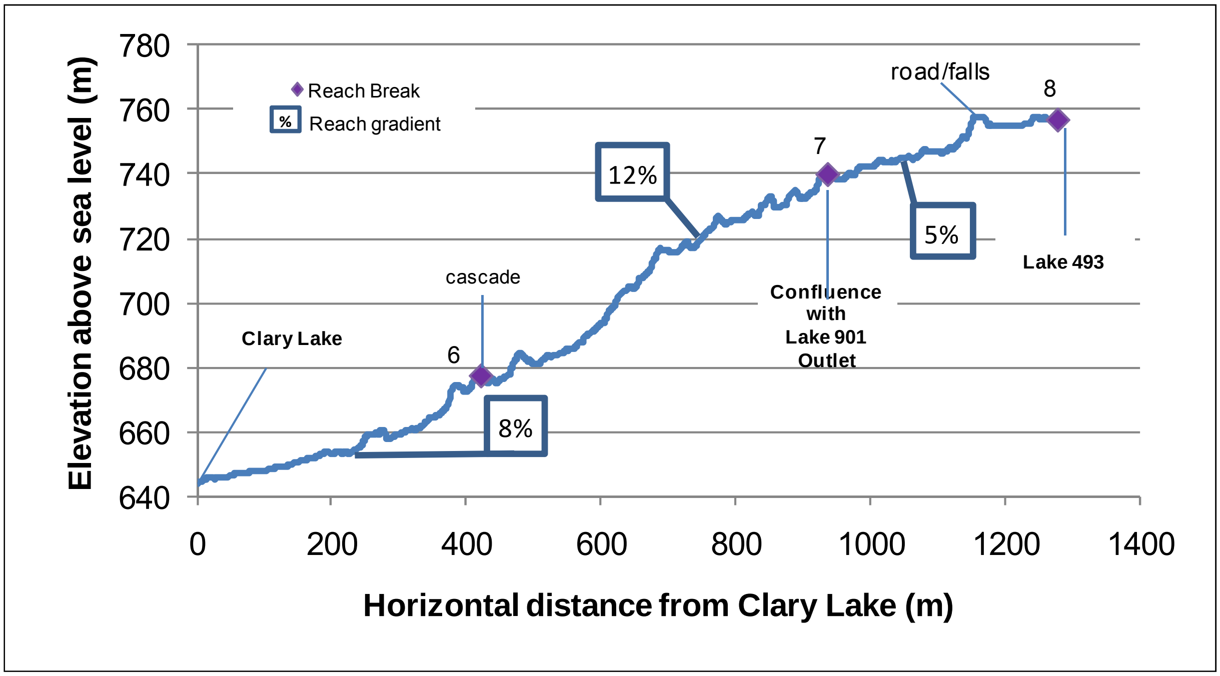


Figure 6.7.4-20: Stream Gradient Profile of Clary Creek from Clary Lake to Lake 493

The potential effect of these predicted flow reductions on rainbow trout in this 900 m section of Clary Creek is two-fold: 1) a potential reduction in spawning and rearing habitat suitability due to decreased water depths and water velocities during the spring freshet; and 2) a potential reduction in upstream passage of fish from Clary Lake to Lake 493 and Lake 901 through the canyon. Although the relationships between discharge and water depths and water velocities in these potential spawning areas in Clary Creek have not be developed, it is unlikely that the predicted changes in stream flow during construction and operations would have a significant negative effect on the annual recruitment of Clary Lake rainbow trout or on the immigration of Clary Lake rainbow trout up into the southeastern portion of the Clay Creek watershed. This is because:

- The availability of suitable spawning habitat in the channels within the delta area is likely too short in most years for rainbow trout spawning and egg incubation to be successful. This is because of the high degree of connectivity between surface and subsurface flows in the highly porous substrates of the delta area. In 2010 for example, water levels dropped significantly in the two channels where hoopnets were set in spring. By the end of the second day, the hoopnets had to be pulled because both channels were dry even though spent fish were still being captured. Rainbow trout eggs require between 30 and 60 days to hatch at water temperatures <8°C (McPhail 2007; Ford et al. 1995). As a result, any egg laid in these streams in 2010 would not have survived. Egg survival in these channels is only likely to occur during very high water years when flow in these channels would be sustained. It is currently unknown at what discharge, flows in these channels go subsurface as they did in spring 2010;

- The proportion of adult rainbow trout in Clary Lake using this section of Clary Creek for spawning is likely very low compared to the proportion of adult rainbow trout using the Clary Creek outlet and the main Clary Lake inlet for spawning. Both of these other streams are significantly larger and have significantly more suitable spawning and rearing habitat than Clary Creek upstream of the Clary Lake. As shown below, predicted flow reductions in the Clary Lake outlet are not expected to reduce the availability or suitability of spawning or rearing habitat downstream of Clary Lake. Flows in the main Clary Lake inlet would not be affected by the Project. As a result, the potential loss to the annual recruitment of the Clary Lake rainbow trout population is likely to be negligible; and
- The number of rainbow trout moving upstream from Clary Lake through the Clary Creek canyon in any given year is likely to be low. This is because the geometry, gradient, and the large boulder cascades within the canyon create already create a significant impediment to upstream fish passage under current baseline conditions. The predicted flow reductions would exacerbate these impediments during low run-off years but they are likely insufficient to completely preclude upstream passage during average or high run-off years.

Based on these lines of evidence, no significant residual effect to rainbow trout is expected to occur at this location during any phase of the Project (Table 6.7.4-46).

6.7.4.10.1.4.4 Clary Lake Outlet

Flow reductions in the Clary Lake outlet are not expected to have a significant adverse effect on rainbow trout. This is because the magnitude of the flow reductions during any given month, during any given phase of the project, are unlikely to affect any of rainbow trout life stage using habitat in the Clary Lake outlet.

In winter (November to March), average monthly flow reductions were predicted to be highest (11% to 24%) during operations. However, during the winter, most rainbow trout are either overwintering in Clary Lake upstream or in deep pools in Clary Creek itself. These pools are relatively insensitive to flow reductions in winter as long the creek does not freeze to the bottom and some flow remains to keep residual pool depths relatively stable and dissolved oxygen concentrations above 6 mg/L (the lower preference limit for rainbow trout; Raleigh et al. 1984). Winter flow reductions predicted to occur during operations are likely insufficient to create such conditions. This is because even during the lowest flow month (February), there would still be water flowing in the creek (0.14 cms compared to 0.18 cms pre-mine)(Knight Piésold 2011, Appendix 6.5-C).

In May and June when rainbow trout are spawning, average monthly flow reductions in the Clary Creek outlet were predicted to be only 7% to 9%. These reductions drop in summer (<6% reductions) when rainbow trout are rearing and foraging in the creek. This is because the unaffected, northeastern portion of the Clary Lake watershed would continue to provide approximately 70% of the spring freshet flows and approximately 75% of the summer low flows to the Clary Lake outlet. Therefore, the suitability of spawning and rearing habitat in Clary Creek downstream of Clary Lake is unlikely to change due to flow reductions created by the Project. No significant residual effect to rainbow trout at this location during any phase of the Project is expected to occur (Table 6.7.4-46).

6.7.4.10.1.5 Change in Surface Water Quality in Lake 901 and Clary Lake Due to Tailings Management Facility Seepage

Modelled surface water quality in Lake 901 and Clary Lake predicted that the following parameters would exceed provincial and / or federal water quality guidelines for the protection of freshwater aquatic biota during at least one of the Project phases:

- Fluoride (Lake 901 and Clary Lake);
- Sulphate (Lake 901 and Clary Lake);
- Phosphorus (Lake 901);
- Aluminum (Lake 901 and Clary Lake);
- Arsenic (Lake 901);
- Cadmium (Lake 901 and Clary Lake);
- Chromium VI (Lake 901);
- Copper (Lake 901);
- Iron (Lake 901);
- Lead (Lake 901);
- Mercury (Lake 901 and Clary Lake);
- Molybdenum (Lake 901 and Clary Lake);
- Selenium (Lake 901 and Clary Lake); and
- Zinc (Lake 901 and Clary Lake).

The proponent acknowledges that lethal or chronic health effects to Rainbow Trout and other freshwater aquatic biota in Lake 901 due to water quality changes caused by the proposed Project would be unacceptable. As such, the proponent is committed to working with Environment Canada, the BC Ministry of Environment, and the Nisga'a Lisims Government to determine if and what water quality objectives (WQOs) would be appropriate for each chemical of concern with predicted exceedences of existing water quality guidelines for the protection of freshwater aquatic biota. the proponent is also committed to monitoring water quality in their mine effluent (as required under the Metal Mine Effluent Regulation [MMER] of the federal *Fisheries Act*) and in Lake 901 (as part of any future Environmental Effects Monitoring [EEM] program) and to providing water treatment of their mine effluent if required. The reader is reminded of these commitments while reading the residual effects assessments below.

6.7.4.10.1.5.1 Fluoride

6.7.4.10.1.5.1.1 Ecologic Toxicity Profile

Fluoride is a major ion found in freshwater and marine environments. Its primary source in natural freshwater waterbodies and streams is from leaching of fluoride-containing bedrock by groundwater. Major anthropogenic sources of fluoride include aluminum smelting and phosphate fertiliser production (CCME 2002).

Fluoride accumulates in the bone tissues of fish (Camargo 2003). In elevated concentrations, the toxic action of fluoride resides in the fact that fluoride ions act as enzymatic poisons, inhibiting enzyme activity and, ultimately, interrupting metabolic processes such as glycolysis and synthesis of proteins (Camargo 2003). Fluoride toxicity increases with increasing fluoride concentrations, exposure time, and water temperature and decreases with increasing water hardness (Camargo 2003). In general, fish species in soft waters with a low ionic content are more adversely affected from fluoride than those present in hard waters as the bioavailability of fluoride decreases with increasing water content of calcium and chloride (Camargo 2003).

6.7.4.10.1.5.1.2 Water Quality Model Results

The water quality model predicted that during the construction and operation phases, average annual fluoride concentrations in Lake 901 will not exceed the BC MOE (0.3 mg/L) (2006b) maximum acceptable guideline limit, based on an assumed hardness of >50 mg/L; however, maximum concentrations (0.37 mg/L) are predicted to exceed the BC MOE guideline during the operations phase. During the closure and post-closure phases, both the average (0.76 mg/L at closure, 0.55 mg/L at post-closure) and, maximum (1.72 mg/L at closure, 1.23 mg/L at post-closure) fluoride concentrations will exceed the BC MOE maximum guideline. Results of the model predict higher fluoride concentrations during closure and post-closure than during construction and operations in the Clary creek watershed. In the Clary Creek watershed, the fluoride concentration predicted during the closure and post-closure phases is driven by seepage through the cyclone sand dam.

6.7.4.10.1.5.1.3 Potential Effects on Rainbow Trout

Although maximum fluoride concentrations during operations, closure, and post-closure phases and average fluoride concentrations during the closure and post-closure phases were predicted to exceed the BC MOE maximum fluoride guideline, this guideline level was considered overly conservative for the protection of rainbow trout (*Oncorhynchus mykiss*) in Lake 901 from lethal and sub-lethal effects. This assessment was based on the following lines of evidence:

- The guideline was incorrectly derived by BC MOE because they inadvertently applied the safety factor recommended by Pimentel and Bulkley (1983) to the temperature adjusted LC_{50} concentration for rainbow trout (Angelovic et al., 1961) twice instead of once (Dr. C. Meays, Water Quality Science Specialist at the Water Protection and Sustainability Branch of the BC MOE, pers. comm. July 6, 2011). This reduced the LC_{50} concentration for rainbow trout from 4.0 mg/L to 0.2 mg/L for soft water waterbodies (i.e., <50 mg/L of $CaCO_3$) and from 6.0 mg/L to 0.3 mg/L for harder water waterbodies (i.e., >50 mg/L of $CaCO_3$);

- The technical appendix that accompanies the fluoride guideline in the *Ambient Water Quality Criteria for Fluoride* (Warrington 1995) notes that in inland areas where natural hardness levels and background fluoride concentrations are elevated (>50 mg/L $CaCO_3$), a higher guideline of 0.3 mg/L was not likely to stress organisms already adapted to fluoride levels in this range;
- A fluoride guideline derived by correctly applying the recommended safety factor only once, would result in a fluoride guideline concentration of 4 mg/L which is more consistent with LC50 concentrations found in other studies (Pimentel and Bulkley 1983; Camargo, 2003);
- Toxicity studies reviewed by BC MOE and CCME which investigated the exposure of rainbow trout to fluoride reported:
  - 72-hr to 96-hr LC50s range from 51 to 200 mg/L;
  - 120-hr to 192-hr LC50s range from 64.1 to 92.4 mg/L;
  - 240-hr to 480-hr LC50s range from 2.6 to 7.5 mg/L; and
- Field studies conducted in Nevada and in Yellowstone National Park in lakes containing up to 14 mg Fl /L have reported healthy populations of rainbow trout (Camargo, 2003).

Using the corrected fluoride concentration guideline (4 mg/L) for the BC MOE maximum fluoride concentration, none of the predicted fluoride concentrations in Lake 901 would exceed this guideline during any phase of the Project. In fact, the highest predicted peak fluoride concentrations during the Project (1.72 mg/L the mine closure phase) would be less than half this new guideline. Furthermore, predicted fluoride concentrations are below effects concentrations specific to rainbow trout. As a result, no lethal or sub-lethal effects on rainbow trout are expected to occur due to any of the predicted changes in fluoride concentrations in Lake 901.

6.7.4.10.1.5.2 Sulphate

6.7.4.10.1.5.2.1 Ecologic Toxicity Profile

Sulphate is ubiquitous in freshwater environments and frequently acts as the main sulphur source for production of aquatic plants and bacteria (Davies et al. 2003). Sulphate levels in most lakes and rivers in British Columbia are naturally low (23 to 30 mg/L) but some lakes in BC have natural sulphate levels in excess of 3000 mg/L (Singleton 2000). In terms of aquatic toxicity, invertebrates have a greater sensitivity to sulphate compared to most fish species (Davies et al. 2003). Also, toxicity to sulphate decreases with increased water hardness (Singleton 2000).

6.7.4.10.1.5.2.2 Water Quality Model Results

The BC MOE (2000) sulphate alert is 50 mg/L, and the maximum guideline is 100 mg/L for the protection of freshwater aquatic life. The water quality model predicted that there is a general increasing trend of sulphate during the first 7 years of operations; after which the levels would be above 500 mg/L. The mean sulphate concentrations during closure (277.9 mg/L) and post-closure phases (284.8 mg/L) of mining in Lake 901 are predicted to exceed BC MOE alert level and the maximum guideline for the protection of freshwater aquatic life.

6.7.4.10.1.5.2.3 Potential Effects on Rainbow Trout

For the protection of freshwater aquatic life, the BC MOE (2000) has derived a maximum value of 100 mg/L for dissolved sulphate, based on the following two sets of studies:

- LC50s (1-4 day studies) ranging from 250 to 2,000 mg/L for sulphate and LC50s showing no effect of 100-500 mg/L for striped bass (*Morone saxitilus*) larvae. Though striped bass are not native to BC, they are used as a surrogate for other bass and perch species.
- Unpublished datasets for *Hyalella* showed the following LC50s:
    - Soft water (25 mg $CaCO_3$/L) = 205 mg/L;
    - Medium water (100 mg $CaCO_3$/L) = 3,711 mg/L; and
    - Hard water (250 mg $CaCO_3$/L) = 6,787 mg/L.

The BC MOE WQG of 100 mg/L considers a 2:1 safety factor in soft water and has an even greater safety factor for sulphate in hard water (BC MOE 2000).

Davies et al. (2003) replicated the studies on which the guideline is based but obtained higher effects concentrations (i.e. less toxic toxicity) than those used to derive the guideline. Davies et al. (2003) suggest modifying the guidelines to account for the ameliorating effects of increasing hardness.

The 50 mg/L alert level was based on effects to aquatic moss populations. This 50 mg/L is based on a German study which found concentrations of 100 mg/L of SO_4 to be toxic to the aquatic moss *Fontinalis antipyretica*, a species known to be widely distributed throughout BC. Sulphate toxicity to other moss species was found to range between 100 and 250 mg/L.

The alert and maximum concentrations are overly conservative guidelines which are based on small datasets, and are designed to protect the most sensitive species among a group of diverse genera. Several studies have been conducted to assess sulphate toxicity specifically to fish species, including rainbow trout (*Oncorhynchus mykiss*):

- Singleton (2000) reported 96-hr LC50s for rainbow trout in three different hardness concentrations:

  - o Soft water (25 mg $CaCO_3$/L) = 5,000 mg/L;
  - o Medium water (100 mg $CaCO_3$/L) = 9,750 mg/L; and
  - o Hard water (250 mg $CaCO_3$/L) = 9,990 mg/L;
- Singleton (2000) also reported 7-Day EC50s (trout embryo viability) for young rainbow trout at three different hardness concentrations:
  - o Soft water (25 mg $CaCO_3$/L) = 1,105 mg/L;
  - o Medium water (100 mg $CaCO_3$/L) = 1,025 mg/L;
  - o Hard water (250 mg $CaCO_3$/L) = 3,116 mg/L; and
  - o Observed a NOEC (no observed effects concentration) of 1,060 mg/L and a LOEC (lowest observed effects concentration) of 3,500 mg/L.

In Lake 901, maximum sulphate concentrations are predicted to be approximately 530 mg/L, a concentration higher than the alert and maximum regulatory concentrations. However, the regulatory concentrations are overly conservative. Adverse effects to rainbow trout in Lake 901 are not expected because predicted concentrations are well below acute and chronic effects concentrations reported in the scientific literature. Therefore, impacts to the local rainbow trout populations are not expected for Lake 901.

6.7.4.10.1.5.3 Phosphorus

6.7.4.10.1.5.3.1 Ecologic Toxicity Profile

Phosphorus is an important nutrient for plant and animal growth. Phosphorous occurs in different forms in the environment as inorganic phosphorus, organic particulate phosphorus, and dissolved organic phosphorus. Its occurrence in the environment may originate from natural sources (e.g. weathering of the mineral apatite) or from anthropogenic sources (e.g. agricultural fertilisers or household cleaning agents).

Phosphorus is one of the primary nutrients determining the production of algae (e.g., phytoplankton and periphyton in streams) and plants in lakes and streams; nitrogen and carbon are the other two limiting nutrients in freshwater aquatic ecosystems. If one of these three elements is limiting and all other elements are present in excess of physical needs, phosphorus can theoretically generate 500 times its weight in living algae (nitrogen 71 times and carbon 12 times) (Wetzel 1983). Depending on the availability of nitrogen and carbon, phosphorus enrichment in freshwater lakes can increase the growth rate and biomass of plants and algae, a process known as eutrophication (Wetzel 1983).

Phosphorus dynamics is lakes is highly complex (Wetzel 1983). For example, the availability of biologically available orthophosphate fluctuates rapidly because of its uptake by photosynthetic algaes and its extreme reactivity with other cations (e.g., iron, calcium) and inorganic particulates (e.g., clays, carbonates) (Wetzel 1983). Such reactions take phosphates out of solution and, therefore, phosphorus is constantly being lost from the water column to the sediments or incorporated into the food-web.

Direct toxicity of phosphorus to aquatic species occurs rarely in nature and is generally not a concern. Of greater concern, are the indirect effects of eutrophication and its corresponding effect on changes in water chemistry, trophic status, and, if primary productivity rates increase high enough for long enough, changes in the biomass and composition of benthic invertebrates and fish communities of lakes and streams.

At certain rates, additions of phosphorus and nitrogen to lakes can be beneficial and is a widely used technique (i.e., fertilisation) for increasing the productivity and biomass of desireable fish species, particularly in low productivity, oligotrophic lakes. For example, Johnston et al. (1999) found that chlorophyll *a* concentration, limnetic macro-zooplankton biomass and annual yield of rainbow trout increased significantly in an oligotrophic, montane lake after five years of fertilisation with inorganic phosphorus and nitrogen compared to a control lake. Fertilisation increased rainbow trout reproductive output, growth, and yield but did not alter yearling survival or mean age at maturity (Johnston et al. 1999).

The potential effects of eutrophication in lakes depends on the degree of eutrophication, the trophic level of the lake prior to eutrophication, the existing chemistry of the lake, and the physical characteristics of the lake (e.g., depth, shoreline development, thermal stratification), and the existing biological community of the lake. At the extreme, the potential adverse effects of excess eutrophication from increased phosphorus and nitrogen loading include, as summarised from Wetzel (1983):

- Oxygen depletion in the hypoliminion as organic material from the phytoplankton and epiphytes settles to the bottom and is decomposed by bacteria. In the extreme, anoxic conditions may persist;
- Promotion of cyanobacteria blooms that can cause summer fish kills due to production of cyanobacteria toxins;
- Decreases in the diversity and quantity of littoral benthic macro-invertebrates as the increase in density of phytoplankton and epiphyte communities begin to shade out the submerged macro-vegetation and decreases littoral habitat diversity;
- Decreases in the respiratory, growth, and survival rates of the adapted BMI community due to the increase in the length of the period of hypolimnetic oxygen reduction;
- Shifts in the percentage composition of the two dominant groups of benthic invertebrates in the profundal zone of lakes: a decrease in chironomids and an increase in oligochaete worms. Under conditions of extreme eutrophication and oxygen depletion, practically the only group of benthic fauna adapted to such conditions is the oligochaete worms; and
- Shift in the fish species community composition from salmonid and coregonid species of quite stringent low thermal and high oxygen requirements to warm-water species that are increasingly tolerant of eutrophic conditions and lower dissolved oxygen concentrations.

Generally, the effect of eutrophication in lakes is the increased production of phytosynthetic orgamisms, a structural simplification of the biotic community, and decreased community stability due to the reduction in the ability of the metabolism of organisms to adapt to the imposed changes caused by increased productivity (Wetzel 1983).

