Information Request 19

Responses to Information Request 19

IR 19 – Lake Productivity – Eutrophication

References:

EIS Guidelines, Section 2.7.2.5 and 2.7.2.4
EIS, Table 2.7.2.5-24 (Summary of Predicted Fish Lake TP Concentrations (µg/L) during all Project Phases)
EIS Appendix 2.7.2.4B-A (Effects of Reduced Inflow on Fish Lake Trophic Status Using the Mass Balance Approach)

Related comments:

CEAR # 277 (Fisheries and Oceans Canada)
CEAR # 302 (Canadian Science Advisory Secretariat)
CEAR # 292 (Environment Canada)
CEAR # 276 (BC Ministry of the Environment)

Rationale:

The EIS Guidelines state that the Proponent shall address issues such as habitat, nutrient and chemical cycles, food chains, productivity and climate information, to the extent that they are appropriate to understanding the effect of the Project on ecosystem health and integrity. Section 2.7.2.5 of the Guidelines includes evaluating changes in nutrients and dissolved oxygen as a result of the project effects for fish and fish habitat.

Taseko has characterized Fish Lake as a P-limited system in the EIS and fish biomass models have been applied that are based upon an underlying P limitation assumption. The MOE noted that the modeling of Fish Lake phosphorus does not include the hypolimnion. This cooler water, which is high in phosphorus, would be drawn from the lake and then reintroduced via the creeks to the epilimnion which could cause a shift in the trophic status if algal blooms result in anoxic conditions.

In addition, the characterization of Fish Lake as a P-limited system has been disputed by DFO Science Advisory Branch in the 2009-2010 review process and in the review of the draft EIS.

It is, therefore, unclear to the Panel if the current limnological characterization of Fish Lake and the predictions based upon chronic food web phosphorus limitation are accurate.

Information Requested:

In order for the Panel to better understand habitat and fisheries changes in Fish Lake associated with the proposed altered hydrology and associated variations in trophic status, the Panel requests that Taseko:

a. Discuss the validity of the models presented in the EIS.

b. Provide predictions of Total Nitrogen, particularly epilimnetic concentrations and the impacts on fish productivity and lake habitat using appropriate water quality models that characterize and incorporate real food web limitation conditions in Fish Lake.

c. Discuss how the recirculation of Fish Lake will impact nitrogen cycling within the watershed and affect lake productivity.

In addition, the Panel requests that Taseko:

d. Discuss the impact the loss of wetland area immediately upstream of Fish Lake could have on the nutrient balance and other ecological characteristics of the lake and the lower watershed.

e. Provide more information on phosphorus loading in Fish Lake through the combined effect of direct deposition of phosphorus from dust emissions on the Upper Fish Creek / Fish Lake watershed and from recycling of water from the Fish Lake outlet to Upper Fish Creek.

Information Request #19a

Discuss the validity of the models presented in the EIS.

Response Summary

The Vollenweider and BATHTUB models were selected to predict the productivity and trophic status of Fish Lake. These two independent, but complementary models are very well established and widely used in aquatic ecology, especially in northern lakes. The use of two models was to determine if the separate predictions corroborate each other and in the process, increase the reliability of productivity predictions in Fish Lake. The application of these models for this purpose is considered suitable and valid.

Discussion

The main questions addressed in this report are:

1. Will the trophic status of Fish Lake change with the planned reduced inflow; and,
2. Will changes in Fish Lake trophic status, if any, as a result of mine development affect the aquatic ecology (primary productivity and fish productivity) of Fish Lake

The two main models employed in determining the productivity of Fish Lake for the New Prosperity Project were the classic empirical mass balance model developed by Vollenweider (Vollenweider, 1975, 1976) and the BATHTUB eutrophication response model developed by the United States Army Corps of Engineers (USGS), (Walker, 1985, 1986, 1999; Nürnberg and LaZerte, 2001). At the core of these two models is the fundamental ecological concept that the productivity and trophic state of a lake is largely dependent on nutrient input and water renewal (Schindler, 2009). Both the Vollenweider and BATHTUB models are based on the water renewal concepts and nutrient influx into an aquatic ecosystem.

