destroyed, as noted in the EIS, the lake is predicted to experience eventual eutrophication and contamination with development of the mine.

Prior involvement by Fisheries and Oceans Canada's Science Branch in the previous CEAA review (2009-2010), and familiarity with the proponent's characterizations of Fish Lake, enabled inferences about data quality, representativeness and sufficiency for a future technical review to be reasonably made.

A review of the New Prosperity mine EIS revealed an intensive effort by the proponent to model the physical, chemical and biological impacts of mine development on the Fish lake watershed, and the productivity of Fish Lake. Several shortcomings, however, were identified in the modeling and the characterization of Fish Lake before, during and after mining operations. In particular, habitat and fish productivity models assuming phosphorus-limitation of Fish Lake may not be appropriate. Moreover, the future effects of past and future climate change and variability, lake eutrophication, and recirculation of lake outflow water to inflows on the nutrient status, thermal regimes, and productivity of Fish Lake have not been fully considered. Failure to adequately characterize the future conditions for Fish Lake contributes real uncertainty in predictions of future habitat and fisheries productivity of the system.

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