6.7.4.10.1.5.3.2 Water Quality Model Results

Phosphorus concentrations in Lake 901 were predicted to fluctuate seasonally in the range between 0.006 mg/L to 0.010 mg/L during construction and operations. These concentrations are within the BC MOE (2006b) phosphorus guideline for lakes where salmonids (such as rainbow trout) are the predominant fish species (0.005 mg/L to 0.015 mg/L) and within the CCME (2004) trigger range[13] for phosphorus in oligotrophic[14] lakes (0.004 mg/L to 0.010 mg/L) (Table 6.7.4-35).

Phosphorus concentrations in Lake 901 were predicted to increase to a maximum of about 0.032 mg/L during the first year of closure and then steadily decline to fluctuate between 0.013 mg/L to 0.025 mg/L for the remainder of the closure phase and for perpetuity into the post-closure phase. Therefore, driven by seepage loading terms from the cyclone sand dam and the tailings beaches, mean and maximum phosphorus concentrations in Lake 901 were predicted to exceed the BC MOE (2006b) phosphorus guideline and the CCME (2004) trigger range for phosphorus in oligotrophic lakes during the closure and post-closure phases of the Project. These exceedences suggest that phosphorus loadings during the closure and post-closure phases may cause the eutrophication of Lake 901.

Phosphorus concentrations in Clary Lake were predicted to fluctuate seasonally in the range between 0.002 mg/L to 0.009 mg/L during construction and operations and between 0.0035 mg/L to about 0.010 mg/L during closure and post-closure. At these concentrations, phosphorus was predicted never to exceed the BC MOE (2006b) guideline level or the CCME (2004) trigger range for phosphorus in oligotrophic[15] lakes (0.004 mg/L to 0.010 mg/L). The lower predicted phosphorus concentrations and smaller seasonal phosphorus concentration fluctuations in Clary Lake compared to Lake 901 was due to Lake 901's closer proximity to the TMF and to the larger portion of Clary Lake inflow coming from unaffected run-off from its larger watershed area. This resulted in much greater dilution of phosphorus in Clary Lake than in Lake 901.

[13] CCME (2004) water quality criteria for phosphorus are published as trigger ranges for trophic states of freshwater ecosystems. The trigger ranges are based on the range of phosphorus concentrations in water that define the reference trophic status for a site (CCME 2004). If phosphorus concentrations exceed the upper limits or fall below the lower limits of the range, a change in the site's trophic status may occur.

[14] Lake 901 was classified as an oligotrophic lake based on comparison of its baseline phosphorus (<0.02 mg/L), and chlorophyll *a* concentrations (1.85 µg/L) compared to Wetzel (1983)'s "General trophic classification of lakes and reservoirs" and calculation of Carlson's Trophic State Indices (Carlson and Simpson 1996) using the baseline total phosphorus (half of the laboratory detection limit of 0.02 mg/L) and chlorophyll a concentrations measured in September 2010.

[15] Clary Lake was classified as an oligotrophic lake based on comparison of its baseline phosphorus (<0.02 mg/L), and chlorophyll *a* concentrations (1.33 µg/L) and Secchi transparency depth (4.5 m) compared to Wetzel (1983)'s "General trophic classification of lakes and reservoirs" and calculation of Carlson's Trophic State Indices (Carlson and Simpson 1996) using the baseline phosphorus and chlorophyll a concentrations measured in September 2010. Clary Lake's TSI indices for total phosphorus (using half of the laboratory detection limit of 0.02 mg/L) and chlorophyll a concentration and Secchi transparency depth were 37, 33, and 38, respectively.

Table 6.7.4-35: Trigger Ranges for Total Dissolved Phosphorus Concentrations in Freshwater Lakes and Streams in Canada (CCME 2004)

Trophic Status	Total Phosphorus (mg/L)
Ultra-oligotrophic	<0.004
Oligotrophic	0.004 - 0.010
Mesotrophic	0.010 - 0.020
Meso-eutrophic	0.020 - 0.035
Eutrophic	0.035 - 0.100
Hyper-eutrophic	>0.1

6.7.4.10.1.5.3.3 Trophic Status of Lake 901

To evaluate potential effects of increased phosphorus loading in Lake 901 on rainbow trout and to determine the appropriate federal phosphorus trigger range for Lake 901, the baseline trophic status of Lake 901 was characterised. This characterisation was based on calculation of Carlson (1977) Trophic State Indices (TSIs) for baseline concentrations of total phosphorus, chlorophyll a (a photosynthetic pigment found in plants and phytoplankton in lakes), and Secchi disk depths (a measure of water clarity and light penetration) measured in September 2010 (Table 6.7.4-36).

Table 6.7.4-36: Baseline Trophic Parameter Values for Clary Lake and Lake 901

Parameter	Clary Lake	Lake 901
Total phosphorus (mg/L)	<0.02	<0.02
Chlorophyll *a* (µg/L)	1.33 (0.07)	1.85 (0.03)
Secchi depth (m)	4.5	2.0

Note: Secchi depth and chlorophyll *a* sampled September in 2010; standard error is in brackets

10 µg/L or half of the laboratory total phosphorus detection limit of 20 µg/L, 1.85 µg/L, and 2.0 metres, respectively).

Carlson TSIs were calculated as follows (Carlson and Simpson 1996):

$$TSI(Secchi\ depth)=60-14.41\times \ln Secchi\ depth$$

Where Secchi Depth is measured in metres.

$$TSI(Chla)=9.81\times \ln Chla)+30.6$$

where: CHLa is chlorophyll *a* density in µg/L.

$$TSI(TP)=14.42\times \ln TP+4.15$$

Where TP is Total Phosphorous concentration in µg/L).

TSIs for Lake 901 based on the equations above were calculated to be 37, 37, and 50 for total phosphorous concentration, chlorophyll a concentration, and secchi depth, respectively. TSIs for total phosphorus and chlorophyll a concentrations were within the ranges for oligotrophic lakes (<30-40) while the TSI for secchi depth was at the high end of the range for mesotrophic lakes (40-50) (Table 6.7.4-37). Secchi depth was considered a less reliable measure of trophic status than the other two metrics because of its greater variability than the other two metrics due to its dependence on time of day, sunshine, and wave conditions during the time of measurement. For summer samples, the Carlson Trophic State Index rates, in order of priority when variables are not in agreement: chlorophyll a >total phosphorous >Secchi depth. Therefore, Lake 901 is an oligotrophic lake based on baseline TSIs for total phosphorus and chlorophyll a.

Table 6.7.4-37: Trophic State Index Ranges for Freshwater Lakes (from Carlson and Simpson (1996))

Trophic Status	TSI score
Oligotrophy	<30 to 40
Mesotrophy	40 to 50
Eutrophy	50 to 70
Hyper-eutrophy	70 to >80

6.7.4.10.1.5.3.4 Potential Effects on Rainbow Trout

Based strictly on the average annual total phosphorus concentrations predicted to occur in Lake 901 during closure and post-closure phases (0.02 mg/L), Lake 901 would be elevated from an oligotrophic lake (TSI[TP]=37) to a mesotrophic lake (TSI[TP]=47) after closure of the proposed mine. This prediction is consistent with Vollenweider and Kerekes' (1980 as cited in Wetzel 1983) model which suggests that phosphorus loadings >10 mg/m^3 (i.e., 0.01 mg/L) will alter the trophic status of a lake. However, the predicted annual average total phosphorus concentrations in Lake 901 at closure were predicted to be below the excessive phosphorus loading level of 25 mg/m^3 or 0.025 mg/L (Vollenweider and Kerekes' 1980 as cited in Wetzel 1983).

The rate and degree of eutrophication, and its potential effect on rainbow trout, in Lake 901 is dependent not only on phosphorus concentrations but also the availability of nitrogen, the other essential nutrient necessary for primary productivity in freshwater ecosystems. Algae require both nitrogen and phosphorous in specific proportions to meet their metabolic needs (Wetzel 1983; BC MOE, 1985; Eisler 2007). If one nutrient is limiting, then algal growth and subsequent eutrophication effects will be limited. The BC MOE Water Quality Criteria for Nutrients and Algae – Technical Appendix (BC MOE, 1985) establishes the following nitrogen (N) / phosphorus (P) ratios for freshwater lakes in BC:

- N:P ratios less than 5:1 indicate that nitrogen is the limiting nutrient;

- N:P ratios between 5:1 to 15:1 indicate no-limitation or co-limitation of nitrogen and phosphorous; and
- N:P ratios greater than 15:1 indicate that phosphorous is the limiting nutrient.

N:P ratios were calculated (Table 6.7.4-38) for the average and maximum total nitrogen and total phosphorous concentrations in Lake 901 predicted during each of the project phases using the output from the water quality model. BC MOE recommends assessing total nutrient concentrations, but recognises this practice may result in overestimates of the bioavailable fractions of these nutrients (BC MOE, 1985).

Table 6.7.4-38: Predicted Nitrogen / Phosphorus Ratios for Lake 901 During the Construction, Operations, Closure, and Post-Closure Phases of the Project

	Construction		Operations		Closure		Post-closure	
	Average	**Maximum**	**Average**	**Maximum**	**Average**	**Maximum**	**Average**	**Maximum**
N:P ratio	0.5:1	0.5:1	0.4:1	0.4:1	0.2:1	0.2:1	0.2:1	0.1:1

The calculated N:P ratios for Lake 901 indicate that nitrogen would be the limiting nutrient in Lake 901 during all phases of the Project. Thus, the predicted increases in total phosphorus concentrations in the lake during closure and post-closure are not expected dramatically accelerate plant, algal, or phytoplankton growth in the lake, and are not expected to have a negative effect on habitat suitability, prey availability, or rainbow trout growth, survival, or recruitment in Lake 901. This contention is supported by comparison of the trophic status of Lake 901 during all phases of the Project based on predicted total nitrogen concentrations using TSI scores calculated using the formula (Kratzer and Brezonik 1981):

$$TSI(TN)=54.54+14.43\times \ln TN$$

Where TN = total Nitrogen in mg/L

Average and maximum TSIs calculated for predicted nitrogen concentrations in Lake 901 were within the range of values for oligotrophic lakes (<40) during all project phases (Table 6.7.4-39).

Table 6.7.4-39: Trophic State Index (TSI) Values for Lake 901 Based on Predicted Total Nitrogen Concentrations During Construction, Operations, Closure, and Post-Closure Phases of the Project

	Construction		Operations		Closure		Post-closure	
	Average	**Maximum**	**Average**	**Maximum**	**Average**	**Maximum**	**Average**	**Maximum**
TSI (TN)	14	21	16	28	24	37	20	27

Phosphorus and nitrogen dynamics in lakes are very complex. Therefore, although the various models and indices discussed above suggest that the increased total phosphorus concentrations in Lake 901 during closure and post-closure phases are not likely to cause excessive eutrophication (and may in fact increase the production of rainbow trout in the lake), the accuracy of this prediction is limited by:

- The highly reactive behaviour of phosphorus in natural waterbodies;
- The relatively small number of baseline water samples taken from Lake 901 and Clary Lake in 2010;
- Relative inaccuracy of the phosphorus loadings predicted to occur in the lake because of the conservative assumptions in the source terms and the conservative assumptions in the water quality model;
- The difficulty of accurately predicting the response of the biological community, at multiple trophic levels, to phosphorus additions from simple or two parameter models or indices; and
- The complexity of the nitrogen cycle in natural waterbodies and the uncertainty regarding its availability in Lake 901 to limit primary productivity and potential eutrophication.

Because of these uncertainties, the proponent is committed to working with Environment Canada, the BC Ministry of Environment, and the Nisga'a Lisims Government to determine if the anticipated rate of phosphorus loading to Lake 901 at closure is acceptable, if water quality objectives should be developed, or if further treatment is necessary.

6.7.4.10.1.5.4 Aluminum

6.7.4.10.1.5.4.1 Ecologic Toxicity Profile

Aluminum is a gill toxicant to fish and its acute and chronic effects on fish are due to a combination of ion-regulatory, osmo-regulatory, and respiratory disruption (Exley et al., 1991; Sparling and Lowe 1996; Gensemer and Playle 1999). Acute effects of aluminum toxicity include mortality due to hypoxia associated with clogging of the gill interlamellar spaces due to aluminum polymerisation on the gill surface (Poleo et al. 1994; Poleo 1995, Witters et al. 1996), disruption of ion exchange due to displacement of calcium ions from the gill membrane (Wood and Macdonald 1987; Freda et al., 1991;) and interference with gill enzyme activity (Staurnes et al., 1993). Sub-lethal effects of aluminum toxicity include reduced feeding rates, growth rates, and metabolic rates as fish respond to aluminum exposure by reducing metabolically costly activities such as routine swimming behavior to allow for the increased maintenance costs associated with acclimation and gill damage repair (Allin and Wilson 1999).

The toxicity of aluminum to fish and other freshwater biota is dependent on a number of factors. These factors include the species of organism (different species and taxa have different tolerances for aluminum) and the confounding effects of other water quality parameters. Principle among these water quality parameters are: pH, water hardness, fluoride, and dissolved organic carbon. Aluminum becomes more soluble and more toxic in freshwaters with pH values less than 6 or greater than 8 (Gensemer and Playle, 1999). Conversely, increasing water hardness, fluoride concentration, and water hardness are known to reduce aluminum toxicity. Fluoride and dissolved organic carbon bind with aluminum which reduces the amount of inorganic, monomeric aluminum species (Al^{3+}, $AlOH^{2+}$, $Al(OH)^{2+}$, $Al(OH)_3$, and $Al(OH)^{4-}$) in the water column making toxic aluminum species less available to interact at the gill membrane surface (Gensemer and Playle 1999). Increasing water hardness reduces aluminum toxicity by increasing the availability of calcium (Ca^{2+}) in the water column and, thereby, increasing the competition with Al^{3+} to bind to negatively charged gill cells (Gensemer and Playle 1999). As a result of these complex interactions, CCME (2005) aluminum guidelines for the protection of freshwater aquatic life state that:

- aluminum concentrations should not exceed 0.005 mg/L at pH values <6.5 and with concentrations of calcium (Ca^{2+}) <4 mg/L and dissolved organic carbon (DOC) <2 mg/L, or
- aluminum concentrations should not exceed 0.1 mg/L at pH values ≥ 6.5 and with concentrations of calcium (Ca^{2+}) ≥4 mg/L and dissolved organic carbon (DOC) ≥2 mg/L.

6.7.4.10.1.5.4.2 Water Quality Model Results

The water quality model predicted that average and maximum aluminum concentrations in Lake 901 will have exceedances over the BC MOE maximum acceptable (0.1 mg/L dissolved aluminum), BC MOE 30-day (0.05 mg/L dissolved aluminum) and CCME (0.1 mg/L total aluminum) guidelines which are based on an assumed pH of 7 during all phases. The highest predicted exceedance levels occur during year 1 of construction (0.169 mg/L). At the commencement of operations the concentrations drop and maintain a relatively constant concentration which ranges between 0.088 mg/L to 0.150 mg/L. The predicted concentrations drop again at the beginning of closure and maintain a level of approximately 0.047-0.150 mg/L and 0.045-0.130 at post-closure.

6.7.4.10.1.5.4.3 Potential Effects on Rainbow trout

Although predicted aluminum concentrations are expected to be above regulatory guidelines, potential adverse effects to the rainbow trout may not necessarily occur for the following reasons:

- The provincial 30-day average criterion of 0.05 mg/L was “set arbitrarily at 50% of the maximum criterion level” (Technical Appendix to the BC MOE Ambient Water quality Criteria for Aluminium (Butcher 1988));
- The provincial and federal guideline levels for maximum acceptable limit for dissolved aluminium (0.1 mg/L) may be overly conservative for waters with pH, hardness, and dissolved carbon concentrations expected to occur in Lake 901 during the construction, operations, closure, and post-closure phases of the Project;

- Dissolved aluminium concentrations predicted by the surface water quality model were based conservatively on a mass-balance model that assumes that dissolved components remain in solution. This is highly conservative for aluminum because aluminium speciation in natural waters is highly complex. First, aluminium solubility is dependent on pH, water temperature, and the presence of complexing ligands (Driscoll and Postek 1996; Poleo and Hytterod 2003). Second, once in solution, aluminium forms inorganic complexes with fluoride, silica, sulphate, and humic (i.e., dissolved organic carbon) and fulvic acids, the formation of which also varies with pH, the concentration of inorganic ligands, ionic strength, and water temperature (Gensemer and Playle 1999). Finally, there is an exchangeable fraction of dissolved aluminium with soils, sediments, and precipitated organic material (Driscoll and Postek 1996). Because of this complexity, lower, more realistic concentrations of dissolved aluminium in Lake 901 would have likely been predicted had a chemical equilibrium model been used that accounted for the precipitation (i.e., physical complexing with sulphate, fluoride, and oxides for example), chelation (i.e., binding to organics), and adsorption (i.e., complexing with silicates) of aluminium likely to occur in Lake 901during all phases of the Project; and
- More recent data on the toxicity of aluminium to rainbow trout indicate that acute toxicity concentrations are likely much higher than those used in the BC MOE maximum acceptable guideline and the CCME guideline for waters with pH >6.5.

The BC MOE maximum acceptable limit guideline and the CCME guideline for dissolved aluminium was based on one study (Minzoni 1984) that tested the mortality of three genera of zooplankton (*Diaptomus*, *Daphnia*, and *Cyclops*) exposed to aluminium. There are a number of flaws in this study that suggests that using its results to set WQGs for aluminium may be inappropriate. First, the pH of the test water in the study decreased to 6.0 during the experiment and the author concluded that the mortality of zooplankton was “mainly due to the low value in pH” not due directly to the concentration of aluminium in solution. As a result, the application of the study’s results to develop the WQG for surface waters with pH >6.5 is uncertain. Second, the study author acknowledges that other studies using the same test organisms found aluminium toxicity thresholds greater than three times higher than those found in their study. Third, the Technical Appendix for the Water Quality Criteria for Aluminium (Butcher 1988) recognises that water hardness and dissolved organic carbon concentrations are known to reduce the toxicity of aluminium to aquatic biota. However, the provincial and federal aluminium guideline do not account for the ameliorating effects of these water quality parameters.

Because of these deficiencies in the guideline and the proliferation of more recent studies looking into the toxicity of aluminium conducted in the last 25 years, alternative site-specific chronic and acute toxicity guidelines for aluminium that incorporate water hardness are proposed (see Appendix 6.7-B for details).

The USEPA (1988) also derived Ambient Water Quality Criteria for aluminum which have recently been re-evaluated and re-calculated by Parametrix et al. (2006) and GEI

Consultants (2010). In summary, the recommendations which took into account a revised dataset that recommended hardness-dependent water quality criteria for aluminum which were as follows:

Recommended Acute Aluminum Criterion = $e^{(1.3695[\ln(hardness)] + 1.8308)}$ Equation 1

Recommended Chronic Aluminum Criterion = $e^{(1.3695 [\ln(hardness)] + 0.9161)}$ Equation 2

Based on Equations 1 and 2, the recommended site-specific aluminum WQGs would be:

	Project Phase		
	Construction	Operations	Closure
Acute (mg/L)	3.6	3.7	4.9
Chronic (mg/L)	0.51	0.55	0.94

The proposed site-specific WQGs are designed to protect a group of diverse genera from the harmful effects of aluminum. Since predicted aluminum concentrations (maximum of 0.169 mg/L) are all below the proposed site-specific WQGs, effects to populations of rainbow trout are not expected.

Furthermore, several studies have been conducted to asses lead toxicity specifically to fish species, including rainbow trout (*Oncorhynchus mykiss*):

- GEI (2010) reviewed of 120 papers reporting aluminum toxicity tests results, and which identified 36 acute data points from 15 studies and 11 chronic data points from 9 studies that were added to the original USEPA (1988) database. Acute data for rainbow trout showed LC50s of less than 8 mg/L at a pH of 7.6 and with hardness ranging from 25 to 125 mg as $CaCO_3$/L. The reported LC50s at a pH ranging from 8.25 and 8.29 and hardness range of 23.2 to 115.8 mg as $CaCO_3$/L were also below 8 mg/L (6.2 and 7.7 mg/L). Following USEPA protocols, GEI calculated a revised Species Mean Acute Value (SMAV) of 7.547 mg/L for rainbow trout.

Since predicted concentrations of aluminum are below the proposed site-specific WQGs, and are below the revised SMAV for rainbow trout, no adverse effects are expected to occur to populations of rainbow trout in Lake 901.

6.7.4.10.1.5.5 Arsenic

6.7.4.10.1.5.5.1 Ecologic Toxicity Profile

Arsenic is a ubiquitous element in the environment and is odourless, tasteless and colourless (CCME 2001). Arsenic is present in both the inorganic and organic forms, and chemical speciation affects the mechanism of toxicity (Eisler 1988; Sharma and Sohn 2009). Chemical speciation is dependent on chemical and microbial oxidation, reduction, and methylation processes (CCME 2001; Sharma and Sohn 2009). High amounts of organic matter, low pH, and low concentrations of minerals, may promote sorption of arsenic to colloidal humic material (CCME 2001). Phosphorous competes with arsenic for chemical binding sites and so elevated phosphorous concentrations could minimise the ability of arsenic to sorp to colloidal humic material. Inorganic arsenic (i.e., arsenite and arsenate) tends to be more toxic than organic arsenic (i.e., methylarsonate (MMA), dimethylarsinate (DMA), trimethyl-arsine oxide (TMAO), and tetra-methyl-arsonium (TETRA) (Eisler 1988; Ventura-Lima et al., 2011). In addition, trivalent species of arsenic are more toxic (approximately 60 times more) than the pentavalent forms (Eisler 1988; Ventura-Lima et al., 2001). Some forms of arsenic, such as arsenobetaine, arsenocholine, and arsenosugars show no toxicity (Ventura-Lima et al. 2011).