These two independent, but complementary models are very well established and widely used in aquatic ecology, especially in northern lakes (refer to Fish Lake Productivity Report, Appendix 2.7.2.4B-A). The use of two models was to determine if predictions from the two independent but related models corroborate each other and in the process, increase the reliability of productivity predictions in Fish Lake. In addition, nutrient data from GoldSim water quality iterations were used in conjunction with the BATHTUB model data to determine the trophic status of Fish Lake during the differsent Project phases (Appendix 2.7.2.4B-G of the Project's Environmental Impact Statement (EIS)).

Beside the use of the two P-based models to address the potential effects of reduced natural inflow and induced recirculation on Fish Lake productivity, several key indicators or indices of trophic state were determined for Fish Lake including hydraulic retention time, internal P recycling, nutrient concentrations and ratios, and fish productivity during the different Project phases.

Rationale for Model Selection

The Vollenweider and BATHTUB models were subsequently selected from a large array of other models based on the following:

1. Extensive literature review of the scientific literature on nutrient dynamics and eutrophication in aquatic ecosystems, especially northern lakes.
2. Discussion and email correspondences with the developers of the BATHTUB model (Dr. David M. Soballe, United States Army Engineer Research and Development Center, Waterways Experiment Station, Vicksburg, MS) on the appropriateness and applicability of the model to the questions being raised.
3. Discussion with senior limnologists and microbial ecologists' colleagues; and,
4. Fish and fish habitat studies of the Fish Lake watershed (Triton, 2011).

The development and application of these models were subsequently peer-reviewed and adjudged to be suitable for productivity assessment in Fish Lake by an independent third-party reviewer.

Conclusion

The selection of models used in predicting productivity in Fish Lake for the New Prosperity Project was based on sound science following an extensive literature review. These models were further subjected to a third-party external review by a senior professional biologist (R. P. Bio.) as well as by senior aquatic ecologist colleagues. These models are valid for predicting the productivity and trophic status of Fish Lake.

After an in-depth review of the various comments from the different regulators (i.e., EC, NRCAN, BCEAO and DFO), it is apparent that the regulators agree that the methods and analyses presented in the report were sound (for example, refer to page 2 of DFO Comments in a November 9, 2012 memo-11-HPAC-PA8-00031-sent to the Chair of the New Prosperity Gold-Copper Mine Project Federal Review Chairman).

References

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Information Request #19b

Provide predictions of Total Nitrogen, particularly epilimnetic concentrations and the impacts on fish productivity and Lake Habitat using appropriate water quality models that characterize and incorporate real food web limitation conditions in Fish Lake.

Response Summary

The BATHTUB model, (as described in IR 19a and *Fish Lake Productivity Report*, Appendix 2.7.2.4B-A of the New Prosperity Project EIS), was used to predict the trophic status of Fish Lake throughout the life of the Project and is considered appropriate for characterizing and incorporating real food web limitation conditions. Several species of nitrogen (N) were used as input to the BATHTUB model iterations and N influence on Fish Lake trophic status with recirculation is therefore taken into consideration. The BATHTUB iterations indicate that the trophic status of Fish Lake could change from the current baseline meso-eutrophic condition to a more productive, eutrophic state during the life of mine and beyond. This in turn could result in diminished fish productivity and a reduced lake water quality. Monitoring of Fish Lake's water quality parameters (IR 25d) will allow for careful evaluation of model predictions with respect to the lake's ecology and should the need arise, appropriate mitigation or remedial measures will be implemented to ensure the sustainability of resident Rainbow Trout populations.

Discussion

The BATHTUB model, (as described in IR 19a and *Fish Lake Productivity Report*, Appendix 2.7.2.4B-A of the New Prosperity Project's Environmental Impact Statement), was used to predict productivity and trophic status of Fish Lake during the life of mine and beyond (i.e., construction, operations, closure, and post-closure phases). BATHTUB is a suite of sub-models utilizing empirical eutrophication algorithms that relate lake trophic status to total phosphorus, total nitrogen, algal biomass, transparency (Secchi depth), and hypolimnetic oxygen depletion rates resulting from different patterns of nutrient loadings. BATHTUB has been cited as an effective tool for water quality assessment and management, particularly where limited data are available for the lake or reservoir (see for instance Ernst et al., 1994; Nadim et al., 2007). However, in this case, many parameters that describe the atmospheric loads, in-lake water quality parameters, water quality of the tributaries as well as morphological characteristics of Fish Lake and tributaries were available and were entered into the model (see Table 2, *Fish Lake Productivity Report*, Appendix 2.7.2.4B-A of the New Prosperity Project EIS).