In 1997, the CCME reviewed the aquatic ecotoxicity literature for arsenic and found data for 21 species of fish, 14 species of invertebrates and 14 species of plants (CCME 2001). Results from the freshwater studies showed that rainbow trout (*Oncorhynchus mykiss*) was among the more sensitive fish species, and was similar to sensitivity of invertebrate copepods and daphnids (CCME 2001). In general, exposure to arsenic in fish species has been noted to cause cytotoxicity, and increased oxidative stress along with alterations in the antioxidant enzyme systems (Ventura-Lima et al., 2011). Phytoplankton are generally thought to be the more sensitive to inorganic arsenic compared to other biota (EHC 2001). Arsenic is not known to biomagnify in freshwater food chains (Eisler 1988).

6.7.4.10.1.5.5.2 Water Quality Model Results

The predicted average concentrations for arsenic in Lake 901 during the construction, operations, post-closure and closure phases will range between 0.0002 mg/L and 0.0042 mg/L, which will all be below the CCME WQG of 0.005 mg/L. The predicted maximum concentrations for arsenic are also not expected to exceed the CCME WQG for the construction and operations phase and will range between 0.0004 mg/L and 0.0010 mg/L. However, for the post-closure and closure phases, the maximum predicted concentrations of 0.0078 mg/L is expected to exceed the CCME WQG. No BC MOE guidelines for arsenic are available at this time.

6.7.4.10.1.5.5.3 Potential Effects on Rainbow Trout

The CCME water quality guideline (WQG) for the protection of freshwater aquatic life is 0.005 mg/L and was derived from reviewing arsenic toxicity data to 21 species of fish, 14 species of invertebrates and 14 species of plants (CCME 2001). This WQG was derived by multiplying the 14-day EC50 (effects concentration) (growth) of 0.050 mg/L for the most sensitive organism to arsenic; which in this case is the alga *Scenedesmus obliquus* by a safety factor of 0.1 (CCME 2001). A review of the toxicity data for arsenic revealed that rainbow trout and climbing perch were the most sensitive fish and were equally as sensitive as invertebrates such as copepods and daphnids. However, the data revealed that some aquatic plants were an order of magnitude more sensitive (CCME 2001).

The arsenic toxicity data for fish revealed that the lowest LC50 (lethal concentration) from the reviewed data was from the Birge et al. study in 1979 for rainbow trout which was 0.550 mg/L (CCME 2001). A 28-day LC50 of 0.54 mg/L in embryos was reported by Eisler

(1988) from the USEPA 1985 study. In comparison, a recent study by Tisler and Zagorc-Koncan (2002) reported a 96-hr LC50 of 15.3 mg/L for juvenile rainbow trout exposed to arsenic contaminated water in a static system. The lowest 7-day LOEC (lowest observed effects concentration) was 0.500 mg/L and the lowest 72-hr LOEC for the survival endpoint was 0.970 mg/L from the Jana and Sahana study in 1989 for climbing perch (CCME 2001). In terms of chronic data, Eisler (1988) reviewed the arsenic aquatic toxicity data and found that rainbow trout that were fed diets containing 10 to 90 mg As (+5)/kg for 16 weeks were only slightly affected compared to those that were fed diets containing 120 mg As/kg (As +3 or As +5) which showed food avoidance, which impacted growth. Rainbow trout fed diets containing 120 to 1600 mg/kg of methylated arsenicals for 8 weeks showed no toxic response (Eisler 1988). In comparison, recent observations from Erickson et al. (2010) indicated that in rainbow trout that were fed diets containing 28 mg As/kg to 76 mg As/kg showed decreased feeding, decreased food conversion efficiency, liver cell abnormalities and digestive effects from consumption of arsenate and arsenite. These effects correlate to exposure to 1.5-7.9 mg As/L to both the rainbow trout and the dietary food items (i.e., *Lumbricus variegatus*) (Erickson et al. 2010).

Overall, adverse effects to rainbow trout populations in Lake 901 are not expected. All predicted concentrations except the maximum concentration for all phases except the post-closure and closure phases are to occur below the CCME WQG. The predicted average concentrations for the post-closure and closure phases will also be below the CCME WQG. However, on occasion, a maximum concentration of 0.0078 mg/L is expected to occur during these two phases. Rainbow trout is one of the more sensitive fish species and its toxicity is similar to that of the most sensitive invertebrate species. Reported LC50s for rainbow trout are all above the predicted maximum concentrations. In addition, chronic studies showed that consumption of dietary items exposed to arsenic showed effects at levels much greater (>1.5 mg/L) than those predicted (0.0078 mg/L) to be present during the post-closure and closure phases.

6.7.4.10.1.5.6 Cadmium

6.7.4.10.1.5.6.1 Ecologic Toxicity Profile

Cadmium has no essential nutritional value or biological to plants or animals (Eisler 1985). Effects in freshwater biota include inhibited reproduction, reduced growth, and high mortality (Eisler 1985). Cadmium manifests greater teratogenic effects than other metals, including arsenic, copper, indium, lead, and mercury (Ferm and Layton 1981, as cited in Eisler 1985). Cadmium appears to biomagnify (increase in concentration with increase in trophic level) in lower trophic levels only, as demonstrated in tests of a freshwater food chain comprising algae (*Chlorella vulgaris)*, cladocera (*Daphnia magna*) and fish (*Leucospius delineatus*) (Ferard *et al.* 1983, as cited in Eisler 1985). In fish, tests show that cadmium affects gill, kidney, intestines, or other tissues, depending on cadmium concentration exposure duration (Eisler 1985; Beširović *et al.* (2010). The mode of toxic action may include induction of DNA damage (Bertin and Averbeck 2006; Viau *et al.* 2008), activation of proteases (Hsu *et al.* 2009; Lee *et al.* 2007), disturbance of Ca^{2+}in ion homeostasis (Yang *et al.* 2007), damage to mitochondria (Belyaeva *et al.* 2006), and enhanced formation of radicals (Liu *et al.* 2009; Pathak and Khandelwal 2006; Risso-de Faverney *et al.* 2001).

The bioavailability and toxicity of cadmium, and its uptake by aquatic organisms, is affected by many physical, chemical, and biological factors. In freshwater systems, cadmium predominantly occurs as the free cadmium ion (Cd^{2+}) and as cadmium carbonate and cadmium chloride (Mantoura et al. 1978, as cited in CCME[3]). The mobility and bioavailability of cadmium is diminished under conditions of high pH, high water hardness, and high organic content (CCME[3]). At pH >9, solubility decreases and cadmium hydroxide is formed (Moore and Ramamoorthy 1984, as cited in CCME[3]). Also under reducing conditions, cadmium and sulphur will form insoluble cadmium sulphide (Muramoto 1982, as cited in CCME[3]). The sorption processes are very important in controlling the bioavailability of cadmium (CCME[3], Trivedi and Axe 1999). Cadmium is removed from suspension by replacing calcium in the lattice structure of carbonate minerals, and by co-precipitating with hydrous iron, aluminum and manganese oxides (CCME[3]). In the presence of organic content, cadmium will adsorb to humic substances and other organic complexing agents (U.S. EPA 1979, as cited in CCME[3]). Dissolved organics appear more beneficial to cladocerans than to fish in lowering the toxicity of cadmium(Geisy et al 1977, as cited in CCME[3]).

Interaction of cadmium with zinc enhances the toxicity of cadmium in the aquatic plants *Lemna* and *Salvinia*, while selenium decreases toxicity in aquatic plants and animals (Reeder et al. 1979a); however, selenium can increase retention and modify distribution of cadmium within organisms (CCME[3]). Freshwater biota are more sensitive to cadmium toxicity than are marine biota (Eisler 1985). Salmonids are the most sensitive of fish families to cadmium toxicity (CCME[3]). Bioaccumulation in freshwater biota appears to increase with higher temperatures (Remacle at al.1982; Rombough and Garside 1982, as cited in CCME[3]) and with lower concentrations of complexing agents. Decreased pH causes increased uptake of cadmium in algae (Hart and Scaife 1977).

6.7.4.10.1.5.6.2 Water Quality Model Results

For Lake 901, the proposed site-specific guidelines recommend that the acute cadmium water quality guideline (based on hardness), during the construction and operations phases be 0.0032 mg/L and chronic water quality guideline for cadmium be 0.0003 mg/L. The alternative approach recommends that at Lake 901, the acute and chronic cadmium water quality guidelines be 0.0076 and 0.0005 mg/L during closure phase, respectively. Predicted mean, 95th percentile, and maximum concentrations of cadmium during closure at Lake 901 are above the site-specific chronic water quality guideline.

The predicted dissolved cadmium concentration at Lake 901 is subject to uncertainty due to the cadmium method detection limits used. It is not possible to indicate with certainty what the potential increase in cadmium might be. The BC MOE (2006a) interim maximum and CCME (2007) guideline for the protection of freshwater aquatic life for cadmium is 0.000023 mg/L, based on a site-wide mean hardness of 65 mg/L. Since the detection limit for waste rock source chemistry was 0.0001 mg/L, any cadmium added to the source chemistry or background would be above the BC MOE (2006a) and CCME (2007) guidelines.

6.7.4.10.1.5.6.3 Potential Effects on Rainbow trout

The aquatic freshwater ambient Water Quality Guideline (WQG) for cadmium, adopted as a working guideline established by the Canadian Council Ministry of the Environment (and BC MOE), is based on the following hardness-dependent equation (CCME 2005):

$$\text{Chronic Guideline (ug/L)} = 10^{0.86 * (\log (\text{hardness})-3.2)} \quad \text{(Equation 1)}$$

Several assumptions made in the development of the CCME guidelines for cadmium appear to be overly conservative or introduce high uncertainty. The CCME hardness-dependant guidelines for cadmium are presented as interim guidelines, and rely heavily on a single unpublished study (Biesinger and Christensen 1972) for which CCME could not verify the exact cadmium compositions and concentrations. CCME's interim guideline relies on toxicity data for only one species (cladoceran, with a limited dataset) and assumes that the relationship between acute toxicity and water hardness observed for cladocerans is similar to that of other freshwater organisms. The CCME chronic hardness-dependent guideline is also based on acute toxicity data (chronic data were not used in its development) and assumes that the relationship between acute toxicity and water hardness is the same as that for chronic toxicity.

Due to the uncertainties and assumptions applied in the CCME (and BC MOE) working criteria, USEPA cadmium Ambient Water Quality Criteria (AWQC) guidelines were selected as site-specific WQC. USEPA guidelines for cadmium are derived from acute toxicity values for 65 species (including 39 invertebrates, 24 fish, and two amphibians), and chronic toxicity values for 21 species (including 7 invertebrates and 14 fish, in 16 genera) (USEPA 2001).

$$\text{Acute AWQC (ug/L)} = e^{1.10166(\ln(\text{hardness})-3.924)} \quad \text{(Equation 2)}$$

$$\text{Chronic AWQC (ug/L)} = e^{0.7409(\ln(\text{hardness})-4.719)} \quad \text{(Equation 3)}$$

Equations 2 and 3 calculate surface water criteria in terms of total cadmium. USEPA recommends multiplying by a hardness-based conversion factor (Equation 4 for acute and Equation 5 for chronic) to obtain dissolved criteria (USEPA, 2009):

$$\text{Acute conversion factor} = 1.136672- \ln (\text{hardness})*0.041838 \quad \text{(Equation 4)}$$

$$\text{Chronic conversion factor} = 1.101672- \ln (\text{hardness})*0.041838 \quad \text{(Equation 5)}$$

This updated approach (Equation 2 for acute and Equation 3 for chronic) is more appropriate than the existing approach used by BC MOE and CCME (Equation 1) to calculate Site WQGs for cadmium as it is based on toxicity data for a diverse set of freshwater organisms and acute and chronic criteria are based on acute and chronic data, respectively. Based on this alternative approach, the cadmium WQGs would be:

	Project Phase		
	Construction	Operations	Closure
Acute (mg/L)	0.0032	0.0032	0.0076
Chronic (mg/L)	0.0003	0.0003	0.0005

These WQGs are designed to protect a group of diverse genera from the harmful effects of cadmium. Published toxicity data was also available for rainbow trout (*Oncorhynchus mykiss*) in Brown et. al. (2001) and USEPA (2001). Brown et. al. (1994) reported lowest observed effects levels (LOEL's) for growth, reproduction and mortality of rainbow trout at various life stages from chronic exposure to concentrations of cadmium in water for periods of up to 90 days. The lowest reported LOEL from rainbow trout from this study is 0.0018 mg/L cadmium at which rainbow trout eggs failed to develop to the fry stage. In this same study no observed adverse effects (NOAECs) on growth or mortality were observed on adult and juvenile life stages of rainbow trout at concentrations up to 0.0055 mg/L (Brown et. al. 1994). Species mean acute values used in the development of the acute AWQC and normalised for hardness are 0.002108 mg/L for rainbow trout (USEPA, 2001). Species mean chronic values for studies used in the development of chronic AWQC and normalised for hardness are 0.001308 mg/L for rainbow trout based on life cycle toxicity tests (USEPA, 2001).

The proposed site-specific chronic WQGs derived from the updated approach are less than lethal and sub-lethal effects concentrations for rainbow trout reported in the literature. However, maximum predicted concentrations of cadmium are less than acute site-specific WQC during all project phases and less than sub-lethal effects concentrations reported in the literature except during closure and post-closure. Maximum predicted cadmium concentrations during closure (0.001717 mg/L) and post closure (0.001713 mg/L) are less than the lowest reported LOEL from Brown et. al. (1994) (0.0018 mg/L) and only slightly higher than the species mean chronic value published in USEPA (2001) (0.001308 mg/L). Average concentrations predicted during these project phases (0.000869 mg/L during closure and 0.000917 mg/L during post-closure) are less than sub-lethal effects for rainbow trout. Sub-lethal effects published in the literature are based on long-term exposure to sensitive early life stages. For less sensitive juvenile and adult life stages the reported no adverse effects level (NOAEL) from the literature (0.0055 mg/L) is higher than all predicted cadmium concentrations for Lake 901. Based on the average predicted concentrations being less than sub-lethal effects for early life stages and the maximum predicted concentrations being less than the reported NOAEL for less sensitive life stages, predicted concentrations of cadmium in Lake 901 are not expected to adversely affect populations of rainbow trout.

6.7.4.10.1.5.7 Chromium VI

6.7.4.10.1.5.7.1 Ecologic Toxicity Profile

Chromium is a naturally occurring element found in animals, rocks, plants, soil, and volcanic dust and gases (ATSDR, 2008). Its trivalent form, chromium (III), is considered an essential nutrient in vertebrates at levels of 50 to 200 micrograms per day because it acts as an essential cofactor in insulin production and forms complexes with protein, amino acids, and other organic acids (Eisler, 2000; Irwin, 1997). Dietary deficiency of chromium (III) results in an inability to clear glucose from the blood and pathology similar to diabetes (Eisler, 2000).

In natural waters, chromium (III) most commonly forms highly insoluble oxides, hydroxides, and phosphates and is adsorbed by suspended particles. Therefore, it is rapidly removed from the water column by settling particulate matter. Because of this, chromium (III) concentrations are likely to be greater in the food supply of fish and benthic macroinvertebrates than in their surrounding water column, making ingestion a common route of exposure (Irwin, 1997; Eisler, 2000). Chromium, however, is poorly absorbed from the gastrointestinal (GI) tract (only 0.5 to 2.8% of dietary chromium absorbed via the GI tract in humans). Although absorbed chromium is carried throughout the body in the blood, eventually being distributed to all tissues, the greatest concentrations are found in the blood, liver, lung, spleen, kidney, and heart. However, systemic chromium (III) does not appear to be stored for extended periods of time within tissue. It is typically eliminated in urine following dermal exposure and in feces following oral exposure (ATSDR, 2008).

In general, toxicological properties of chromium salts to aquatic organisms, including fish and benthic macroinvertebrates, are significantly influenced by a variety of biological and abiotic factors. These include variables such as the species, age and developmental stage of the organism, and potential differences in sensitivities of local populations; the temperature, pH, salinity and alkalinity of the medium; the interaction of chromium with other contaminants; the duration of exposure; and the chemical form of chromium (Eisler, 2000; Irwin, 1997). For example, high concentrations of total dissolved solids and hardness tend to ameliorate toxic effects to freshwater biota (Eisler, 2000).

The mechanisms of chromium toxicity and carcinogenicity are very complex (ATSDR, 2008). Naturally occurring chromium (III) is believed to have low toxicity due to poor membrane permeability and noncorrosivity (Irwin, 1997). However, trivalent chromium can form complexes with peptides, proteins, and DNA, resulting in DNA-protein crosslinks, DNA strand breaks, and alteration in cellular signalling pathways (ATSDR, 2008).

6.7.4.10.1.5.7.2 Water Quality Model Results

The water quality model predicts that dissolved chromium concentrations in Lake 901 to stay below the BC MOE (2006a) and CCME (2007) guidelines for chromium (III) of 0.0089 mg/L and chromium (VI) of 0.001 mg/L at all phases of the proposed Project. The dissolved chromium concentrations ranges from 0.0002 mg/L to 0.0007 mg/L throughout all phases of the proposed Project.

The water quality model was based on total dissolved chromium concentrations, which includes both of the free chromium ion species chromium (III) and chromium (VI). It is not based specifically on chromium (III), which is less soluble in water than chromium (VI). CCME (1999) reports that the percentage of chromium (VI) in a total dissolved chromium sample generally ranges between 70% and 90% of total chromium.

6.7.4.10.1.5.7.3 Potential Effects on Rainbow trout

CCME and BC MOE WQGs are designed to protect a group of diverse genera from the harmful effects of chromium. Although studies show that rainbow trout (*Oncorhynchus mykiss*) are among the most sensitive species of freshwater teleosts to chromium (III) toxicity, it is not believed that predicted model concentrations in Lake 901 would elicit acute or chronic effects on the resident rainbow trout population based on the following lines of evidence:

- The BC MOE interim water quality guideline for chromium (III) is based on toxicity to the rainbow trout. It was derived by multiplying the 102-day Lowest Observable Effects Concentration (LOEC) (mortality) of 0.089 mg/L by a safety factor of 0.1 (CCME, 1999). If peak chromium concentrations are below the conservative benchmark, which is 10 times lower than the LOEC, rainbow trout will be protected;
- USEPA (1995) collected acute and chronic toxicity data for rainbow trout to derive the ambient water quality criteria (AWQC) for chromium (III). Acute effects to rainbow trout are not expected to occur below concentrations of 9.669 mg chromium (III)/L, and chronic effects to rainbow trout are not expected below 0.150 mg chromium (III)/L; and
- Rainbow trout are able to regulate chromium, either actively, by reduced absorption or increased excretion, or passively, by the limitation of binding sites for chromium *in vivo* (Eisler, 2000).

The water quality model predicts that chromium concentrations at Lake 901 are all below the WQGs for chromium (III) during all project phases. Therefore, based on the lines of evidence, predicted concentrations of chromium in Lake 901 are not expected to adversely affect resident populations of fish, such as rainbow trout.

6.7.4.10.1.5.8 Copper

6.7.4.10.1.5.8.1 Ecologic Toxicity Profile

Copper occurs abundantly throughout the environment, and is an essential component of many biological processes in plants and animals. Toxic effects of copper in aquatic invertebrates vary with phylum; effects include disruption of membrane permeability and cytoplasmic function in snails, and impaired osmotic and ionic regulation, antennal gland degeneration, and respiratory enzyme inhibition in crayfish *Orconectes rusticus* (Alberta Environmental Protection 1996). In fish, toxic effects include interference with osmoregulation (Hodson et al. 1979 , as cited in Eisler 1998), oxygen transport, and energy metabolism (ATP synthesis) (Hansen et al. 1992b, as cited in Eisler 1998). Copper disrupts gill function in rainbow trout by interfering with ion regulation (Reid and McDonald 1991, as cited in Eisler 1998), inhibiting sodium influx, and stimulating sodium efflux (Lauren and McDonald 1986, Reid and McDonald 1988, as cited in Alberta Environmental Protection 1996).

In addition to concentration, toxicity of copper depends on numerous physical, chemical, and biological factors. Copper exists in four oxidation states, of which the cupric ion (Cu^{+2}) is the most common and toxic form encountered by aquatic life (Eisler 1998). The cupric ion, the copper hydroxide ion ($Cu(OH)^{+}$) and copper carbonate ($Cu(CO_3)$ make up 98% of dissolved copper in freshwater systems ((Nelson et al. 1986, as cited in Alberta Environmental Protection 1996). The cupric ion is dominant at pH <6, while the aqueous copper carbonate complex is dominant from pH 6.0 to 9.3 (US EPA 1980, as cited in Eisler 1998). The bioavailability of the cupric ion, and thus its toxicity, decreases significantly through complexation with inorganic and organic compounds (Alberta Environmental Protection 1996). In general, the formation of these compounds is affected by pH, alkalinity, hardness, temperature (Eisler 1998), and by the presence of humic and fulvic acids (Alberta Environmental Protection 1996). Copper readily complexes with fulvic acids and dissolved organic matter (Gardner and Ravenscroft 1991; Lin et al. 1994, as cited in Alberta Environmental Protection 1996).

In hard, moderately polluted water, 43 to 88% of the copper is bound up with suspended solids and removed from biologically availability (Shaw and Brown 1974, as cited in Eisler 1998). In living organisms, copper interacts with many other essential and non-essential trace elements, and the simultaneous effect exerted on toxicity from both elements may be additive (sum of individual toxic effects), synergistic (greater than the sum of individual toxic effects), or antagonistic (less than the sum of individual toxic effects) (Alberta Environmental Protection 1996, and Kirchgessner et al. 1979, as cited in Eisler 1998). Examples include synergistic effects for ova of brown trout (*Salmo trutta*) from copper-iron interactions, and from copper-aluminum interactions (Sayer et al. 1991, as cited in Eisler 1998), and synergistic effects from copper-zinc interactions for a broad range of aquatic organisms (Eisler 1998). Studies indicate that sensitivity to copper in fish may decrease with older lifestages and with size, depending on the species (Alberta Environmental Protection 1996). Increased toxic effects have also been associated with intermittency (versus continuity) of exposure, increased temperature, decreased pH for fish species sensitive to pH, and increased pH for fish species that are not sensitive to pH (due to diminished competition, at higher pH, of cupric and hydrogen ions at receptor sites) (Alberta Environmental Protection 1996). Decreased toxic effects have been observed with increasing alkalinity, increasing hardness, and increasing dissolved oxygen, again, depending on the fish species (Alberta Environmental Protection 1996). Invertebrates do not appear to vary in sensitivity with respect to life stage (Alberta Environmental Protection 1996).

6.7.4.10.1.5.8.2 Water Quality Model Results

The model shows that the average copper concentration in Lake 901 will be 0.0003 mg/L which will not exceed the BC MOE 30-day average of 0.002-0.0044 mg/L, the CCME WQG of 0.002 mg/L or the site-specific WQG of 0.0048 mg/L. The maximum copper concentration will be 0.0005 mg/L during the construction phase which will also not exceed the BC MOE maximum of 0.00228-0.00655 mg/L, the CCME WQG or the proposed site-specific WQG of 0.014 mg/L. During the operations phase, the average copper concentration in Lake 901 is predicted to be 0.0006 mg/L and the maximum will be 0.0015 mg/L. Similar to the construction phase, predicted copper concentrations in Lake 901 during the operations phase are also not expected to exceed guidelines. In particular, the BC MOE 30-day average for the operations phase is 0.002-0.0047 mg/L, the BC MOE maximum is 0.00282-0.00683 mg/L and the proposed site-specific acute and chronic WQG are 0.014 mg/L and 0.0051 mg/L. During post-closure the predicted average concentration of copper will be 0.0038 mg/L which will exceed the lower end of the BC MOE 30-average which ranges between 0.002 and 0.005 mg/L. The CCME WQG which ranges between 0.002 and 0.003 mg/L will also be exceeded. The proposed site-specific WQG of 0.0071 mg/L will not be exceeded. The predicted maximum concentration of 0.0070 mg/L will exceed the BC MOE maximum (0.0041-0.00915 mg/L) and the CCME WQG. The proposed site-specific WQG of 0.017 mg/L will not be exceeded. In the closure phase, the predicted average copper concentration in Lake 901 will be 0.0040 mg/L which will exceed the BC MOE 30-day average of 0.002-0.0137 mg/L. The maximum will be 0.0074 mg/L, which will exceed the CCME WQG (0.002-0.004 mg/L) and the lower end of the BC MOE maximum WQG of 0.00423-0.0124 mg/L. In all cases, the proposed site-specific WQG for copper for the closure phase of 0.030 mg/L (acute) and 0.0097 mg/L (chronic) will not be exceeded in Lake 901.

6.7.4.10.1.5.8.3 Potential Effects on Rainbow trout

The aquatic freshwater Water Quality Guidelines (WQG) for total copper established by the BC MOE (Singleton) (1987) are based on hardness-dependent equations and are as follows:

When hardness is less than or equal to 50 mg/L as $CaCO_3$:

Chronic Guideline (µg/L) = 2 µg/L (Equation 1)

When hardness is greater than 50 mg/L as $CaCO_3$:

Chronic Guideline (µg/L) = 0.04 x (hardness) (Equation 2)

Regardless of hardness, the acute guideline is as follows:

Acute Guideline (µg/L) = 0.094 x (hardness) + 2 (Equation 3)

The federal guideline (CCME formerly CCREM) is also hardness-based and is as follows:

$$\text{WQG } (\mu g/L) = e^{0.8545 \times \ln(\text{hardness}) - 1.465} \times 0.2 \quad \text{(Equation 4)}$$

Where WQG is not lower than 2 µg/L ,and

Hardness = mg/L as $CaCO_3$.

Both the BC MOE and the CCME copper guidelines are overly conservative and have a high degree of uncertainty. For example, BC MOE did not base their acute WQG equation (Equation 3) on acute data, rather they derived their equation from USEPA's chronic criteria which were based on chronic effects data. Also, an arbitrary ordinate intercept of 2 µg/L was added to the equation to ensure that the acute criterion was higher than the chronic criterion. Chronic equations (Equation 1 and Equation 2) derived by the BC MOE are based on a study that did not evaluate chronic effects but instead evaluated acute toxicity. In comparison, the CCME value is based on the 1984 USEPA chronic Ambient Water Quality Criteria (AWQC) and includes an application factor of 0.2 to account for unspecified uncertainties in the dataset.

In 2007, the USEPA updated the copper AWQC. The 2007 update includes LC50 and EC50 values reported from 350 acute toxicity tests for 15 species; including 22 species of fish. Species included sensitive salmonid fish including rainbow trout (*Oncorhynchus mykiss*). These data were used to revise the acute and chronic equations:

$$\text{Acute Guideline (ug/L)} = e^{0.9422 * \ln(\text{hardness}) - 1.700} \quad \text{(Equation 5)}$$

$$\text{Chronic Guideline (µg/L)} = = e^{0.8545 * \ln(\text{hardness}) - 1.702} \quad \text{(Equation 6)}$$

The 2007 chronic AWQC, unlike the existing regulatory approach by the BC MOE (which is extrapolated chronic exposure based on acute data), is based on experimental data showing the relationship between chronic and acute effects. The current USEPA chronic AWQC for copper (2007) was derived from chronic data for 6 invertebrates species and 10 fish species. Fish species included sensitive salmonid fish species such as rainbow trout (*Oncorhynchus mykiss*). Overall, USEPA's approach uses a more thorough and up-to-date data set, and derives a logarithmic relationship between hardness based on rigorous statistical review of the data and derives the slope using the species sensitivity distribution approach.

Based on USEPA's approach, alternative copper WQGs would be:

	Project Phase		
	Construction	**Operations**	**Closure**
Acute (mg/L)	0.014	0.0141	0.0301
Chronic (mg/L)	0.0048	0.0051	0.0097

These alternative WQGs are designed to protect a group of diverse genera from the harmful effects on copper. Toxicity studies in the scientific literature for rainbow trout were reviewed by USEPA and HydroQual and was used to develop and parameterise the biotic ligand model (BLM). Essentially, the BLM links bioavailable concentrations of copper to toxicological effects, and accounts for the effects of several contributing factors including hardness, pH, temperature, and the concentration of other dissolved ions. The toxicity data compiled by USEPA and HydroQual (2007) indicated that under site-specific conditions in Lake 901, acute and chronic effects to aquatic species are expected to occur at the following concentrations:

	Project Phase		
	Construction	Operations	Closure
Acute (mg/L)	0.0146	0.0143	0.0163
Chronic (mg/L)	0.0084	0.0083	0.0082

The proposed site-specific acute and chronic WQGs determined from the USEPA AWGC approach are less than the lethal and sub-lethal effects concentrations for aquatic species including rainbow trout used to develop the BLM model. Overall, the water quality model predicts that copper concentrations at Lake 901 are all below the proposed site-specific WQGs derived by the USEPA method and the BLM method for all project phases. Therefore, predicted concentrations of copper in Lake 901 are not expected to adversely affect populations of rainbow trout.

6.7.4.10.1.5.9 Iron

6.7.4.10.1.5.9.1 Ecologic Toxicity Profile

Iron is a macronutrient, and is required for blood hemoglobin synthesis in vertebrates. Iron occurs in two forms: insoluble ferric iron (Fe^{3+}) and the soluble ferrous iron (Fe^{2+}). In toxic concentrations, ferric iron (Fe^{3+}) impairs fish respiration by accumulating on gills and blocking gill function (Dalzell and MacFarlane 1999, and Lehtinen and Kingstedt 1983 and Peuranen *et al.* 1994, as cited in Phippen *et al.* 2008). Ferrous iron (Fe^{2+}) has been associated with the disruption of body sodium balance in brook trout (*Salvelinus fontinalis*) (Gonzalez *et al.* 1990), but the mode of toxicity is not well understood (Phippen *et al.* 2008).

Iron solubility and toxicity is affected parameters including pH, dissolved oxygen, amounts of dissolved and total organic carbon, presence of organic acids, chloride concentration, exposure to sunlight (Phippen *et al.* 2008). In general, ferrous (dissolved) iron occurs at lower pH, and precipitates out of solution as ferric iron at higher pH in the presence of oxygen.

Ambient levels of ferrous (dissolved) iron are generally very low (Phippen *et al.* 2008). Ferric iron typically occurs in colloidal suspension of ferric (Fe^{3+}) hydroxide particles (CCME[3]). The toxicity of colloidal iron may be reduced by the presence of organic material (humic acids), which has an ameliorating effect on ion regulation and prevents most of the accumulation of iron on the gills (Phippen *et al.* 2008). Fish and crustaceans are the most susceptible taxa to chronic toxicity of iron (Johnson *et al.* 2007).

6.7.4.10.1.5.9.2 Water Quality Model Results

The mean iron concentration in Lake 901 is predicted to stay below the BC MOE maximum guideline (0.35 mg/L) (2008) and CCME (0.3 mg/L) (2007) guidelines during all phases of the proposed Project. During construction the range of the predicted values ranged from 0.196-0.3617 mg/L. The 95th percentile (0.3524 mg/L) and maximum (0.3617 mg/L) value for iron is predicted to exceed the BC MOE maximum and CCME guideline during construction. The maximum value (0.3005 mg/L) for iron is predicted to exceed the CCME (2007) guideline in Year 1 of the operations phase.

6.7.4.10.1.5.9.3 Potential Effects on Rainbow trout

BC MOE and CCME WQGs are designed to protect a group of diverse genera from the harmful effects of lead. Several studies have been conducted to asses lead toxicity specifically to fish species, including rainbow trout (*Oncorhynchus mykiss*), and brook trout (*Salvelinus fontinalis*), a species of the same subfamily *Salmoninae*, as the rainbow trout. Adverse effects on rainbow trout (*Oncorhynchus mykiss*) from predicted concentrations of iron in Lake 901 are unlikely based on the following lines of evidence:

- The BC MOE guideline (0.35 mg/L) is based on the lowest 96-hour LC50 value reported for testing conducted by the BC MOE (3.5 mg/L for *Hyalella azteca*) divided by a safety factor of 10 (BC MOE 2008). The BC MOE testing upon which the criteria is based also evaluated rainbow trout and reported a 96-hour LC50 of 15.2 mg/L (BC MOE 2008). All predicted concentrations of iron in Lake 901 are less than the LC50 value for rainbow trout applying the same safety factor as was used in the development of the guideline (1.52 mg/L);
- Loeffelman et. al. (1985) reported a 96-hour LC50 for rainbow trout at a concentration of 4.4 mg/L ferrous (dissolved) iron. A 33-day exposure of rainbow trout eggs to concentrations of ferrous iron up to 5.7 mg/L resulted in insufficient mortality to calculate an LC50 (Loeffelman et. al. 1985). A lowest observed adverse effects level (LOAEL) was reported for effects on survival, deformities and short term growth for post hatch rainbow trout larvae at a ferrous iron concentration of 1.2 mg/L (Loeffelman et. al. 1985). All predicted concentrations of iron in Lake 901 are below chronic and acute toxicity values for lethal and sub-lethal effects for rainbow trout in the scientific literature; and
- Smith and Sykora (1976) showed that chronic exposure of brook trout to lime-neutralised suspended iron at concentrations of 12, 6, 3, 1.5 and 0.75 mg/L over periods up to 90 days had no effect on the hatching success of brook trout. At concentrations of 12 mg/L iron, Sykora *et al.* (1972) observed adverse effects on growth of brook trout and at 6 mg/L the brook trout test population was more susceptible to injury and disease. All predicted concentrations of iron in Lake 901 are below chronic sub-lethal effects concentrations for brook trout published in the literature.

While predicted concentrations of iron in Lake 901 may be above conservative regulatory guidelines for some phases of the project, those concentrations are below acute and chronic effects levels specific to fish including rainbow trout. Therefore, predicted concentrations of lead in Lake 901 are not expected to adversely affect populations of rainbow trout.

6.7.4.10.1.5.10 Lead

6.7.4.10.1.5.10.1 Ecologic Toxicity Profile

Lead accumulates in organisms and alters development at multiple levels of organisation, including cell, tissue, organ and body system, with adverse consequences to metabolism, growth, behaviour, learning, reproduction and survival (Eisler 1988). Lethal concentrations of lead in freshwater fish cause excess secretion and coagulation of mucous over the entire body, resulting in interference with respiration and death by anoxia (Aronson 1971, Eisler 1988). Nutritional deficiencies of calcium, zinc, iron, vitamin E, copper, thiamin, phosphorus, magnesium, fat, protein, minerals, and ascorbic acid may increase lead uptake in fish.

Benes *et al.* 1985 report that lead exists in three physiochemical forms in surface waters depending on numerous physical and organic conditions: dissolved-labile (Pb^{+2}, $PbOH^{+}$, and $PBCO_3$), dissolved-bound (colloids or strong complexes), and particulate. Physical conditions favouring the solubility and bioavailability of lead include low pH and elevated temperatures up to 40°C. High concentrations of suspended sediments, and high concentrations of salts of calcium, iron, manganese, zinc, and cadmium decrease lead solubility (Eisler 1988).

Some chronic and acute toxicity tests suggest that freshwater daphnids are more sensitive than amphipods and fish (Eisler 1988). Rainbow trout appear to be more sensitive to lead than other salmonids (Eisler 1988). Toxicity in fish is elevated at younger life stages, and intoxication of lead in fish has been shown to increase with growth rate (Eisler 1988). The major route of lead absorption is by ingestion and uptake through the intestinal tract, and diet is a major factor influencing the rate of uptake and absorption (Eisler 1988). Toxic effects of lead in salmonid fish is ameliorated by elevated water hardness and salmonid calcium status (Varanasi and Gmur 1978, as cited in Eisler 1988).

6.7.4.10.1.5.10.2 Water Quality Model Results

The hardness-dependent guidelines used to determine exceedances are unadjusted provincial and federal guidelines. Comparison of predicted water quality in Lake 901 to guideline values is provided in Table 6.7.4-40:

Table 6.7.4-40: Summary of Water Quality Predictions

Values (ug/L)	Project Phase			
	Construction	**Operations**	**Closure**	**Post-Closure**
Guidelines				
BC MOE Max.	3 – 91.7	3.6 – 101	13 – 392	12.1 – 121
BC MOE 30-day	n/a – 6.89	3.5 – 7.3	3.8 – 18.6	3.8 – 8
CCME-PAL	1 – 2	1 – 2	2 – 7	2 – 4
Water Quality Predictions				
Average	0.13	0.21	2.03	2.19
Maximum	0.22	0.46	**4.03**	**4.03**

Notes: **Bold** Water quality model prediction may exceed CCME-PAL guideline value

During construction and operations there are no exceedances predicted above the BC MOE maximum, the BC MOE 30-day, or the CCME (2007) guidelines. The water quality model predicted that lead concentrations in Lake 901 would increase in the closure phase. During closure, the average annual concentration (2 ug/L) is predicted to remain below the CCME guideline (2 to 7 ug/L) but the peak monthly levels (4 ug/L) may exceed. During post-closure, the lead concentration (which ranges from 0.71 ug/L up to 4.03 ug/L) is predicted to exceed the CCME guidelines (2 to 4 ug/L). There are no exceedances predicted above the BC MOE guidelines.

6.7.4.10.1.5.10.3 Potential Effects on Rainbow Trout

For hardness > 8 mg/L as $CaCO_3$, the freshwater WQGs for lead established by the British Columbia Ministry of Environment (BC MOE) in 1987 are calculated according to the following hardness-dependent equations, as described in *Technical Appendix for the Water Quality Criteria for Lead* (Nagpal 1987):

$$\text{Acute guideline (ug/L)} = e^{1.273*\ln(\text{hardness}) -1.460} \qquad \text{(Equation 1)}$$

$$\text{Chronic guideline (ug/L)} = 3.31 + e^{1.273*\ln(\text{hardness}) -4.705} \qquad \text{(Equation 2)}$$

Equation 1 is directly adapted from the United States Environmental Protection Agency (USEPA) acute Ambient Water Quality Criteria (AWQC) for lead (USEPA, 1985). Equation 2 is a modified version of the USEPA chronic AWQC for lead, based on setting the chronic guideline to 4.0 ug/L at a hardness of 30 mg/L. Figure 1 from the *Technical Appendix* (Nagpal, 1987) demonstrates that both the acute and chronic USEPA criteria are below the experimentally observed acute and chronic values and may be overprotective.

According to Charles Delos of the USEPA Office of Water in Washington DC, and member of the USEPA Science Advisory Board Aquatic Life Criteria Guidelines Consultative Panel, USEPA is re-assessing its lead criterion (Delos 2011). Mr. Delos provided AMEC with the draft toxicity data set currently under internal agency review. AMEC then used the USEPA data set to derive updated acute and chronic guidelines:

$$\text{Acute guideline (ug/L)} = e^{1.4421 * \ln(\text{hardness}) - 1.84} \quad \text{(Equation 3)}$$

$$\text{Chronic guideline (ug/L)} = 2.62 + e^{1.4421 * \ln(\text{hardness}) - 4.58} \quad \text{(Equation 4)}$$

To account for the conservative assumptions that go into the USEPA chronic equation, we have also applied BC MOE's adjustment process described previously, setting the chronic guideline to 4 ug/L at a water hardness of 30 mg/L as $CaCO_3$. This updated approach (Equation 3 for acute and Equation 4 for chronic) is more appropriate than the existing approach (Equation 1 and Equation 2) to calculate Site WQGs for lead as it uses the most current available data set and does not include data from the mysid, a marine species included in the existing approach, that is unlikely to inhabit the Site which is entirely freshwater. Based on this alternative approach, the lead WQGs would be:

	Project Phase		
	Construction	**Operations**	**Closure**
Acute (ug/L)	69	200	62
Chronic (ug/L)	5	10.4	5.3

These WQGs are designed to protect a group of diverse genera from the harmful effects of lead. Several studies have been conducted to asses lead toxicity specifically to fish species, including rainbow trout (*Oncorhynchus mykiss*) and brook trout ( ):

- Acute thresholds (96h LC50) for rainbow trout are reported in the range 1,200 ug/L in soft water (28 mg/L as $CaCO_3$) up to 506,500 ug/L in hard water (353 mg/L as $CaCO_3$) (Demayo et. al., 1982; Davies et. al., 1976);
- Acute thresholds (96h LC50) for brook trout reported by Holcombe et. al. (1976 as cited in Eisler (1988)) were 3,362 - 4,100 ug/L in water with a hardness of 44 mg/L as $CaCO_3$. Lead has been shown to be more toxic to fish in soft water than in hard water and in very hard waters the 96h LC50 may exceed 400,000 ug/L (Moore and Ramamoorthy, 1984);
- Sauter et. al. (1976) conducted early life stage tests with rainbow trout and obtained chronic values in the range 71 - 146 ug/L at a water hardness of 35 mg/L as $CaCO_3$. These values were somewhat higher than the chronic values from Davies et. al. (1976) which were in the range 7.2 - 14.6 ug/L at a water hardness of 28 mg/L as $CaCO_3$, potentially due to longer exposure in the latter study (19 months vs 2 months). The ameliorating effect of elevated hardness was demonstrated by Davies et. al. (1976) with chronic lifetime values for dissolved lead ranging up to 360 ug/L at a water hardness of 353 mg/L as $CaCO_3$. Demayo et. al. (1982) reported lifetime maximum acceptable toxicant concentrations (MATC) for rainbow

trout in the range of 4 - 7.6 ug/L for pre-hatch fry and 7.6 - 14.6 ug/L for post-hatch fry at a water hardness of 28 mg/L as $CaCO_3$; and

- Studies of chronic exposure were reported by Holcombe et. al. (1976) and USEPA (1980). Exposure of three generations of brook trout to mean total lead concentrations (0.9 - 474 ug/L) showed that all second-generation trout exposed to 235 and 474 ug/L and 34% of those exposed to 119 ug/L developed severe spinal deformities (Holcombe et. al. 1976). Scoliosis also appeared in 21% of the newly hatched third-generation alevins exposed to 119 ug/L, and weights of these fish 12 weeks after hatch were significantly reduced. The MATC for brook trout in water with a hardness of 44 mg/L as $CaCO_3$ and a pH of 6.8-7.6 lies between 59 and 119 ug/L for total lead and between 39 and 84 ug/L for dissolved lead. USEPA (1980) reported a lifetime MATC for lake trout of 48 - 83 ug/L with a water hardness of 33 mg/L as $CaCO_3$.

The proposed site-specific acute and chronic WQGs derived from the updated approach are less than lethal and sub-lethal effects concentrations for rainbow trout and brook trout reported in the literature. The water quality model predicts that lead concentrations at Lake 901 are all below the proposed site-specific WQGs for all project phases. Therefore, predicted concentrations of lead in Lake 901 are not expected to adversely affect populations of rainbow trout.

6.7.4.10.1.5.11 Mercury

6.7.4.10.1.5.11.1 Ecologic Toxicity Profile

Mercury has no essential nutritional value or biological function to plants or animals (Eisler 1987). In vertebrates, mercury is mutagen, teratogen, carcinogen (Eisler 1987), and neurotoxicant (CCME[1]). Mercury alters genetic and enzymatic systems, damages the immune system, the central nervous system, the reproductive system, and causes birth defects (USGS 2000). In the aquatic environment, mercury occurs as elemental mercury (Hg^o), mercurous ion (Hg_2^{2+}), mercuric ion (Hg^{2+}), and as organo-mercury compounds such as methyl mercury. The mercuric ion is the most toxic inorganic form (Eisler 1987).