As described in IR 19a and *Fish Lake Productivity Report*, the BATHTUB model is considered suitable for characterizing and incorporating real food web limitation conditions in Fish Lake. Specifically, BATHTUB helps address the two pertinent questions related to the New Prosperity Project configuration:

1. Will the trophic status of Fish Lake change with the recirculating inflow; and,

2. Will change in Fish Lake trophic status, if any, as a result of mine development affect the aquatic ecology (primary productivity and fish productivity) of Fish Lake

The two major nutrients, nitrogen (N) and phosphorus (P), which influence productivity in most northern lakes were included in the model calibration. With respect to N, several species of N, including total nitrogen, inorganic nitrogen, and organic nitrogen were used as input into the model in order to predict water quality and metric of productivity, however, predicted N concentrations were not reported in the *Fish Lake Productivity Report.* The rationale for excluding modeled N from BATHTUB output was based on the advice of the model developers (Dr. Soballe, pers. comm.) and extensive literature review of the current state of N modeling with respect to N dynamics and fluxes in aquatic ecosystems (see for example Wetzel, 2001; Schlesinger, 1997; Schindler, 2012).

Although there is a considerable amount of “empirical” or mass balance modeling done with N and P, N species are more difficult to model because N is not a conservative element (Schlesinger, 1997). There are many routes through which N can enter a lake. For example, through atmospheric deposition, precipitation, internal regeneration, loading from the catchment area, and nitrogen fixation by nitrogen fixing heterocystous cyanobacteria (Schindler et al., 2008, Schindler, 2012). In contrast, N can also be removed via several routes including outflow, sedimentation and denitrification (Schlesinger, 1997; see also Sterner, 2008). BATHTUB iterations account for nutrient fluxes from sediments (i.e., sedimentation and internal nutrient regeneration). The interactions, exchanges and fluxes of N in natural aquatic ecosystems, are almost all biologically mediated, with the atmosphere and other pools being difficult to quantify (Schindler, 2012). These rates or fluxes of various N species also cannot be assumed to be constant in space or time.

In order to answer the specific request for predictions of Total Nitrogen, the following Table 19B-1 is provided taking into consideration the described limitations of BATHTUB to accurately predict epilimnetic N concentrations in Fish Lake.

Table 19B-1 Total Nitrogen Predicted through the Life of the Project (µg/L)

Phase	*Parameters*	*July*	*August*	*Sept*	*October to June*
Baseline	TN	76	76	76	76
1: Start operation to end mining/ milling (Yr 1- 17)	TN†	598.9	609	658	691
2: Closure (Yr 18-21)	TN†	604	614	662.8	700.2
3: Post-closure 1 (Yr 22-31)	TN†	593.9	604	653.2	686.4
4: Post-closure 2 (Yr 31 and beyond)	TN†	628.8	633.8	686.4	731.8

†A significant portion of Total Nitrogen (TN) is predicted organic nitrogen concentrations.

BATHTUB model iterations for TN were only performed for epilimnetic waters since Goldsim-predicted P concentrations showed that the hypolimnetic waters were largely hyper-eutrophic during all Project phases. It should be emphasized that the predicted N in the BATHTUB framework presented in the above table may not be a realistic characterization of the complex natural N cycling processes in Fish Lake, because of the factors discussed earlier in this report.