Methyl mercury, the most toxic of all forms of mercury, is usually created through microbial (CCME[2]). Methylation usually occurs only under anoxic conditions in sediment. Methyl mercury biomagnifies in upper trophic levels (e.g., in predatory fish and piscivorous birds). Natural processes, including microbial activity, ultraviolet irradiation from sunlight, turbulence and wind (CCME[3]) can results in demethylation (CCME[1]), which transforms mercury into a form which can volatise back into the atmosphere.

The bioaccumulation of mercury in fish, and the toxic effect of mercury in all aquatic biota, is affected by numerous physical, chemical, and biological factors (Environment Canada 2002, as cited in CCME[2]). In general, lakes with low calcium (<5 mg/L), low alkalinity (acid neutralising capacity of 50 µeq/L or less), and low pH (<6) are associated with elevated mercury concentrations in fish (Grieb *et al.* 1990 and Spry and Wiener 1991, as cited in CCME[2]). The toxicity of mercury decreases with increased selenium concentration, salinity, and dissolved oxygen, and with decreased temperature (reviewed by Cuvin-Aralar and Furness 1991; Heit and Fingerman 1977; MacLeod and Pessah 1973; McKenney, Jr. and Costlow, Jr. 1981; Slooff *et al.* 1991; Snell *et al.* 1991, as cited in CCME[2]). Mercury toxicity is not significantly affected by water hardness (Keller and Zam 1991, as cited in CCME[2]). Chronic sensitivity is approximately the same in invertebrates as it is in fish (CCME[2]).

Because of its highly volatile state, atmospheric fallout is a primary source of elemental mercury even in undisturbed areas (USGS 2000).

6.7.4.10.1.5.11.2 Water Quality Model Results

During construction and operation there are no predicted exceedances of mercury above the BC MOE 30-day (2006b) or the CCME (2007) mercury guidelines. The BC MOE 30-day and CCME guidelines are 0.00002 mg/L and 0.000026 mg/L, respectively. Average and maximum concentrations are predicted to exceed both of these guidelines during closure and post closure phases of the Project mine life time. During the closure phase, the predicted average and maximum concentrations in Lake 901 are 0.000060 mg/L and 0.000115 mg/L, respectively. Predicted average and maximum concentrations during the post closure phase are 0.000063 mg/L and 0.000115 mg/L, respectively.

Mercury analyses for humidity cells for process and waste rock source terms were frequently below detection and thus these source terms modelled may be overestimated. This would result in the model calculating exceedances when none may occur.

6.7.4.10.1.5.11.3 Potential effects on Rainbow trout

Early life stages of fish including eggs, larva, and juvenile life stages (fry, fingerlings and smolt) are generally more vulnerable to mercury exposure than other life stages (Eisler, 1987). Exposure to mercury at concentrations above toxicity thresholds can result in reproductive impairment, reduction in growth and increased mortality. The CCME guideline and BC MOE 30-day guideline for mercury are established to protect sensitive life stages of freshwater aquatic life from chronic effects of mercury as well as to prevent undesirable accumulation of mercury from water to the food chain that may harm the most sensitive consumers (e.g., avian species) of aquatic life (BC MOE, 2001).

These WQGs are designed to protect a group of diverse genera from the harmful effects of lead. Potential effects on rainbow trout (*Oncorhynchus mykiss*) were evaluated by comparing predicted concentrations to published toxicity data available in the scientific literature:

- Chronic toxicity (LC50s) values reported for embryo or larval stages of rainbow trout exposed to concentrations of mercury in water for 28 days ranged from <0.0001 mg/L to 0.0047 mg/L (Eisler, 1987). Additional reported lethal chronic toxicity values for embryo or larval stage rainbow trout range from a NOED for mortality 0.07 mg/L to a LOED of 0.02 mg/L (Beckvar et. al. 2005);
- In Boening (2000), LC50 values are published for acute exposure (24 to 96 hour test durations) to organic mercury (methyl mercury chloride) that range from 0.024 mg/L

to 0.084 mg/L for rainbow trout fry; acute LC50 values range from 0.220 mg/L to 0.652 mg/L for rainbow trout adults; and

- Chronic sub-lethal no observed adverse effects levels (NOELs) reported in Phillips and Buhler (1978) range from 0.099 mg/L to 2.98 mg/L for juvenile life stages.

The BC MOE 30-day guideline and CCME guideline for mercury are below the lowest acute and chronic lethal and sub-lethal effects concentrations for rainbow trout reported in the literature. Although the average and maximum concentrations are predicted to exceed both guidelines during closure (predicted average and maximum concentrations are 0.000060 mg/L, and 0.000115 mg/L, respectively) and post closure (predicted average and maximum concentrations are 0.000063 mg/L and 0.000115 mg/L, respectively), the predicted concentrations of mercury in Lake 901 are also lower than the lowest acute and chronic lethal and sub-lethal effects concentrations for rainbow trout reported in the literature. Therefore, predicted concentrations of mercury in Lake 901 are not expected to adversely affect populations of rainbow trout.

6.7.4.10.1.5.12 Molybdenum

6.7.4.10.1.5.12.1 Ecologic Toxicity Profile

Molybdenum, an essential trace metal, is widely distributed throughout the environment. Biological functions of molybdenum include nitrogen fixation in plants, oxygen-reduction enzyme systems (Venugopal and Luckey 1978), and growth promotion in periphyton, phytoplankton, and macrophytes (CCME[3]). Molybdenum does not appear to be highly toxic to fish (Davies *et al.* 2005). The toxic mode of action in molybdenum is not as well understood as other metals (Ricketts 2009).

The uptake and effect of molybdenum in aquatic biota depends on numerous abiotic and biotic factors. In natural waters, molybdenum is typically found as molybdenum sulphide (MoS_2), molybdate (MoO_4^{2-}), and bimolybdate ($HMoO_4^-$) (Jarrell et al. 1980, as cited in CCME[3]). The fate of molybdenum is primarily influenced by sorption and co-precipitation with hydrous oxides of iron and aluminum (Allaway 1977, as cited in CCME[3]). At pH >7 the molybdate anion (MoO_4^{2-}) is predominant, while at pH <7 polymeric forms are predominant (CCME[3]).

Responses to molybdenum appear to be species specific. Some aquatic insects are known to concentrate molybdenum (Davies *et al.* 2005); however, molybdenum does not appear to bioaccumlate in fish (Davies *et al.* 2005). Acute toxicity tests performed with fish indicate that the fathead minnow (*Pimephales promelas*) is more sensitive than the rainbow trout (*Oncorhynchus mykiss*) (CCME[3]).

6.7.4.10.1.5.12.2 Water Quality Model Results

Mean molybdenum concentrations in Lake 901 are predicted to stay below the BC MOE 30-day average guideline (1.0 mg/L) (BC MOE 2006b), BC MOE maximum guideline (2.0 mg/L), and CCME guideline (0.073 mg/L) (CCME 2007) during the construction (0.00103 mg/L) and operations (0.04066 mg/L) phases, and are predicted to be above

CCME guideline during closure (0.4936 mg/L) and post-closure (0.501 mg/L) phases of mining. The 95th percentile for molybdenum are predicted to be above the CCME guideline during the operations (0.1029 mg/L), closure (0.935 mg/L), and post-closure (0.926 mg/L) phases of the proposed Project.

6.7.4.10.1.5.12.3 Potential Effects on Rainbow Trout

Predicted effects on rainbow trout (*Oncorhynchus mykiss*) are not likely to occur based on the following lines of evidence:

- Molybdenum is generally reported in the literature to be acutely lethal to various fish species at relatively high concentrations (70 mg/L to >2,000 mg/L) (Davies et al., 2005, i.e. at concentrations over two orders of magnitude above modeled concentrations in Lake 901;
- Predicted concentrations do not exceed the BC MOE 30-day or maximum guidelines for molybdenum during any of the project phases. The BC MOE guidelines are based on the lowest 96 hour LC50 for all aquatic species evaluated (selected value is for fathead minnow) with safety factors applied for the 30-day average and maximum guidelines of 0.02 and 0.05, respectively. Data evaluated in the development of these standards showed no adverse effects levels (NOAELs) on growth and mortality for rainbow trout at 17 times the 30-day average guideline (BC MOE 1986);
- The CCME guideline was derived by multiplying the lowest chronic toxicity value, a 28-d LC50 of 0.73 mg/L for rainbow trout (Birge 1978), by a safety factor of 0.1 (CCME 1991). However, this value from Birge 1978 is controversial as different bioassays demonstrate a wide toxicity range (0.73 mg/L to >90 mg/L Mo) (Davies et al., 2005), and is likely over conservative;
- Duplication of Birge (1978) by Davies (2005) using similar water chemistry along with the standard bioassay protocol demonstrated that molybdenum was not acutely toxic to the early life stages of rainbow trout over 32 days up to a maximum molybdenum concentration of 400 mg/L. An additional bioassay exposing early life stages of rainbow trout to a maximum molybdenum concentration of 1,500 mg/L for 32 days did not cause sufficient mortality to allow an LC50 to be calculated. These effects concentrations are over three orders of magnitude higher than predicted concentrations in Lower Lime Creek during all project phases; and
- Neither the CCME nor BC MOE guidelines have quantified the ameliorating effects of hardness on molybdenum. Therefore, the guidelines may be conservative and may overestimate any potential adverse effects. (BC MOE 1986; CCME 2007).

While some modeled concentrations of molybdenum may be above CCME and BC MOE guidelines, predicted concentrations are expected to be at levels below effects concentrations for rainbow trout. Therefore, adverse effects to populations of rainbow trout in Lake 901 are not expected.

6.7.4.10.1.5.13 Selenium

6.7.4.10.1.5.13.1 Ecologic Toxicity Profile

Selenium (Se) is an essential trace element that occurs both naturally and in waste from a broad range of industries (Lemly 2004). Selenium is distinguished as having the narrowest biological tolerance range of all essential trace elements (Wake et al. 2004). Selenium can become toxic at concentrations from three to five times above beneficial values (Wake et al. 2004). Hamilton (2004), in a review of selenium contamination investigations, concluded that the toxicity of selenium is expressed through the food chain. For animals at higher trophic levels, dietary exposure, rather than waterborne exposure, is the dominant route of selenium uptake (e.g., Dallinger et al. 1987). Selenium has a very steep dose response curve due to its propensity for rapid bioaccumulation in the food chain (Lemly 2004). Prey can concentrate selenium from 100 to 30,000 times above ambient levels (Lemly 2004). In sensitive fish species, the dose response can transition from no effects to reproductive failure within a few µg Se/L (Lemly 2004). In addtition to reproductive effects, toxic effects are also manifested as juvenile and adult mortality (Lemly and Smith 1987). Other sub-lethal effects include teratogenesis at the embryo-larval stage. The precise mode of action for selenium toxicity is not clear (Mézes and Balogh 2009).

In natural waters, selenium occurs in four oxidation states: selenides (HSe^- and H_2Se); selenite (SeO_3^{2-}) and selenate (SeO_4^{2-}). The selenides are either insoluble, or quickly decompose to become insoluble elemental selenium (U.S. EPA 1979b, 1980c). Selenite and selenate are soluble, with selenite favoured at pH 3.5-9.0 (US. EPA 1979b), and selenate favoured in alkaline conditions. Lemly and Smith (1987) developed a model of the selenium cycle to show how selenium mobility or cycling rate in an aquatic environment determines the occurrence and duration of toxic events. The cycle turns through immobilisation (removal and sequestration) of dissolved selenium in sediments, and mobilisation (release and biological uptake) from sediments. Immobilisation occurs as dissolved selenium (selenate and selenite) undergoes chemical and microbial reduction, followed by adsorption and settling with clay and organic particles and coprecipitation with iron (Lemly and Smith 1987).

Mobilisation occurs through oxidisation and methylation of selenium by physical and biological processes, and, most importantly (Lemly and Smith 1987, Lemly 1999), through direct uptake from sediments by plants, benthic invertebrates, and bottom-feeding fish and wildlife. In this way, inorganic forms of selenium are eventually converted into organic selenium and assimilated into protein (Morgan 2008). Organic selenium is much more toxic than inorganic selenium (Niimi and LaHam 1975) and has a far greater bioaccumulation potential (Lemly 2004). While some is returned to the environment through methylation, excretion, and volatilisation (Mézes and Balogh 2009), it is through this process of direct uptake and dietary exposure that selenium can persist at toxic levels even when its concentration in water is low (Lemly and Smith 1987, as cited in Lemly 2004).

Selenium toxicity also dependents on the presence of metals and non-metals which exhibit joint action with selenium. Copper, germanium, antimony, and tungsten are antagonistic to the toxicity of selenium, whereas selenium is antagonistic to the toxicity of silver, cadmium, mercury, and thallium (BC MOE). Joint action with arsenic can result in either an increase or a decrease of toxicity (BC MOE). Joint action with sulphate depends on the form of selenium (BC MOE). Adams (1976), working with the fathead minnow, found that the toxicity of selenium was directly related to water temperature. Lemly (1982), working with juvenile bluegill and largemouth bass, found that neither water temperature nor water hardness had any effect on the uptake of waterborne selenium. Invertebrates are generally more sensitive to selenite than are fish.

6.7.4.10.1.5.13.2 Water Quality Model Results

Mean selenium concentrations in Lake 901 are predicted to stay below the BC MOE 30-day (0.002 mg/L) (2006b) and CCME (0.001 mg/L) (2007) guidelines during the construction (0.0003-0.0007 mg/L) and operations (0.0003-0.0012 mg/L) phases and are predicted to have exceedances to both guidelines during closure (0.0009 to 0.0093 mg/L) and post-closure (0.0018 to 0.0093 mg/L) phases of mining. The 95th percentile and maximum values for selenium are predicted to exceed the BC MOE and CCME guidelines during operations, closure, and post-closure phases of mining.

6.7.4.10.1.5.13.3 Potential Effects on Rainbow Trout

Regulatory guidelines were developed “to protect all forms of aquatic life and all aspects of the aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long term” (CCME 1999). For this reason, these guideline levels are considered overly conservative for the protection of rainbow trout (Oncorhynchus mykiss) in Lake 901 from lethal and sub-lethal effects of selenium.

Selenium toxicity in aquatic environments depends on many factors (form and concentration of selenium, water hardness, temperature, presence of other substances, period and type of exposure, and the type and characteristics of the aquatic receptor species). As noted in the Technical Appendix to the BC MOE Water Quality Guidelines for Selenium (BC MOE 2001):

- Selenium interacts with several metals and non-metals (antimony, copper, germanium and tungsten) alleviating selenium toxicity. Additionally, selenium counters the toxicity of cadmium, mercury (or methyl mercury), silver and thallium.

The United States Environmental Protection Agency (US EPA) and the CCME are currently reviewing the aquatic toxicity guidelines for selenium. Chronic effects of selenium on fish are usually manifested at an early life stage, resulting in characteristic larval deformities. Rather than utilise surface water quality measurements, it has been shown that reproductive tissue (e.g., eggs) concentrations of selenium are more reliable indicators of potential selenium impacts to fish. Reproductive toxicity studies in fish indicate that the threshold for early life-stage selenium toxicity ranges from below 10 mg/kg dry weight to greater than 30 mg/kg dry weight in eggs, with cold-water species being more tolerant than warm-water species (McDonald, et al. 2010).

A general guideline for fish egg or ovary tissue of 20 mg/kg dry weight is being considered for broad application to Canadian species, and is considered to be conservative as no species mean toxicity thresholds lower than this value could be identified (DeForest, et al. 2011). A more appropriate value specific to rainbow trout, would be 23 mg/kg dry weight (DeForest, et al. 2011) and would equate a 10% increase in the frequency of larval deformity (i.e. an EC10).

The BC MOE and CCME selenium guidelines (0.002 mg/L) are based on effects to redear sunfish (*Lepomis microlophus*) which were noted to occur as low as 0.005 mg/L (BC MOE 2001). However, Lake 901 is a cold-water lake in a mineral-rich region. Cold-water fish are more tolerant of selenium than warm-water fish. BC MOE (2001) reports that effects to rainbow trout are not expected until approximately 1.1 mg/L, thus rainbow trout are tolerant to adverse selenium impacts at concentrations more than two orders of magnitude above regulatory guidelines. While maximum predicted selenium concentrations in Lake 901 are expected to be above BC MOE regulatory guidelines during the closure and post-closure phase of the project, those guidelines are highly conservative, and are well below the effects thresholds for rainbow trout. Therefore, predicted selenium concentrations are not considered to pose a threat to rainbow trout in Lake 901.

6.7.4.10.1.5.14 Zinc

6.7.4.10.1.5.14.1 Ecologic Toxicity Profile

Zinc is the most widely used essential trace metal in biology (Vallee and Falchuk 1993). Zinc is a component of the structure and function of a diverse array of enzymes and proteins, including those involved in DNA and RNA synthesis (CCREM 1987, Vallee and Falchuk 1993). At toxic levels of zinc, effects on fish are reported to include increased mucous secretion, anorexia, impaired reproduction, reduced growth, reduced brood size, and reduced size of young at birth (Gül et al. 2009).

The bioavailability (and therefore toxicity) of zinc is dependent on many physical and organic factors (Holcombe and Andrew 1978). Zinc occurs in both dissolved and suspended form in natural waters (Suter II and Tsao 1996). Zinc typically occurs as simple hydrated ions, and in inorganic compounds, stable organic complexes, inorganic clays, and organic colloids (Suter and Tsao 1996). In general, the bioavailability of zinc decreases with increased concentration of organic and inorganic zinc complexes. Toxicity decreases with higher water hardness, higher alkalinity, and lower pH (Holcombe and Andrew 1978). Zinc toxicity is also affected by the presence of other metals, through both additive and synergistic effects (Brown and Dalton 1970; Marking 1977; Sprague 1964; Anderson and Weber 1976, as cited in CCREM 1987). Sensitivity to zinc toxicity varies with species. Freshwater algae may be more sensitive to zinc than freshwater macrophytes and animals (Suter and Tsao 1996). Salmonids are less sensitive to zinc in harder water. In a study involving water hardness and rainbow trout (*Onchorhynchus mykiss*), Sinley and Goettl (1974) found that both acute and chronic toxicity decreases as water hardness increases, and eggs may be more sensitive to zinc than adults under chronic conditions. Sinley and Goettl (1974) also showed that acclimation an important factor in chronic toxicity in rainbow trout.

6.7.4.10.1.5.14.2 Water Quality Model Results

The model shows that mean zinc concentrations in the Clary Creek watershed during the construction (0.0043 mg/L), and operations (0.0044 mg/L), are below the BC MOE 30-day (0.008 mg/L based on hardness values of 48 and 51 mg/L as $CaCO_3$ for construction and operations, respectively), BC MOE maximum (0.033 mg/L based on hardness values of 48, and 51mg/L as $CaCO_3$ for construction and operations, respectively) and CCME WQG (0.03 mg/L). During closure the maximum (0.0392 mg/L) zinc concentrations are predicted to be above the BC MOE 30-day and the CCME guidelines. During post-closure the predicted maximum concentration (0.0391 mg/L) would also be above all three guidelines.

6.7.4.10.1.5.14.3 Potential Effects on Rainbow Trout

The aquatic freshwater ambient Water Quality Guideline (WQG) for zinc established by the BC MOE (Nagpal) in 1997 is based on hardness-dependent equations. When hardness exceeds 90 mg/L as $CaCO_3$:

Chronic Guideline (µg/L) = 7.5 + 0.75 x (hardness-90) Equation 1

Acute Guideline (µg/L) = 33 + 0.75 x (hardness -90) Equation 2

When hardness is less than or equal to 90 mg/L as $CaCO_3$, the guideline concentrations are fixed:

Chronic Guideline = 7.5 µg/L Equation 3

Acute Guideline = 33 µg/L Equation 4

The federal CCME (formerly CCREM) guideline for zinc is tentatively set at a concentration of 30 µg/L, regardless of hardness, under the basis that “sufficient data are not available to show that chronic toxicity decreases as water hardness increases” (citing USEPA 1980 guidance). However, in 1987, USEPA revised their zinc chronic guidelines to include hardness as a dependent variable (USEPA, 1987; 1996).

Both the BC MOE and the CCME zinc guidelines are overly conservative and have a high degree of uncertainty. For example, the BC MOE guidelines assume a linear relationship between hardness and toxicity but more recent reviews by the USEPA indicate that the relationship is logarithmic / exponential. Also, both studies are now outdated and are based on different species. Lastly, one of the two studies used to derive the slope for the hardness-dependent equation did not actually measure hardness.

Alternatively, the approach used by the USEPA to derive its Ambient Water Quality Criteria (AWQC) for zinc (1987) are derived from acute toxicity values for 43 species and chronic toxicity values for 9 species (including trout, salmon, and benthic invertebrates). Overall, USEPA’s approach uses a more thorough and up-to-date data set, and derives a logarithmic relationship between hardness based on rigorous statistical review of the data and derives the slope using species sensitivity distribution approach.

Based on USEPA's approach, alternative zinc WQGs would be:

	Project Phase		
	Construction	**Operations**	**Closure**
Acute (mg/L)	0.121	0.122	0.242
Chronic (mg/L)	0.0638	0.0671	0.128

These alternative WQGs are designed to protect a group of diverse genera form the harmful effects of zinc. Toxicity studies in the scientific literature for rainbow trout (*Oncorhynchus mykiss*) were reviewed by USEPA and HydroQual and were used to develop and parameterise the biotic ligand model (BLM). Essentially, the BLM links bioavailable concentrations of zinc to toxicological effects, and accounts for the effects of several contributing factors including hardness, pH, temperature, and the concentration of other dissolved ions. The toxicity data compiled by USEPA and HydroQual (2007) indicate that that under site-specific conditions in Lake 901, acute and chronic effects to rainbow trout are expected to occur at the following concentrations:

	Project Phase		
	Construction	**Operations**	**Closure**
Acute (mg/L)	0.33	0.3	0.47
Chronic (mg/L)	0.134	0.13	0.17

The proposed site-specific acute and chronic WQGs determined from USEPA AWQC approach are less than lethal and sub-lethal effects concentrations for rainbow trout which were used to develop the BLM model. The water quality model predicts that zinc concentrations at Lake 901 are all below the proposed site-specific WQGs for all project phases. Predicted concentrations of zinc in Lake 901 are therefore not expected to adversely affect populations of rainbow trout.