With regards to N impacts on food web limitations in Fish Lake, we maintain that Fish Lake P is most likely the primary nutrient limiting primary productivity in Fish Lake over multi-annual time scales (also described in IR 19c). That is not to say that N-limitation or co-N and P limitation may not occur over short but still ecologically meaningful time scales (Schindler et al. 2008; see also recent review by Schindler, 2012). In fact, a large number of studies suggest that several biologically-mediated mechanisms can in the long run, supplement cycles of carbon (C) and nitrogen (N) in freshwater ecosystems (Schindler, 1977; Sterner, 2008; Schindler, 2012), thereby allowing freshwater productivity to remain directly correlated to P concentrations (Schindler et al. 2008). In addition, a qualitative examination of Fish Lake phytoplankton community collected in August 1999 showed high numbers of nitrogen-fixing and bloom-forming cyanobacteria (i.e., *Aphanizomenon* and *Anabaena*) with no blooms occurring (Shortreed and Morton, 2000), providing further support that Fish Lake is primarily P-limited. In that analysis, *Fragilaria* abundances were observed to be greater than the large cyanobacteria.

As described in the Fish Lake Productivity report, a relationship between TP and fish production is to be expected since TP typically controls primary production in northern lakes. Specifically, TP is directly or indirectly connected to fish production in two ways: through food webs and lake trophic status. The food web concept suggests that there should be a positive relationship between fish production (biomass and yield) and secondary production, and between secondary productivity and primary productivity (Dillion et al., 2003), even if there are significant allochthonous (external) inputs supplementing fish diets (France and Stedman, 1996). As well, if P is controlling primary productivity (trophic status) of a lake, a relationship or correlation would be expected between TP and fish production. Based on these two ecological concepts, the potential effects of the proposed Project on trophic status and fish production through the various Project phases were modeled and described in the Fish Lake Productivity report (see Section 3.1).

There is always some degree of uncertainty when predicting effects, particularly decades into the future, in a complex aquatic ecosystem (Pace, 2003). In order to address uncertainties regarding the limitations of modeling N and potential N influence on the lake's ecology, adaptive management plans will be implemented over the life of the project to monitor and mitigate against adverse changes to the lake's trophic status. Adaptive management strategies will be complemented by monitoring programs. Specifically, water quality, sediment quality, and aquatic biota in Fish Lake and other water bodies in the regional study area will be routinely monitored (Table 2.7.2.4B-57). Other studies planned as part of the monitoring program include ground water quality, fish spawning, and tissue chemistry. These comprehensive plans detailed in Section 4.6.1 of the new Prosperity EIS Report can and are expected to provide real-time indications of water quality in Fish Lake. The planned sampling program will be conducted during construction, operations, closure, and post-closure phases.

Conclusions

The potential effects of reduced natural inflow and induced recirculation on nutrient balances and productivity in Fish Lake are modeled and detailed in *Fish Lake Productivity Model* report (Appendix 2.7.2.4B-A of the New Prosperity Project's Environmental Impact Statement). The potential impact of Fish Lake recirculation on nitrogen (N) cycling is considered in the reported effects. Difficulties in modeling N fluxes in natural ecosystems may have influenced the modeled results but adaptive management techniques implemented through the life of the project will help mitigate against adverse changes to the Fish Lake ecology.

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Information Request #19c

Discuss how the recirculation of Fish Lake will impact nitrogen cycling within the watershed and affect lake productivity.

Response Summary

Several species of nitrogen (N) were inputted into the BATHTUB model iterations and N influence on the change in Fish Lake trophic status with recirculation is therefore taken into consideration. The model analyses indicates that the trophic status of Fish Lake could change from the current baseline meso-eutrophic condition to a more productive, eutrophic state during the life of mine and beyond. While N input may be reduced with inflow, it is difficult to accurately predict N since several in-lake ecosystem processes including denitrification, nitrification, and internal nutrient regeneration may continuously alter N concentrations in Fish Lake. Monitoring of Fish Lake's trophic status will allow for model verification of the lakes ecology and appropriate mitigation will be implemented to deal with changes before they become a problem.

Discussion

The principal feature of the New Prosperity Project is the retention of Fish Lake and the intent for the lake to remain functioning and able to sustain the resident monoculture population of Rainbow Trout (Taseko, 2011). The revised Project will preserve Fish Lake as well as large portions of Upper Fish Creek and tributaries feeding the lake. Based upon the current mine configuration, this would result in a reduction in watershed area and subsequent runoff of approximately 60%. To offset the anticipated losses in lake inflow, the Proponent plans to pump Fish Lake outflows back to Fish Lake through the main Fish Lake inlets. In addition, Fish Lake volume will be maintained with the installation of an outlet control structure and a commitment by the Proponent to maintain the baseline levels through the life of mine and beyond. Based on this arrangement, some changes to Fish Lake nutrient balance and productivity would be expected.

The BATHTUB model was one of the models used to predict the productivity and trophic status of Fish Lake. For the BATHTUB model calibration, many parameters that describe the atmospheric loads, in-lake water quality parameters, water quality of the tributaries as well as morphological characteristics of Fish Lake and tributaries were entered into the model (see Table 2, *Fish Lake Productivity Report*, Appendix 2.7.2.4B-A of the New Prosperity Project EIS).

The two major nutrients, N and phosphorus (P), which influence productivity in most northern lakes were included in model input. With respect to N, several species, including total nitrogen, inorganic nitrogen, and organic nitrogen were used as input into the model in order to predict water quality and metric of productivity (ortho-phosphate, Carlson indices, algal biomass [*Chlorophyll a* concentrations] and transparency [secchi depth] of Fish Lake.

Unlike P, nitrogen exists in gaseous form. Depending on factors such as watershed characteristics, climate and trophic status of a lake, N can enter a lake via atmospheric deposition, precipitation, internal regeneration, loading from catchment, and nitrogen fixation by nitrogen fixing heterocystous cyanobacteria (Schindler et al., 2008, Schindler, 2012; see also Taseko responses to CEAA Information Request IR19 (d) and IR25 (c)). In contrast, N can be removed via outflow, sedimentation and denitrification. BATHTUB iterations account for nutrient fluxes from sediments (i.e., sedimentation and internal nutrient regeneration). However, it is difficult to accurately model and predict ecosystem processes such as N fixation and denitrification. That being said, the model analyses indicates that the trophic status of Fish Lake could change from the current baseline meso-eutrophic condition to a more productive, eutrophic state during the life of mine and beyond. In order to deal with the difficulty in modeling N influences on the lake's ecology, adaptive management plans will be implemented over the life of the project to monitor and mitigate against adverse changes to the lake's trophic status.

Conclusion

The potential effects of reduced natural inflow and induced recirculation on nutrient balances and productivity in Fish Lake are modeled and detailed in *Fish Lake Productivity Model* report (Appendix 2.7.2.4B-A of the New Prosperity Project's Environmental Impact Statement). The potential impact of Fish Lake recirculation on nitrogen (N) cycling is considered in the reported effects. Difficulties in modeling N fixation and denitrification may have influenced the modeled results but adaptive management techniques implemented through the life of the project will be instituted to mitigate against adverse changes to the Fish Lake ecology.

References

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Information Request #19d

Discuss the impact the loss of wetland area immediately upstream of Fish Lake could have on the nutrient balance and other ecological characteristics of the lake and the lower watershed.

Response Summary

The ecological characteristics of Fish Lake have been modeled taking into account the loss of wetland upstream. The results of both the BATHTUB model iterations and Carlson indices indicate the trophic state of Fish Lake may shift from meso-trophic to a more productive, eutrophic state during the life of mine and beyond.

While Fish Lake productivity is predicted to increase with mine development (*Fish Lake Productivity Model* report, Appendix 2.7.2.4B-A of the New Prosperity Project EIS document), the change would be gradual and measurable so that monitoring coupled with the use of adaptive management program outlined in the New Prosperity Project Environmental Impact Statement (EIS) document would allow the proponent adequate time to monitor and if needed implement appropriate mitigation or contingency measures to maintain water quality required to support and sustain a viable population of monoculture Rainbow Trout.

Discussion

a) Rationale

The revised New Prosperity Project will ensure the sustainability of a viable population of the resident monoculture population of Rainbow Trout within Fish Lake for the life of mine (LOM) and beyond (Taseko, 2011). The revised Project will preserve Fish Lake as well as large portions of Upper Fish Creek and tributaries feeding the lake. Based upon the revised mine configuration, this would result in a reduction in watershed area and subsequent runoff of approximately 60%. The planned reduction in the catchment area immediately upstream of Fish Lake may potentially influence the nutrient balance of Fish Lake and the lower watershed. In general, the decreased natural inflow to Fish Lake is expected to result in reduced nutrient input by a magnitude proportional to the change in flow, assuming nutrient loading from these external sources represent the majority of the nutrient loading to the lake (cf. Brett and Benjamin, 2008; Schindler, 2009).