6.7.4.10.1.6 Change in Benthic Macro-Invertebrate Community in the Clary Creek Watershed

Potential changes in abundance and composition of the benthic invertebrate community in Clary Creek due to the potential direct effects on fish habitat and the indirect effects of changes in water quality, stream flow, and lake levels in the Clary Creek watershed are assessed in Section 6.7.4.9. No significant residual effects to BMI production or drift were predicted to occur. As a result, no significant residual effects to rainbow trout due to potential changes in BMI community were predicted to occur. This was because:

- The small change in wetted width and water velocities predicted to occur at various locations in Clary Creek due to predicted flow reductions during different phases of the Project was unlikely to have a significant effect on benthic invertebrate production or on the amount of BMI drift avaible to rainbow trout;

- The change in lake levels predicted to occur in Clary Lake due to flow reductions and water withdrawals was predicted to have a small effect on the littoral area of the lake because of its steep shoreline bathymetry;
- Rainbow trout in Clary Lake feed primarily on zooplankton and not BMI; and
- Water quality of the discharge effluent from the Project would be monitored such that no water would be released downstream that didn't meet water quality objectives designed to ensure the protection of freshwater aquatic biota in the Clary Creek watershed, including the benthic macro-invertebrate community.

This potential indirect residual effect is rated as not significant (minor). However, the level of confidence is low because of the uncertainty regarding the potential combined effects of changes in habitat, water quality, stream flows, and water temperatures due to the Project on the benthic macro-invertebrate community in Lime Creek.

6.7.4.10.1.7 Summary of Potential Residual Effects

A summary of the potential residual effects of the Project on rainbow trout in the Clary Creek watershed provided in Table 6.7.4-41. These include the direct effects of harmful alteration, disruption, or destruction of fish habitat under the TMF and changes in fish passage at stream crossings along the existing Kitsault Road and the indirect effects of changes in water quality, lake levels, stream flows, and benthic macro-invertebrate prey.

Table 6.7.4-41: Summary of Residual Effects for Rainbow Trout

Project Phase	Residual Effect	Direction
C,O,D/C, PC	Loss of fish habitat under and downstream of the TMF	Negative
C,O, D/C, PC	Change in fish passage at stream crossings	Positive
O, D/C, PC	Change in surface water quality due to TMF seepage	Negative
C,O, D/C, PC	Change in lake levels	Negative
C, O, D/C, PC	Change in stream flows	Negative
C, O, D/C, PC	Change in benthic macro-invertebrates	Negative

Note: C - construction; O - operations; D/C - decommissioning and closure; PC - post-closure

6.7.4.10.2 Significance of Potential Residual Effects

This section provides assessments of the significance of each of the potential residual effects of the Project to adversely or positively affect rainbow trout in the Clary Creek watershed. Criteria ratings have been assigned based on professional judgement using the rating criteria described in Section 5 (Assessment Methodology) and the residual effects assessments provided in Section 6.7.4.10 above.

6.7.4.10.2.1 Loss of Fish Habitat Under and Downstream of the Tailings Management Facility

Loss of the fish habitat in the two Lake 901 inlet tributaries under, within and downstream of the TMF was assessed to have a not significant (moderate) effect on rainbow trout (Table 6.7.4-42). These two streams provide the only source of spawning habitat for rainbow trout in Lake 901 and are, therefore, critical to the annual recruitment of the rainbow trout population, particular since the lake is currently isolated from other lakes and streams downstream by the impassable culvert at the Kitsault Road crossing. However, this residual effect is restricted to the Lake 901 rainbow trout population (i.e, local) and would be mitigated by implementation of the fish habitat compensation measures described above (i.e., enhancement of flows and spawning habitat in the Lake 901 outlet) and in the Fish Habitat Mitigation and Compensation Plan (Appendix 11.2-A).

The ecological context of this residual effect was considered high only because of the inherent uncertainty of the proposed mitigation / compensation measures to offset the loss of spawning habitat provided by these two streams. Removal of the culvert at the Kitsault Road crossing would increase immigration to the lake and would significantly reduce the potential for the Lake 901 rainbow trout population to be extirpated by the Project. However, should monitoring determine that the Lake 901 rainbow trout population is decreasing in size and / or changing in age and size structure over time due to reduced spawning success, additional mitigation / compensation measures may be necessary either, for this rainbow trout population specifically, or for some other fish population elsewhere in the region (e.g., Kitsault River salmon stocks). Any such additional mitigation / compensation measures would be developed in consultation with DFO, the BC MOE, and Nisga'a Fisheries.

Table 6.7.4-42: Residual Effects Assessment of Loss of Fish Habitat Under and Downstream of the Tailings Management Facility on Rainbow Trout

Parameter	Stage of Development / Rating			
	Construction	Operations	Closure / Decommissioning	Post-closure
Residual Effect				
Loss of fish habitat under and downstream of the TMF				
Effect Attribute				
Direction	Negative	Negative	Negative	Negative
Magnitude	Low	Medium	Medium	Medium
Geographic extent	Local	Local	Local	Local
Duration	Medium-term	Chronic	Chronic	Chronic
Frequency	Continuous	Continuous	Continuous	Continuous
Reversibility	No	No	No	No
Ecological Context	High	High	High	High
Probability of occurrence	High	High	High	High
Certainty	High	High	High	High
Residual Effect Significance	Not significant (minor)	Not significant (moderate)	Not significant (moderate)	Not significant (moderate)

Parameter	Stage of Development / Rating			
	Construction	Operations	Closure / Decommissioning	Post-closure
Residual Effect				
Loss of fish habitat under and downstream of the TMF				
Effect Attribute				
Level of Confidence	High	Medium	Medium	Medium

6.7.4.10.2.2 Change in fish passage at stream crossings along the Kitsault Road

Removal of the hung culvert on the Lake 901 outlet was assessed to have a not significant (minor) positive effect on rainbow trout in Lake 901 (Table 6.7.4-43). This would be a positive residual effect because it would allow rainbow trout from Lake 493 and, potentially from Clary Lake, to immigrate upstream into Lake 901 which they currently cannot do. Such an effect would increase gene flow and would provide a secondary source of fish for the Lake 901 rainbow trout population.

This positive residual effect was considered to be low in magnitude and local in geographic extent because it was expected that, even with the barrier removed, the actual number of fish that would be move into Lake 901 would be relatively low in any given year. This was because the number of fish moving upstream from Clary Lake is likely naturally low given the steep, bedrock canyon they must negotiate to reach Lake 901. This may be made more difficult in average and low water years after the Project is built due to the flow reductions that are predicted to occur in Clary Creek downstream of the Lake 901 outlet. As a result, rainbow trout moving downstream from Lake 493 are a more likely source of potential migrants. The benefits of this immigration would be limited to the Lake 901 rainbow trout population (i.e., local in geographic extent).

Table 6.7.4-43: Residual Effects Assessment of Change in Fish Passage at Stream Crossings Along the Kitsault Road on Rainbow Trout

Parameter	Stage of Development / Rating			
	Construction	Operations	Closure / Decommissioning	Post-closure
Residual Effect				
Change in fish passage at streams crossing along the Kitsault Road				
Effect Attribute				
Direction	Positive	Positive	Positive	Positive
Magnitude	Low	Low	Low	Low
Geographic extent	Local	Local	Local	Local
Duration	Chronic	Chronic	Chronic	Chronic
Frequency	Continuous	Continuous	Continuous	Continuous
Reversibility	No	No	No	No
Ecological Context	Low	Low	Low	Low

Parameter	Stage of Development / Rating			
	Construction	Operations	Closure / Decommissioning	Post-closure
Residual Effect				
Change in fish passage at streams crossing along the Kitsault Road				
Effect Attribute				
Probability of occurrence	High	High	High	High
Certainty	High	High	High	High
Residual Effect Significance	Not significant (minor)	Not significant (minor)	Not significant (minor)	Not significant (minor)
Level of Confidence	High	High	High	High

6.7.4.10.2.3 Change in Surface Water Quality Due to Tailings Management Facility Seepage

Potential residual effects to rainbow trout due to changes in the surface water quality from TMF seepage were rated separately for Lake 901 and Clary Lake due to the differences in predicted water quality concentrations and guideline exceedences in the two lakes.

Potential residual effects on rainbow trout due to the predicted change in water quality in Lake 901 were assessed to be not significant (minor) during the construction phase and not significant (moderate) during operations, closure, and post-closure phases(Table 6.7.4-44). The not significant (minor) rating during construction was based on the assumption that seepage volumes from the TMF to Lake 901 would be low to negligible as the TMF supernatnant pond would yet be high enough to discharge into the Clary Creek watershed. The rationale for the not significant (moderate) ratings during operations, closure, and post-closure phases was based on the following:

- Some of the uncertainties regarding the volume and concentration of potential chemicals of concern in the TMF seepage entering the lake due to:
  - The conservative assumption that TMF supernatant water quality does not improve during the closure and post-closure phases due to dilution from natural precipitation;
  - The conservative assumptions regarding the loading sources from the mine; and
  - The conservative assumption in the water quality model that all potentially toxic water quality parameters remain biologically available over the life of the mine despite the numerous confounding effects of other water quality parameters found in the natural receiving environment (e.g., toxicity dependency on water hardness, pH, and the presence of other antagonistic chemicals (e.g., selenium and mercury));
- Some of the uncertainties surrounding the potential toxicity of these chemical of concern to rainbow trout given:

- Some of the guideline exceedences predicted were due to the detection limits at the laboratory being above the guideline concentrations (e.g., mercury);
- The fact that some water quality parameters in the lake already exceed one or more of the federal or provincial guidelines for the protection of freshwater aquatic biota under current baseline conditions (e.g., total and dissolved aluminum, cadmium, copper, total and dissolved iron, lead, and zinc) while a viable, healthy rainbow trout population appears to exist in the lake; and
- The fact that some of the provincial and federal guidelines appear to be overly protective for rainbow trout either because the guidelines were based on other fish species or other organisms more sensitive than rainbow trout but are not found in Lake 901 (or in freshwater), were not adjusted for the concentrations of other parameters found in the lake known to reduce the toxicity / bioavailability of the chemical (e.g., hardness), or are recognised to need updating based on more recent toxicological studies conducted since the guidelines were promulgated.

If deemed necessary, the proponent's commitment to develop and adhere to site-specific water quality objectives (SSWQOs) as determined in consultation with Environment Canada, the BC Ministry of Environment, and the Nisga'a Lisims Government.

Despite the uncertainties inherent in modelling, the water quality modelling conducted was the best available method for predicting the likely concentrations of these potential chemicals of concern in Lake 901. The guideline exceedences predicted by this model may therefore be accurate. As a result, the proponent would commit to developing and adhering to WQOs for any of the chemicals of concern which may be warranted. Some of these potential have been discussed in this document, in the discussion of the potential effects of water quality changes in Lime Creek on Dolly Varden and coho salmon, and in Section 6.6, Surface Water Quality. These WQOs and the corresponding Environmental Effects Monitoring (EEM) program would be developed in consultation with Environment Canada, the BC Ministry of Environment, and the Nisga'a Lisims Government.

Potential residual effects of changes in water quality to rainbow trout in Clary Lake were assessed to be not significant (minor) for all phases of the Project. The rationale for the lower significance ratings in Clary Lake compared to Lake 901 was based on the lower concentrations of the chemicals of concern predicted to occur in Clary Lake, the attenuating effects of the larger unaffected upstream catchment areas available to Clary Lake from the TMF (via Lake 901), and the reasons above.

Table 6.7.4-44: Residual Effects Assessment of Change in Surface Water Quality Due to Tailings Management Facility Seepage on Rainbow Trout

Parameter	Stage of Development / Rating			
	Construction	Operations	Closure / Decommissioning	Post-closure
Residual Effect				
Change in surface water quality in Lake 901 due to TMF seepage				
Effect Attribute				
Direction	Negative	Negative	Negative	Negative
Magnitude	Low	Medium	Medium	Medium
Geographic extent	Local	Local	Local	Local
Duration	medium-term	Long-term	Long-term	Chronic
Frequency	Continuous	Continuous	Continuous	Continuous
Reversibility	No	No	No	No
Ecological Context	Medium	Medium	High	High
Probability of occurrence	Low	High	High	Unknown
Certainty	High	High	High	High
Residual Effect Significance	Not significant (minor)	Not significant (moderate)	Not significant (moderate)	Not significant (moderate)
Level of Confidence	Medium	Medium	Medium	Medium
Residual Effect				
Change in surface water quality in Clary Lake due to TMF seepage				
Effect Attribute				
Direction	Negative	Negative	Negative	Negative
Magnitude	Low	Low	Low	Low
Geographic extent	Local	Local	Local	Local
Duration	medium-term	Long-term	Long-term	Chronic
Frequency	Continuous	Continuous	Continuous	Continuous
Reversibility	No	No	No	Yes
Ecological context	Low	Low	Medium	Medium
Probability o f occurrence	Low	High	High	Unknown
Certainty	High	High	High	High
Residual Effect Significance	Not significant (minor)	Not significant (minor)	Not significant (minor)	Not significant (minor)
Level of Confidence	Medium	Medium	Medium	Medium

6.7.4.10.2.4 Change in Lake Levels

Potential residual effects of lake level changes in Clary Lake on rainbow trout were assessed to be not significant (negligible) (Table 6.7.4-45). The rationale for this assessment was that the magnitude of potential change was low, the geographic extent was local (i.e., limited to Clary Lake), and the ecological context was low. The certainty of this assessment was high because it was based on a quantitative assessment of the potential change in littoral area in the lake based on bathymetry and nearshore habitat mapping and the known importance of littoral areas to rainbow trout.

Table 6.7.4-45: Residual Effects Assessment of Lake Level Changes in Clary Lake on Rainbow Trout

Parameter	Stage of Development / Rating			
	Construction	Operations	Closure / Decommissioning	Post-closure
Residual Effect				
Change in Lake Levels in Clary Lake				
Effect Attribute				
Direction	Negative	Negative	Negative	Negative
Magnitude	Low	Low	Low	Low
Geographic extent	Local	Local	Local	Local
Duration	Short-term	Long-term	Long-term	Chronic
Frequency	Continuous	Continuous	Continuous	Continuous
Reversibility	No	No	No	No
Ecological Context	Low	Low	Low	Low
Probability of occurrence	High	High	High	High
Certainty	High	High	High	High
Residual Effect Significance	Not significant (negligible)	Not significant (negligible)	Not significant (negligible)	Not significant (negligible)
Level of Confidence	High	High	High	High

6.7.4.10.2.5 Change in Stream Flows

The significance of potential residual effects to rainbow trout due to changes in stream flows in the Clary Creek watershed were rated separately for the four locations at which residual stream flow changes were predicted to occur: 1) Lake 901 inlets downstream of the TMF; 2) Clary Lake outlet; 4) Clary Creek downstream of the Lake 493 and Lake 901 confluence; and 4) the Lake 493 outlet.

6.7.4.10.2.5.1 Lake 901 Inlets

Potential residual effects on rainbow trout due to flow reductions in the Lake 901 inlet tributaries downstream of the TMF were assessed to be not significant (moderate) (Table 6.7.4-46. This was not because the streams would continue to provide some suitable spawning habitat for the Lake 901 rainbow trout population (which they are assumed to not), but because of the implementation of Fish Habitat Mitigation and Compensation Plan (Appendix 11.2-A) which includes measures to provide new spawning habitat in the Lake 901 outlet and to improve access to Lake 901 but also includes options to provide off-site habitat compensation (e.g., Kitsault River side-channels, habitat restorations along the Cranberry Connector) to ensure that “no-net-loss” of fish habitat is met.

The moderate significance rating was given because of the inherent uncertainty regarding the success of compensation options to offset habitat losses and because the options to offset the loss of these streams for rainbow trout in Lake 901 are limited. Similarly, the magnitude and ecological context ratings were medium because it was assumed that some of the loss of annual recruitment caused by the reduction of stream flows in these two inlet tributaries could be offset by the new spawning habitat and improved fish passage in the Lake 901 outlet.

Table 6.7.4-46 Residual Effects Assessment of Change in Stream Flows in the Clary Creek Watershed on Rainbow Trout

Parameter	Stage of Development / Rating			
	Construction	Operations	Closure / Decommissioning	Post-closure
Residual Effect				
Change in stream flow in Lake 901 inlets downstream of the TMF				
Effect Attribute				
Direction	Negative	Negative	Negative	Negative
Magnitude	Medium	Medium	Medium	Medium
Geographic extent	Local	Local	Local	Local
Duration	Medium-term	Long-term	Long-term	Chronic
Frequency	Continuous	Continuous	Continuous	Continuous
Reversibility	No	No	No	No
Ecological Context	Medium	Medium	Medium	Medium
Probability of occurrence	High	High	High	High
Certainty	High	High	High	High
Residual Effect Significance	Not significant (minor)	Not significant (moderate)	Not significant (moderate)	Not significant (moderate)
Level of Confidence	Medium	Medium	Medium	Medium
Residual Effect				
Change in stream flows in the Lake 493 outlet				
Effect Attribute				
Direction	Negative	Negative	Negative	Negative
Magnitude	Low	Low	Low	Low
Geographic extent	Local	Local	Local	Local
Duration	medium-term	Long-term	Long-term	Chronic
Frequency	Continuous	Continuous	Continuous	Continuous
Reversibility	No	No	No	Yes
Ecological context	Low	Low	Low	Low
Probability of occurrence	High	High	High	High
Certainty	High	High	High	High
Residual Effect Significance	Not significant (minor)	Not significant (minor)	Not significant (minor)	Not significant (minor)
Level of Confidence	High	High	High	High

6.7.4.10.2.5.2 Lake 493 outlet

Potential residual effects on rainbow trout due to flow reductions in the Lake 493 outlet were assessed to be not significant (minor) (Table 6.7.4-47). This was because:

- the predicted flow reduction was unlikely to significantly reduce the amount or suitability of the cascade / riffle habitat present in the stream;
- the stream does not provide suitability spawning or overwintering habitat for rainbow trout under pre-mine baseline conditions; and
- because the importance of this section of Clary Creek to the Lake 493 and Clary Lake rainbow trout populations is likely very low given that fish in this stream cannot move back upstream to Lake 493 past the bedrock waterfalls, habitat quality is generally low, and few fish in Clary Lake are likely to move up past the steep bedrock canyon into this section of Clary Creek.

Table 6.7.4-47 Residual Effects Assessment of Change in Stream Flows in the Clary Creek Watershed on Rainbow Trout

Parameter	Stage of Development / Rating			
	Construction	Operations	Closure / Decommissioning	Post-closure
Residual Effect				
Change in stream flow in Clary Creek downstream of the Lake 901 and Lake 493 confluence				
Effect Attribute				
Direction	Negative	Negative	Negative	Negative
Magnitude	low	low	low	low
Geographic extent	Local	Local	Local	Local
Duration	Medium-term	Long-term	Long-term	Chronic
Frequency	Continuous	Continuous	Continuous	Continuous
Reversibility	No	No	No	No
Ecological Context	low	low	low	low
Probability of occurrence	High	High	High	High
Certainty	High	High	High	High
Residual Effect Significance	Not significant (minor)	Not significant (minor)	Not significant (minor)	Not significant (minor)
Level of Confidence	Medium	Medium	Medium	Medium
Residual Effect				
Change in stream flows in the Clary Lake outlet				
Effect Attribute				
Direction	Negative	Negative	Negative	Negative
Magnitude	Low	Low	Low	Low
Geographic extent	Local	Local	Local	Local
Duration	medium-term	Long-term	Long-term	Chronic
Frequency	Continuous	Continuous	Continuous	Continuous

Parameter	Stage of Development / Rating			
	Construction	Operations	Closure / Decommissioning	Post-closure
Residual Effect				
Change in stream flow in Clary Creek downstream of the Lake 901 and Lake 493 confluence				
Effect Attribute				
Reversibility	No	No	No	Yes
Ecological context	Low	Low	Low	Low
Probability o f occurrence	High	High	High	High
Certainty	High	High	High	High
Residual Effect Significance	Not significant (minor)	Not significant (minor)	Not significant (minor)	Not significant (minor)
Level of Confidence	High	High	High	High

6.7.4.10.2.5.3 Clary Creek Downstream of the Lake 901 and Lake 493 Confluence

Potential residual effects on rainbow trout due to flow reductions in Clary Creek downstream of the Lake 901 and Lake 493 confluence were assessed to be not significant (minor) (Table 6.7.4-44). This was largely because the magnitude and the ecological context of the potential effect was considered to be low while the geographic extent of the residual effect was local. The magnitude and ecological context were considered low because:

- The number of rainbow trout moving up the steep, bedrock canyon in Clary Creek is likely low under pre-mine baseline conditions and, while upstream fish passage may be reduced with lower flows, such movements are non-obligatory and do not lead rainbow trout from Clary Lake to critical habitat not available elsewhere;
- The proportion of the Clary Lake rainbow trout population using the lower reaches of Clary Creek upstream of the lake for spawning is likely very low in comparison to the proportion of rainbow trout using other, larger, more suitable spawning streams unaffected by the Project (i.e., the Clary Lake outlet and the main Clary Lake inlet); and
- The spawning success and egg incubation success of any rainbow trout using habitat in the lower reaches of Clary Creek upstream of Clary Lake is likely restricted only to very high water years when flows in the braided channels in the delta area remained wetted throughout the spring.

6.7.4.10.2.5.4 Clary Lake outlet

Potential residual effects on rainbow trout due to flow reductions at the Clary Lake outlet were assessed to be not significant (minor) (Table 6.7.4-44). This was because the magnitude of flows reductions predicted to occur are unlikely to change the availability or suitability of habitat in this stream for rainbow trout during, any month during any phase, of the Project. Potential flow reductions at the Clary Lake outlet are largely attenuated by the larger run-off volumes entering Clary Lake from the unaffected northeastern portion of its watershed.

6.7.4.10.2.6 Change in benthic macro-invertebrates

Potential residual effects to rainbow trout due to residual effects to benthic macro-invertebrates in the Clary Creek watershed were assessed to be not significant (minor) (Table 6.7.4-48). This significance rating was based on a low magnitude of effect, the local geographic extent, and a low ecological context. The geographic extent was limited to the local study area which for rainbow trout included only Lake 901, Clary Lake and the streams downstream of Lake 493 and Lake 901 draining into Clary Lake. The magnitude and ecological context of the residual effect to rainbow trout were considered low because the potential residual effects to benthic macro-invertebrates in lakes and streams in which rainbow trout are present downstream of the Project were also assumed to be low. This was because:

- Water quality objectives that would be established in the Clary Lake watershed for the protection of rainbow trout would also provide equal protection for benthic macro-invertebrate communities in the lakes and streams;
- Predicted flow changes in streams would not be sufficient to alter the abundance or community composition of the benthic invertebrate drift upon which juvenile and adult rainbow trout depend;
- Predicted lake level changes in Clary Lake would not be sufficient to significantly alter the littoral area of the lake and hence the abundance or community composition of the littoral area benthic macro-invertebrate communities; and
- Benthic macro-invertebrates comprise only a very small proportion of the diet of rainbow trout in the lakes.

Table 6.7.4-48: Residual Effects Assessment of Change in Benthic Macro-Invertebrates on Rainbow Trout

Parameter	**Stage of Development / Rating**			
	Construction	Operations	Closure / Decommissioning	Post-closure
Residual Effect				
Change in Benthic macro-invertebrates				
Effect Attribute				
Direction	Negative	Negative	Negative	Negative
Magnitude	Low	Low	Low	Low
Geographic extent	Local	Local	Local	Local
Duration	Medium-term	Long-term	Chronic	Chronic
Frequency	Continuous	Continuous	Continuous	Continuous
Reversibility	No	No	No	No
Ecological Context	Low	Low	Low	Low

Parameter	Stage of Development / Rating			
	Construction	Operations	Closure / Decommissioning	Post-closure
Residual Effect				
Change in Benthic macro-invertebrates				
Effect Attribute				
Probability of occurrence	Low	Low	Low	Low
Certainty	Medium	Medium	Medium	Medium
Residual Effect Significance	Not significant (minor)	Not significant (minor)	Not significant (minor)	Not significant (minor)
Level of Confidence	Medium	Medium	Medium	Medium

6.7.4.11 Cumulative Effects Assessment

6.7.4.11.1 Rationalisation for Carrying Forward Project Related Residual Effects Into the Cumulative Effects Assessment

Only potential residual effects that have the potential to affect rainbow trout in Clary Lake were carried forward into the cumulative effects assessment (Table 6.7.4-49). The rationale for this decision was three-fold:

- The only other on-going or reasonably foreseeable future project in the Clary Creek watershed is the exploration and potential future mining of the Bell Moly deposit located in the headwaters of the northeastern portion of the Clary Creek watershed upstream of Clary Lake;
- Clary Lake is where the potential residual effects to rainbow trout due to change in surface water quality and / or stream flows from the Kitsault Project and from exploration or future mining of the Bell Moly deposit would combine;
- Clary Lake was used in the past as the freshwater supply for previous mining operations at the Kitsault Mine; and
- It is highly unlikely that stream-resident or adfluvial rainbow trout in Lake 901 or Lake 493 would move upstream into the headwater lakes and streams of the northeastern portion of the Clary Creek watershed where the Bell Moly deposit is located. Stream resident rainbow trout are generally sedentary in summer and fall when maintaining territories and during the winter when finding overwintering in deep pools; only during the spring spawning period do these fish undertake any longer-range movements but these are typically <600 metres (Mellina et al. 2005). The distance between Lake 901 and Lake 493 to the lakes and streams near the Bell Moly deposit is over 3 km.

Table 6.7.4-49: Project Related Residual Effects - Rationale for Carrying Forward Into the Cumulative Effects Assessment

Project Component	Project Phase	Residual Effect	Rationale	Carried Forward in CEA
Construction, operation, and decommissioning of the TMF and northeast seepage control ponds	C,O,D/C, PC	Loss of fish habitat under and downstream of the TMF	Habitat losses in Lake 901 inlet tributaries would only effect the Lake 901 rainbow trout population. No downstream effect from such losses are predicted to be manifested in Clary Lake	No
Upgrading of stream crossings along the Kitsault	C,O, D/C, PC	Change in fish passage at stream crossings	The potential benefits of improving fish passage in the Lake 901 outlet are likely to be highly localised and given the relatively sedimentary nature of stream-resident rainbow trout are unlikely to provide benefits to fish in Clary Lake or streams and lakes in the northeastern portion of the watershed	No
Construction, operation, and decommissioning of the TMF and northeast seepage control ponds; water diversions	C,O, D/C, PC	Change in lake levels	Lake level changes in Clary Lake were determined to have a negligible effect on rainbow trout. Only residual effects with minor, moderate, or significant residual effects are carried forward in the CEA.	No
Construction, operation, and decommissioning of the TMF and northeast seepage control ponds	O, D/C, PC	Change in surface water quality due to TMF seepage	Potential changes in surface water quality due to the Kitsault Project could cumulatively affect water quality, and rainbow trout, in Clary Lake also potentially affected by exploration of the Bell Moly deposit	Yes
Construction, operation, and decommissioning of the TMF and northeast seepage control ponds; water diversions	C, O, D/C, PC	Change in stream flows	Potential changes in stream flows due to the Kitsault Project could cumulatively affect lake levels in Clary Lake and stream flows at the Clary Lake outlet also potential affected by changes in streams flows caused by exploration of the Bell Moly deposit	Yes
Construction, operation, and decommissioning of the TMF and northeast seepage control ponds, water diversions	C, O, D/C, PC	Change in benthic macro-invertebrates	Potential changes in surface water quality due to the Kitsault Project could cumulatively affect water quality, and rainbow trout, in Clary Lake also affected by exploration of the Bell Moly deposit	Yes

Note: C - construction; D/C - decommissioning and closure interaction; O - operations

6.7.4.11.2 Interaction Between Rainbow trout and Other Past, Present or Future Projects / Activities

Table 6.7.4-50 presents potential interactions between each of the residual effects to rainbow trout carried forward into the cumulative effect assessment and its potential interaction with other past, present, or reasonably foreseeable projects or human land uses. The only other projects which could potentially interact with the residual effects to rainbow trout from the Kitsault Project is the past use of Clary Lake as the freshwater supply sources during previous mining operations at the Kitsault Mine and the on-going exploration and potential future mining of the Bell Moly deposit in the upper Clary Creek watershed. No other past, present, or reasonably foreseeable future project or land use has the potential to cumulative effect rainbow trout in the Clary Creek watershed because:

- No other project is, was, or will be located in the Clary Creek watershed;
- No rainbow trout or any other fish species, potentially affected by other past, present, or future projects outside of the Clary Creek watershed can get past the 35 metre high waterfall in Clary Creek near its confluence with the Illiance River;
- The Nisga'a Nation has angling guide tenures on the Illiance and Kitsault rivers under the NFA. As far as is known, no guiding occurs for rainbow trout in the Clary Creek watershed; and
- As far as is known, there is no active fishery for rainbow trout by Aboriginal peoples or any recreational fishermen.

Use of Clary Lake for freshwater supply during previous Kitsault mining operations in the early 1970s has created a potential cumulative effect to rainbow trout because the lake was raised by approximately one metre to so that pumps would not be "cut-off" from the majority of inflows to Clary Lake by the shallow narrows between the north and south basins of the lake during summer and winter low flow conditions. Raising the lake may have mobilised naturally-occurring, soil bound metals, most importantly mercury. Any trace amounts of these metals cycling within the aquatic food web in the lake, therefore has the potential to cumulatively affect any rainbow trout also potentially subjected to changes in water quality in Clary Lake due to construction and operation of the Kitsault Project.

Exploration of the Bell Moly deposit has the potential to alter water quality and stream flows in the northeastern portion of the Clary Creek watershed. Any residual effects from this exploration has the potential to cumulatively affect rainbow trout that may also be affected by residual effects from construction and operation of the TMF in the southeastern portion of the Clary Creek watershed (i.e., Lake 901 catchment).

An assessment of the spatial and temporal overlap between known or potential residual effects on rainbow trout from other past, present, or reasonably foreseeable future projects or land uses and predicted residual effects on rainbow trout from the Kitsault Project is provided in Table 6.7.4-50.

Table 6.7.4-50: Assessment of Interaction Between Other Projects, Human Activities and Reasonable Foreseeable Projects with Rainbow Trout

Potential Effect	Historical Land Use					Representative Current and Future Land Use					Reasonably Foreseeable Projects
	Kitsault Mine and exploration	Kitsault Townsite (on-going)	Alice Arm (on-going)	Previous mine operations	Previous mine exploratoin	Transportation and access	Mining exploration	Trapping and guide outfitting	Nisga'a hunting, trapping, fishing, and other uses	Aboriginal huntgin, fishing, and other uses	Northwest Transmission Line Project
Change in surface water quality due to TMF seepage	o	NI	NI	NI	NI	NI	-	NI	NI	NI	NI
Change in stream flows	NI	NI	NI	NI	NI	NI	-	NI	NI	NI	NI
Change in benthic macro-invertebrates	NI	NI	NI	NI	NI	NI	o	NI	NI	NI	NI

Note: Interaction definitions: o - interaction; - - key interaction; + - benefit; NI - no interaction

The certainty of the assessment of potential cumulative effects on rainbow trout is limited most notably by the lack of past fish tissue and water quality data in Clary Lake prior to and during the previous mining operations at Kitsault when Clary Lake was used as the freshwater supply source. Baseline fish tissue data from rainbow trout captured in Clary Lake in 2010 are available (Table 6.7.4-51). However, these data only provide a snap-shot of current fish tissue metal concentrations and, for most chemical of concern, are unlikely to reflect contaminant loads that rainbow trout may have encountered after the lake was raised. For example, mean total mercury concentrations in Clary Lake rainbow trout (0.045 mg/Kg) are currently greater than the provincial and the federal screening value for the protection of piscivorous wildlife from methylmercury (0.033 mg/Kg; BC MOE 2001a; CCME 2000). However, elevated methlymercury concentrations, the toxic and biologically available form of mercury released by increased microbial activity in flooded areas, typically do not persist in aquatic system for more than 20 to 30 years (Bodaly et al. 1997). Mercury concentrations in fish tissues at the levels observed in Clary Lake rainbow trout in 2010 are similar or lower than mercury concentrations in rainbow trout in other unaffected, natural lakes in British Columbia (Table 6.7.4-52). This suggests that mercury concentrations in Clary Lake rainbow trout were either not affected by raising of the lake in the 1970's (due to low mercury availability in the surrounding soils and vegetation or the short duration of inundation: < 5 years) or that any methylmercury that had accumulated in Clary Lake rainbow trout after flooding is no longer present in the system.

Table 6.7.4-51: BC MOE Regional Fish Tissue Metal Concentration for Rainbow Trout in Pinchi Fault Lakes

Lake	Mean Total Mercury Concentration (mg/Kg dry weight)	S.D.
Chuchi Lake	<0.050	
Indata Lake	0.087	0.05
Takla Lake	0.080	0.02
Tchentlo Lake	<0.050	
Tezzeron Lake	0.062	0.03
Tsayta Lake	0.070	0.02

Table 6.7.4-52: Assessment of Spatial and Temporal Overlap Between the Project and Other Projects and Human Actions with Rainbow Trout

	Human Activity	Residual Environmental Effect	Extent	Duration	Rationale	Cumulative Effect (Contribution from Project or Overlap)
Historical land use	Kitsault Mine and exploration	Change in water quality due to raising the lake for freshwater withdrawals	Limited to Clary Lake	Overlap may potentially occur through each mine phase	Potential mobilising of naturally occurring metals due to flooding (i.e., mercury methylation)	Potential for residual effect on rainbow trout in Clary Lake due to changes in surface water quality from TMF seepage
	Kitsault Townsite (on-going)	No interaction				
	Alice Arm Townsite (on-going)	No interaction				
	Previous mining	No interaction				
	Previous mining exploration	No interaction				
Representative current and future land use	Transportation and access	No interaction				
	Mining exploration	Change in surface water quality and stream flows due to mine exploration at the Bell Moly deposit	Limited to Clary Lake	Overlap may potentially occur through each mine phase	Use of water for drilling and potential downstream water quality changes due to sedimentation, spills, and release of drill cuttings and mud	Potential for residual effect on rainbow trout in Clary Lake due to changes in surface water quality and flow changes due to construction and operation of the TMF
	Trapping and guide outfitting	No interaction				

	Human Activity	Residual Environmental Effect	Extent	Duration	Rationale	Cumulative Effect (Contribution from Project or Overlap)
	Nisga'a Nation and Aboriginal hunting, trapping, fishing and other uses	No interaction				
	Aboriginal hunting, trapping, and fishing and other uses	No interaction				
Reasonably foreseeable projects	Northwest Transmission Line Project	No interaction				

6.7.4.11.3 Mitigation Measures

No additional mitigation measures besides those discussed above to reduce or eliminate potential direct or indirect Project effects on rainbow trout are proposed to further reduce or eliminate potential cumulative effects with other past, present, or reasonably foreseeable projects or land uses. The likely effectiveness of each of the mitigation measures that would be used to reduce Project effects on rainbow trout have already been assessed above and it is only those Project effects with potential residual effects to rainbow trout that are being assessed here for their potential interaction with other past, present, or future effects to rainbow trout in the Clary Creek watershed.

Although not strictly a mitigation measure, an environmental effect monitoring program would be developed in consultation with Environment Canada, the BC MOE, and the NLG prior to construction of the Project. This monitoring program would be designed and implemented with two-fold purpose of: 1) assessing whether predictions made during the impact assessments are accurate; and 2) determining whether any unanticipated effects are occurring, and if so, to trigger the implementation of additional mitigation, adaptive management, and / or compensation as required.

Modern mine exploration operations require strict government permit requirements including use of best management practices to reduce or eliminate potential effects to fish-bearing habitat downstream during on-going mine exploration at the Bell Moly deposit. These mitigation measures are likely to be highly effective at reducing any potential cumulative effect on rainbow trout in Clary Lake (Table 6.7.4-53). The likely success of this mitigation measure is increased because the proponent owns the lease for the Bell Moly deposit and the proponent would ensure that all on-going and future exploration activities associated with the Bell Moly deposit are conducted to the most stringent environmental best practices.

Table 6.7.4-53: Potential Cumulative Effect by Project Phase on Rainbow Trout and Mitigation Measures

Project Cumulative Effect	Project Phase	Mitigation / Enhancement Measure	Mitigation Success Rating
Change in surface water quality in Clary Lake	C, O, D/C, PC	Seepage control; erosion control and best management practices, adherence to site-specific water quality objectives in Lake 901; surface water quality monitoring; Best management practices during mining exploration drilling	High prevention / reduction of potential cumulative effects
Change in streams flows entering Clary Lake	C, O, D/C, PC	Water management, minimising encroachment into the Clary Creek watershed; stream flow monitoring; Best management practices during mining exploration drilling	High prevention / reduction of potential cumulative effects

Project Cumulative Effect	Project Phase	Mitigation / Enhancement Measure	Mitigation Success Rating
Change in benthic macro-invertebrate communities	C, O, D/C, PC	Seepage control; erosion control; minimising encroachment into the Clary Creek watershed; adherence to site-specific water quality objectives in Lake 901; surface water quality and stream flow monitoring; Best management practices during mining exploration drilling	High prevention / reduction of potential cumulative effects

Legend: C - construction; D/C - decommissioning and closure; O - operations; PC - post-closure

6.7.4.11.4 Potential Residual Cumulative Effects and Their Significance

Given that Clary Lake flooding occurred over 30 years ago and lasted less than five years, it is unlikely that any remnants of this flooding on rainbow trout health or tissue metals concentrations persist today. Any potential change in surface water quality in Clary Lake due to the Kitsault Project is, therefore, unlikely to have a cumulative effect with past mining activities at Kitsault during the 1960s and 1970s. No residual cumulative effect from past Kitsualt mine operations would occur as a result (Table 6.7.4-54).

Potential cumulative effects on rainbow trout in Clary Lake due to the Kitsault Project and on-going exploration activities at the Bell Moly deposit are unlikely to create cumulative effects to rainbow trout in Clay Lake due to changes in stream flows entering Clary Lake or the amount of benthic invertebrate drift or benthic macro-invertebrate production in Clary Lake. This is because the amount of water needed for modern drilling is negligible in comparison to the volume of run-off entering Clary Lake at any given time of year. Similarly, modern drilling guidelines and best management practices would effectively eliminate potential effects to benthic invertebrate communities downstream of the drill locations.

Table 6.7.4-54: Summary of Residual Cumulative Effects for Rainbow Trout

Project Phase	Residual Cumulative Effect After Mitigation or Enhancement	Direction	Likelihood of Occurrence
C, O, D/C, PC	Change in surface water quality due to TMF seepage and past flooding of Clary Lake during previous mine operations	Negative	Unlikely
C, O, D/C, PC	Change in surface water quality in Clary Lake due to TMF seepage and on-going or future mine exploration at the Bell Moly deposit	Negative	Likely
C, O, D/C, PC	Change in stream flows entering Clary Lake due to flow reductions caused by the TMF and on-going or future mine exploration at the Bell Moly deposit	Negative	Unlikely
C, O, D/C, PC	Change in benthic macro-invertebrates	Negative	Unlikely

Legend: C - construction; D/C - decommissioning and closure; O - operations; PC - post-closure

Table 6.7.4-55 summarises potential residual cumulative effects identified for rainbow trout in Clary Lake and the Project phases of their occurrence. The potential cumulative effect on rainbow trout in Clary Lake due to the combined effects on water quality changes from TMF seepage from the Kitsault Project and mine exploration drilling were assessed to be not significant negligible.

Table 6.7.4-55: Residual Cumulative Effects Assessment on Rainbow Trout by Project Development Phase

Parameter	Current / Future Cumulative Environmental Effect(s) Without Project	Project Contribution Cumulative Environmental Effect	Project Phase
Change in surface water quality in Clary Lake due to TMF seepage on on-going or future mine exploration at the Bell Moly deposit			*C,O,D/C, PC*
Effect Attribute			
Magnitude	Low	Medium	
Geographic extent	Regional	Local	
Duration	Short-term	Chronic	
Frequency	Intermittent	Continuous	
Reversibility	Yes	No	
Direction	Negative	Negative	
Certainty	Low	Medium	
Residual Effect Significance	Not significant (negligible)	Not significant (minor)	
Level of Confidence	High	Medium	

Legend: C - construction; D/C - decommissioning and closure; O - operations; PC - post-closure

6.7.4.12 Limitations

The assessment of potential project-specific and cumulative effects on rainbow trout was dependent on results of quantitative modelling conducted to determine the potential changes in surface water quality, stream flows, lake levels and air-borne contaminants and dust deposition in the Clary Lake watershed. Models are simplified abstractions of reality. They are useful because they provide a means of predicting future conditions that would otherwise not be possible without actually imposing the effect on the environment and monitoring changes in the receptors. As such, the accuracy of any model's predictions are dependent on the quality of the input data, the accuracy of calibrated model to predict existing conditions, and the number and validity of the assumptions included in the model.

Although all of the models used to predict changes in surface water quality, stream flows, lake levels and air-borne contaminant and dust deposition were calibrated using real data, each model had limitations on the available input data (e.g., using regional data sets to calibrate site-specific watershed models) and had necessary assumptions (e.g., all the dissolved metals remain in solution and do not form more complex compounds that would make them biologically unavailable) that may affect the accuracy of the models to predict future conditions. The limitations and assumptions for each of these models are described in greater detail in Section 6.2 (Air Quality), Section 6.5 (Hydrology), and Section 6.6 (Surface Water Quality).

Most critically to the assessment of potential effects of the Project on rainbow trout, was the uncertainty regarding the effect of the predicted exceedences of existing provincial and federal water quality guidelines for the protection of freshwater aquatic biota for a number of potential chemicals of concern (e.g., selenium, arsenic) in Lake 901 and Clary Lake. Taken at face value, these predicted exceedences would result in significant adverse effects to rainbow trout health, growth, and survival, and to the aquatic foodwebs upon which they depend, in both lakes. However, as the assessment above explains, some of these guidelines may be overly protective and site-specific water quality guidelines may be more appropriate. Methods to arrive at some these alternative site-specific water quality guidelines have been provided in this assessment. The BC MOE and the CCME acknowledge that site-specific water quality guidelines for certain chemicals of concern may be more appropriate than existing provincial and federal guidelines depending on site-specific conditions. Both agencies provide guidance on how these guidelines could be derived (McDonald et al. 1997; CCME 2007).

The proponent is committed to working with Environment Canada, the BC Ministry of Environment, and the NLG to derive appropriate water quality objectives where warranted and to develop additional mitigation measures necessary to avoid potential changes in surface water quality in lakes in the Clary Creek watershed downstream of the TMF.