b) Methods

To evaluate how the proposed changes to Fish Lake natural inflow and induced recirculation will affect Fish Lake productivity or trophic status, two productivity models were employed (see details in *Fish Lake Productivity Model* report, Appendix 2.7.2.4B-A of the Project’s Environmental Impact Statement). These models, the classic empirical model developed by Vollenweider, which is retention time and load driven (Vollenweider, 1975, 1976); and, the

"BATHTUB" model developed by the United States Army Corps of Engineers, USGS, which is morphometric and process driven (Walker, 1985, 1986, 1999; see also Nadim et al. 2007) were used to predict the potential effects of reduced flow on primary productivity and fish productivity in Fish Lake during the different Project phases. Specifically, the BATHTUB model was used to model changes in trophic status as a result of reduced flow and planned recirculation during the various Project phases. For the BATHTUB model calibration, many parameters that describe the atmospheric loads, in-lake water quality parameters, water quality of the tributaries as well as morphological characteristics of Fish Lake and tributaries were entered into the model (see Table 2, *Fish Lake Productivity Report*, Appendix 2.7.2.4B-A of the New Prosperity Project EIS). It should be emphasized that the planned reduction in the adjacent catchment area of Fish Lake was part of the morphological attributes of the tributaries used as model input (see also Taseko responses to CEAA Information Request (IR)19c and IR25c).

Detailed descriptions of the Vollenweider and the BATHTUB models' underlying theories, program operations, model options, output variables, calibrations, and application scenarios are provided in *Fish Lake Productivity Model* report. These two independent, but complementary models analyses were supplemented by the Monte Carlo Simulation Software GoldSim water quality iterations (refer to Fish Lake Productivity Report, Appendix 2.7.2.4B-A). The main questions addressed in *Fish Lake Productivity Model* report *were*:

1. Will the trophic status of Fish Lake change with the planned reduced natural inflow; and,
2. Will change in Fish Lake trophic status, if any, as a result of mine development affect the aquatic ecology (primary productivity and fish productivity) of Fish Lake

c) Potential effects of loss of wetland area immediately upstream of Fish Lake

The potential effects of loss of wetland are on Fish Lake productivity was modeled and detailed in *Fish Lake Productivity Model* Report (see Appendix 2.7.2.4B-A of the Project's Environmental Impact Statement). The highlights of the predictions made in the report of the anticipated reduced inflow on Fish Lake productivity based on model iterations are presented here. Fish Lake is a relatively small (111 ha), shallow (maximum depth of 12 m, mean depth of 4 m), dimictic, meso-eutrophic lake with a substantial amount of Phosphorous retained in the sediments. Model prediction showed that over 60% of the Phosphorous may be retained in the sediments (Kirchner and Dillon, 1975, Table 19D-1 below). The proposed 60% reduced natural inflow to Fish Lake was therefore expected to increase hydraulic residence time (HRT) in Fish Lake from the current 0.72 years to 1.81 years. However, the planned recirculation of water from the outlet of Fish Lake back through the principal inlets will lower HRT to 1.05 years, and minimize the effects of reduced flow on the ecology of the lake. In addition, the Proponent is committed to maintaining Fish Lake water volume (lake water elevation) through the life of mine and beyond (Taseko, 2001).

Table 19D-1. Hydraulic Residence Time for Fish Lake Under Different Flow Regimes

Flow Regime	***Inflow Sources***	***Lake Volume***	***Annual Outflow***	****HRT = Lake Volume/Outflow***
Baseline (current) flow	Watershed + precipitation = 6.13×10^6 m^3	4.44×10^6 m^3	6.13×10^6 m^3	0.72 years
Flow reduced by 60%	Watershed + precipitation = 2.45×10^6 m^3	4.44×10^6 m^3	2.45×10^6 m^3	1.81 years
With recirculated flow	Watershed + precipitation + mitigation flows = 4.66×10^6 m^3	4.44×10^6 m^3	4.66×10^6 m^3	1.05 years

*Brett and Benjamin, 2008

The results of the BATHTUB analysis are presented in Figures 3 to 26 and Tables 18 and 19 in *Fish Lake Productivity Model* report. For the prediction of water quality parameters (ortho-phosphate, TN, Carlson indices, algal biomass [Chl *a*] and transparency), nutrient loadings during the four different Project phases were conducted for the months of October to June, July, August, and September. BATHTUB iterations were only performed for epilimnetic waters since Goldsim-predicted P concentrations showed that the hypolimnetic waters were largely hyper-eutrophic during all Project phases. The Project phases represented in the figures and tables are Baseline, Phase 1 (start of operations to end mining/milling -Years 1 to 17), Phase 2 (Closure - Years 18 to 21), Phase 3 (Post-closure - Years 22 to 31) and Post closure 2 (Year 31 and beyond).

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Information Request #19e

Provide more information on phosphorus loading in Fish Lake through the combined effect of direct deposition of phosphorus from dust emissions on the Upper Fish Creek / Fish Lake watershed and from recycling of water from the Fish Lake outlet to Upper Fish Creek.

Response Summary

The Goldsim model was used to predict phosphorus (P) concentrations in the lake through-out the life of the project. This model took into account the combined effect of direct deposition of phosphorus from dust emissions and the recirculation of lake water. The mean 95th % daily concentrations of P derived from the Goldsim model are shown in Table 19E-1 below. Detailed information on the modeling of phosphorus can be found in Appendix 2.7.2.4B-A (Effects of Reduced Inflow on Fish Lake Trophic Status using the Mass Balance Approach)

Table 19E-1. Goldsim Modeled Mean Phosphorus Concentrations

		Epilimnion	**Hypolimnion**
	Project Phase	Mean 95th % daily value (mg/l)	Mean 95th % daily value (mg/l)
Oct. to June	Years 1-17	0.038	0.137
	Years 18-21	0.04	0.144
	Years 22-31	0.037	0.129
	Years 32 on.	0.047	0.185
July	Years 1-17	0.019	0.137
	Years 18-21	0.020	0.144
	Years 22-31	0.018	0.129
	Years 32 on.	0.025	0.185
August	Years 1-17	0.021	0.150
	Years 18-21	0.022	0.156
	Years 22-31	0.020	0.144
	Years 32 on.	0.027	0.189
September	Years 1-17	0.031	0.118
	Years 18-21	0.032	0.122
	Years 22-31	0.030	0.113
	Years 32 on.	0.037	0.140

Discussion

The potential phosphorus (P) loading as a result of direct dust emissions on Fish Lake and the recirculation effects on water and sediment quality are addressed in the recently submitted New Prosperity EIS document. The phosphorus concentrations were modeled using the Goldsim software. Water being recirculated was assigned the chemistry of Fish Lake water at the specific time in the life of the project. This chemistry included contributions from dust, specifically a dissolved component and a separate particulate component estimated based on the particle sizes and the amount of dust settling through the water column at any given time.

The resulting mean 95% daily phosphorus concentrations produced from the Goldsim model were combined with other nutrients, (total phosphorus, ortho-phosphate, total nitrogen, and inorganic nitrogen), metals and morphological characteristics into the BATHTUB model to further refine and predict the trophic status of the lake. In addition, the proposed loss of wetland in the Upper Fish Creek upstream of Fish Lake was part of the morphological attributes of the tributary used as model input. Phosphous retention times and contributions from sediment were also taken into account. BATHTUB has been widely reported as an effective tool for water quality assessments and management, especially in lakes (Ernst et al., 1994; Nadim et al., 2007). Detailed descriptions of the BATHTUB model's underlying theories, program operations, model options, output variables, calibrations, and application scenarios are provided in Appendix 2.7.2.4B-A (Effects of Reduced Inflow on Fish Lake Trophic Status using the Mass Balance Approach)

With respect to sediments quality, P loading as a result of dust emissions was modeled and incorporated into Fish Lake total sediments budget. Sediment quality predictions (including P concentrations) were conducted for Fish Lake using baseline data, dust fall, and sediment inputs during construction and operations and are presented in Table 2.7.2.4C-9, Page 813 of the EIS Document (September 2012).

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