6.7.4.13 Conclusion

The overall residual effect to rainbow trout in the Clary Creek watershed from the Project was rated as not significant (moderate). This significance rating was based on:

- The assessment that predicted losses of critical spawning habitat in Lake 901 inlets could at least be partially offset by enhancement of existing habitat in the Lake 901 outlet, by improvement of upstream fish passage at the Lake 901 outlet, and potentially, maintenance of on-going stocking of Clary Creek watershed lakes. At worst, the potential effect of this loss of fish habitat would be restricted to Lake 901 and would not affect populations in other parts of the Clary Creek watershed upstream or downstream of Lake 901;
- The assessment that predicted changes in surface water quality in Lake 901 and Clary Lake would not significantly affect the health, growth, survival or reproduction of rainbow trout because of the likely effectiveness of mitigation measures to minimise increases in chemical concentrations in Lake 901 (i.e., northeast TMF seepage control ponds and the diversion from Lake 493) and the proponent’s commitment to adhere to any site-specific water quality objectives for the protection of rainbow trout and other aquatic biota developed in consultation with Environment Canada, the BC MOE, and the NLG throughout the life of the Project;

- The assessment that predicted changes in stream flows at different locations in the watershed, while potentially substantial on a percentage basis at certain locations, would not have a significant effect on any critical stream habitat necessary for the long-term sustainability of any rainbow trout population in the Clary Creek watershed and, additionally, would not exacerbate any existing impediments to upstream migration of rainbow trout in the watershed necessary for accessing critical habitat; and
- The assessment that the potential for cumulative effects any rainbow trout due to residual effects from the Kitsault Project and other past, present, or reasonably foreseeable future project or land use is highly unlikely.

The moderate rating was determined because of the inherent uncertainties regarding the models upon which the rainbow trout assessment was based, the uncertainties regarding the success of habitat enhancement measures to offset habitat losses in the Lake 901 inlets, and because of the potential additive effects to rainbow trout due to habitat losses, predicted changes in surface water quality and stream flows. These additive effects would be most likely to occur to rainbow trout in Lake 901, the lake most directly affected by the Project. While the potential additive effects on rainbow trout were not quantitatively assessed, additional mitigation / compensation would be developed should monitoring show that rainbow trout health, growth, survival and reproduction in Lake 901 was declining. Any additional mitigation / compensation deemed necessary would be developed during consultations with Fisheries and Oceans Canada, BC MOE and Nisg̲a'a Fisheries.

6.7.5 Benthic Macro-Invertebrates

6.7.5.1 Introduction

Benthic macro-invertebrates (BMI) play an important role in the assessment of freshwater aquatic habitat and the assessment of pollutants that may affect water quality. As an important food source for fish species, they also represent a direct linkage between potential changes in stream flows, habitat changes, and water quality to fish. Although not directly used by people, BMI were selected as a VC because they can be used as an early indicator of potential effects of the Project in the Lime Creek and Clary creek watersheds and because of their importance to Dolly Varden, coho salmon, and rainbow trout which people do use and value.

The Project footprint spans over both the Lime Creek and Clary Creek watersheds and has the potential to create direct, indirect, and combined effects on BMI during all phases of the Project. Potential direct effects to BMI include loss of stream and lake habitat under the project footprint. Potential indirect effects to BMI include changes in water quality as a result of increased sediment loading, increased total suspended solids, and/or release of mine effluent or TMF seepage into downstream streams and lakes, and changes in stream flows in Lime Creek due to capture of run-off, alteration of upstream catchment areas, and/or diversion of upstream tributaries. Potential combined effects include, but are not limited to, changes in habitat, water quality and discharge in streams and changes in habitat, water quality and water levels in lakes.

Potential cumulative effects of the Project on BMI were assessed only for those direct, indirect, or combined effects that would likely result in a residual impact. Each of these residual impacts was then assessed for its potential to interact with residual effects from other past, present, or reasonably foreseeable projects in the Lime Creek and Clary Creek watersheds. In the Lime Creek watershed, this included potential cumulative effects from past mining of the Kitsault deposit. In the Clary Creek watershed, this included potential cumulative effects from past Kitsault mining and past and current mine exploration activities at the Bell Moly deposit. Potential cumulative effects on BMI were not assessed beyond these two watersheds because, unlike Dolly Varden and coho salmon, there is no potential for freshwater BMI to move between watersheds where other past, present, or reasonably foreseeable Projects exist.

6.7.5.2 Relevant Legislation and Legal Framework

For this assessment the legislation and legal framework cited fro the protection of fisheries habitat is considered as the bassis for habitat protection and in turn the protection of BMI. The relevant legislation and legal framework presented in each of the BMI and Coho Salmon VCs are considered to provide suitable legal framework for the assessment of potential effects of the proposed Project on BMI.

6.7.5.2.1 Federal

Fish habitat, as defined in the federal *Fisheries Act*, is “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”. By this definition, fish habitat includes areas that currently produce fish, area that could potentially produce fish, or areas that provide the nutrients, water, or food supply to fish-producing habitat downstream. Therefore, because BMI are the primary food source for many freshwater fish species, they are an integral part of fish habitat under the federal *Fisheries Act*.

Section 35(1) of the federal *Fisheries Act* prohibits the harmful alteration, disruption, or destruction (HADD) of fish habitat in Canada. Such a HADD is defined as “any change in fish habitat that reduces its capacity to support one or more life processes of fish” (DFO 1998). Section 35(2) of the *Fisheries Act* allows a HADD of fish habitat if it is authorised by Fisheries and Oceans Canada (DFO). Such an authorisation will be issued by DFO only if it is satisfied that its guiding principle for the management of fish habitat in Canada will be met, that is there will be “no-net-loss (NNL) of productive capacity of fish habitat”. Based on definition of fish habitat above, any loss of habitat used by BMI could potentially require compensation under the *Fisheries Act*.

The Canadian Council of Ministers of the Environment (CCME) and the British Columbia Ministry of Environment (MoE) have developed water quality guidelines for the protection of freshwater aquatic biota. These guidelines exist for many of water quality parameters potentially altered by the Project. Depending on the parameters, these guidelines are may be derived from toxicological studies conducted using aquatic plants, plankton, algae, benthic macro-invertebrate larvae, or fish. Typically, the guidelines are designed to protect the most sensitive organism under the most conservative of environmental conditions. Many of these guidelines have been developed using benthic macro-invertebrates as the end-point receptors.

6.7.5.2.2 Provincial

The province of British Columbia is responsible for the management of freshwater fish in BC. While this responsibility largely surrounds the management of fisheries for their sustained recreational use, the province has enacted legislation and various regulations that serve to protect and manage fish habitat. By protecting fish habitat, it is implied that the following laws and regulations would also provide protection of BMIs:

- *Fish Protection Act*: provides authority to consider impacts to fish and fish habitat before approving new or renewing existing water licenses and before issuing approvals for working in or near a stream; ensures sufficient water for fish when making decisions about licenses or approvals under the *Water Act*; allows the listing of streams with recognised fish values as being sensitive to water withdrawals; protects riparian areas through provisions of the *Riparian Areas Regulation*;
- *Water Act*: allows for effects to fish and fish habitat through the diversion or storage of water and to water in and about a stream; the *Water Act* has been amended for consistency with the *Fish Protection Act*; and
- *Forest and Range Protection Act*: provides guidance on discretionary and mandatory Riparian Management Areas around fish bearing streams, lakes, and wetlands.

6.7.5.2.3 Nisg̱a'a Lisims Government

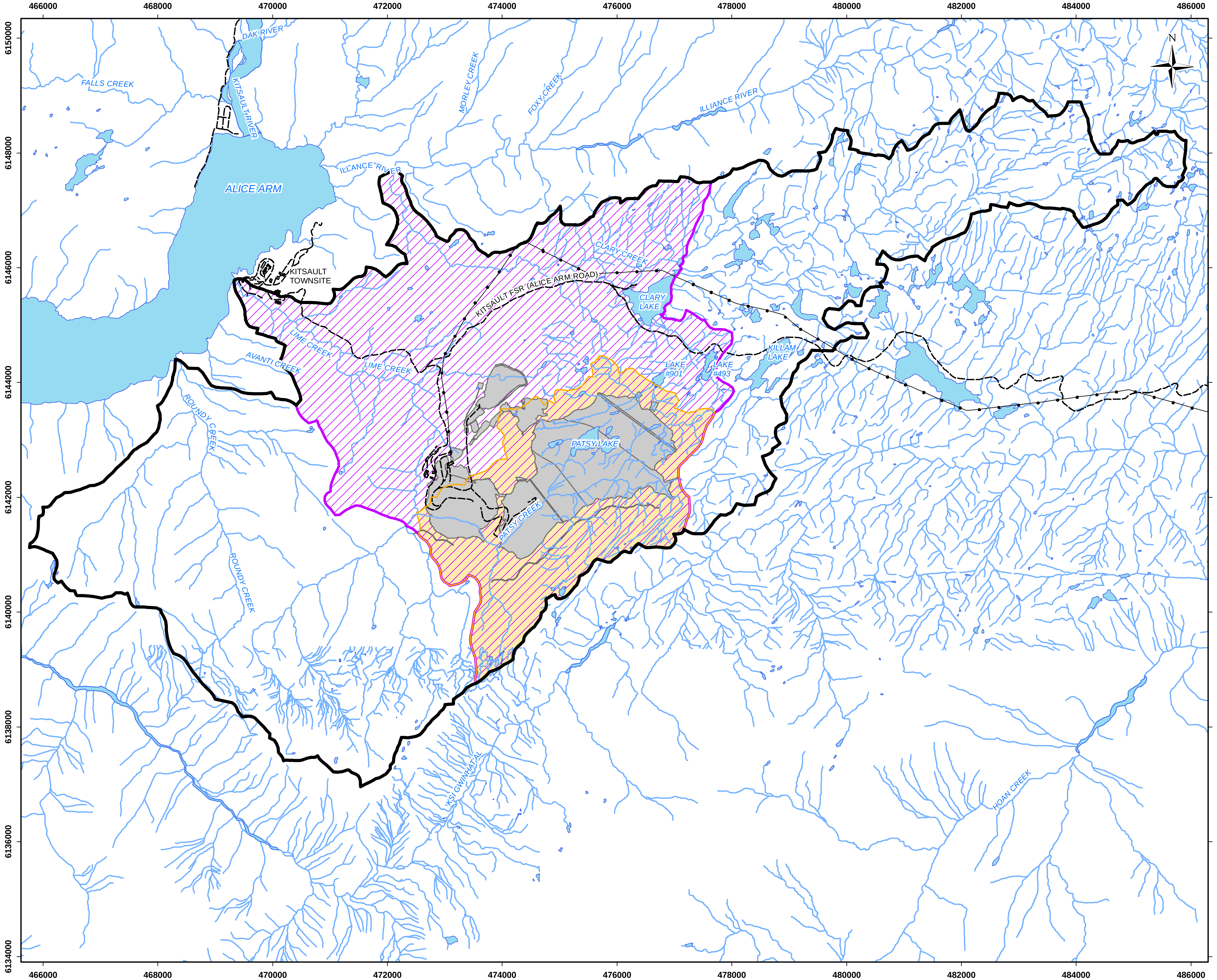
There are no laws or regulations within the Nisg̱a'a Final Agreement that specifically addresses the protection of freshwater aquatic BMIs.

6.7.5.3 Spatial Boundaries

A description of and rationale for the Local Study Area (LSA), Regional Study Area (RSA), and cumulative effects study area (CESA) for BMI are provided in the sections below.

6.7.5.3.1 Local Study Area

The LSA for BMI included portions of both the Lime Creek and Clary Creek watersheds. This is because, although most of the project is located in the Lime Creek watershed and most of the potential impacts to BMI could occur here, the north embankment of the TMF encroaches into the headwaters of the Clary Creek watershed. In the Lime Creek watershed, the LSA for BMI included Patsy Creek from its headwaters at Pasty Lake downstream to its confluence with Lime Creek and Patsy Lake. In the Clary Creek watershed, the LSA for BMI includes the two headwater tributaries of Lake 901 that are potentially affected by the northeast embankment of the TMF: stream 76800 and ILP 887 (Figure 6.7.5-1). This LSA was selected because it defines the limit of the potential direct affects of the Kitsault Project footprint on BMI and their habitat.



Scale:1:65,000

0 0.5 1 2

Kilometres

Reference

1. Base Data
Geobase 1:20,000 (TRIM)
Land and Resource Data Warehouse 1:20,000 (TRIM)
2. Kitsault Mine General Layout
Supplied by AMEC and Knight Piesold December 2010

CLIENT: Avanti Kitsault Mine Ltd.

PROJECT: Kitsault Mine Project

Benthic Macro Invertebrate (BMI) Study Area

DATE: December 2011	ANALYST: MY	**Figure** 6.7-5-1
JOB No: VE51988	QA/QC: BH	PDF FILE: 10-50-111_BMI_study_area.pdf
GIS FILE: 10-50-111.mxd		
PROJECTION: UTM Zone 9	DATUM: NAD83	

Y:\GIS\Projects\VE\VE51988_Kitsault\Mapping\10_fisheries-aquatics\Baseline\10-50-111.mxd

6.7.5.3.2 Regional Study Area

The RSA for BMI included the streams and lakes included in the LSA plus:

- Lime Creek from the Patsy Creek confluence downstream to Alice Arm; and in the Clary Creek watershed
- Lake 901 and the Lake 901 outlet;
- Lake 493;
- Clary Creek from Lake 493 downstream to Clary Lake;
- Clary Lake;
- Clary Creek from Clary Lake downstream to the impassable waterfalls upstream of the confluence of Clary Creek and the Illiance River (Figure 6.7.5-1).

This RSA was selected because it encompasses all watercourse and waterbodies with the Lime Creek and Clary Creek watersheds where potential direct and indirect effects of the Kitsault Project could affect BMI through potential changes in surface water quality, changes in stream flows, and/or changes in lake levels.

6.7.5.3.3 Cumulative Effects Study Area

The Cumulative Effects Study Area (CESA) for BMI includes all of streams and lakes in the Lime Creek and Clary Creek watersheds included in the LSA and RSA plus the Lime Creek watershed upstream of the confluence of Lime and Patsy creeks and the north-eastern portion of the Clary Creek watershed upstream of Clary Lake (Figure 6.7.5-1). This CESA was selected because it includes all of the potential residual effects from past mining and exploration activities at the Kitsault deposit in the Lime Creek watershed and all current and past mine exploration activities at the Bell Moly deposit in the upper Clary Creek watershed. These are the only two past, present, or reasonably foreseeable projects that have the potential to interact with any potential residual effects from the Kitsault Project on freshwater BMI.

6.7.5.4 Temporal Boundaries

Temporal boundaries for assessment of potential effects of the Kitsault Project on BMI were based on the reasonable expectation of time over which the proposed Project has had or would have effects on BMI. Thus, the selection of temporal boundaries for BMI was driven by the duration of each of the four primary phases of the proposed Project:

- **Construction Phase:** estimated 25 month period that includes preparation of land for construction of mine infrastructure, construction of mine infrastructure including the tailing management facility, camp complex, processing plant, and access roads and transmission lines, and implementation of the construction phase water management plan;

- **Operations Phase:** estimated at approximately two months of commissioning, and 15 to 16 years of mining (last two years are milling low grade ore). Phase includes progressive reclamation;
- **Decommissioning and Closure Phase:** estimated at 15 to 17 years. Includes a closure period during which the buildings and un-needed infrastructure will be removed, facilities reclaimed and closure water management plan is enacted; and
- **Post-Closure Phase:** estimated at five years or more. Includes post-closure monitoring until on-site water quality has stabilised and indicates no future adverse effects on local receiving waters; stabilisation of waste rock and TMF will also be considered in post-closure monitoring.

The Kitsault site has legacy effects due to two previous mining operations in the 1970s and early 1980s. Of particular relevance to BMI was the deposit of at least 8 million tonnes of mine tailings directly into Lime Creek during the first mine operation between 1963 and 1972. While the high discharge and energy of Lime Creek Watershed has likely removed all of these tailings from Lime Creek and deposited them in Alice Arm, any residual effects of this deposition would be reflected in the baseline condition of the Lime Creek BMI community presented in the Appendix 6.7-A and summarised in Section 6.7.5.6.

6.7.5.5 Information Source and Methods

BMI communities in the streams and lakes of the Lime Creek and Clary Creek watersheds were sampled in the summer of 2009 by Rescan Environmental Limited and in the summer of 2010 by AMEC Earth & Environmental. In addition, stomachs from Dolly Varden in Lime Creek and stomachs from rainbow trout in Clary Lake were analyzed in 2010 to determine the relative composition of benthic macro-invertebrates in the diet of both fish species.

6.7.5.5.1 BMI Field Methods in 2009

In 2009, BMI communities were sampled at four stream sites in the Lime Creek watershed in August. These included one site in Patsy Creek (PC2 upstream of the Patsy and Lime Creek confluence), one site in upper Lime Creek (LC3 upstream of the Patsy and Lime Creek confluence), and two sites in lower Lime Creek (LC0 and LC1, downstream and upstream of the town of Kitsault, respectively). With the exception of LC1 where seven replicates were collected, five replicate BMI samples were collected at each site using a Hess sampler with a 250 μm mesh net. Each sample consisted of a composite of three pooled samples taken 5 to 10 m apart.

BMIs were also collected from Patsy Lake in 2009. Three replicate samples were collected from the deepest part of Patsy Lake (approximately 25 m) with an Ekman grab. Samples were brought to the surface and sieved in a 500 μm sieve bucket in the lake to separate benthic organisms from the silt and fine debris. Three replicates were collected and composited by placing the sieved contents of all three grabs into a clean, pre-labeled 500 ml jar. All samples were preserved with 10% buffered formalin.

6.7.5.5.2 BMI Field Methods in 2010

In 2010, BMI communities were sampled in three of the same four sites sampled in 2009 in the Lime Creek watershed. These included the sites in Patsy Creek, in upper Lime Creek, and one site in lower Lime Creek (LC1-10; at the same location as LC1 in 2009). In addition, three stream sites were sampled for BMIs in the Clary Creek watershed in 2010. These included sites in the Lake 901 inlet and outlet (WSC 910-929800-05800-76800) and in the Clary Lake outlet (WSC 910-929800-05800). BMI samples were collected in late August/early September, 2010. Sample timing was consistent with sampling conducted in 2009 sampling and the CABIN protocol (EC 2010a).

Similar to 2009, BMIs from stream sites were collected from riffle habitats using a Hess sampler with a 243 µm mesh net. At each site, five composite samples, comprised of three pooled samples taken at locations 1 to 2 m apart, were collected. Sampling methods were similar to those used in 2009 and were based on standard procedures as described in the "BC Field Sampling Manual" (Clark 2003) and the "Metal Mining Guidance Documents for Aquatics Environmental Effects Monitoring" (EC 2002). Water depth and mean water column velocity were recorded at each Hess sample site using a Swoffer Current Meter 2100 and a graduated wading rod.

In addition to the Hess samples, a BMI kick sample was also collected at each stream sample site in 2010. These kick-net samples were collected following the CABIN protocol for wadeable streams (EC 2010a). Each kick was conducted with a 400 µm mesh kick-net by one crew member working in a zig-zag pattern across the site in an upstream direction for 3 minutes. Substrates were disturbed in front of the net to a depth between 5 and 10 cm. Larger substrates encountered during the sampling were cleaned by hand immediately upstream of the kick-net.

BMI samples were collected from Patsy Lake, Clary Lake, and Lake 901 in 2010. Five separate samples were collected from each lake using an Ekman grab. Samples were collected at the deepest part of each lake at least 5 m apart. For each grab sample, sample volume was approximately 4,000 cm^3 from 225 cm^2 of lake bed to a depth of approximately 18 cm. Similar equipment, sampling methods, and sampling handling and preservation were used in 2010 as in 2009. In both 2009 and 2010, BMI samples from lakes were collected following standard procedures described in the "BC Field Sampling Manual" (Clark 2003).

6.7.5.5.3 Fish Diet Analysis in 2009 and 2010

Twelve Dolly Varden stomachs from Lime Creek were analyzed for diet composition in fall 2009. These fish included eight sea-run adults (>180 mm) and four smaller adults or juveniles (<180 mm). Twenty-one rainbow trout stomachs from Clary Lake were analyzed for diet composition in summer 2010. These included fish ranging in size from 112 mm long to 282 mm long.

6.7.5.5.4 Laboratory Methods and Data Analysis

BMI samples collected in 2009 were identified and enumerated by Environmental Research and Consulting in Summerland, BC. Individual invertebrates were sorted and identified to the lowest possible taxonomic level (typically genus). BMI samples collected in 2010 were identified and enumerated by Cordillera Consulting in Summerland, BC. The 2010 Hess samples were processed following the CABIN Laboratory protocol (MacDermott et al. 2010) and the CABIN kick-net samples were sub-sampled following the Skeena CABIN protocol (Perrin et al. 2005). The same CABIN laboratory protocol for sorting and taxonomic identification and enumeration used for the stream samples was followed for the lake samples.

Data analysis for BMI samples in 2009 and 2010 followed provincial guidelines (BC MOE 2009) and was consistent with metal mining environmental effect monitoring guidelines (EC 2002). Cladocera and Copepoda were excluded from all analyses of BMI data, even if they were present in the samples, because they were assumed to be lake-generated and not stream-generated.

BMI community data were analysed for density (# of organisms/m^2), and relative abundance (% of total organisms present), and the following community metrics:

- % Ephemeroptera, Plecoptera, Tricoptera (EPT);
- Family richness;
- Pielou's Evenness (*J*);
- Shannon Diversity Index (*H'*);
- Simpson's Diversity index (*D*); and
- Bray-Curtis Index (B-C).

All community metrics were conducted at the family level because it is sufficient to detect community responses to human disturbances and analysis to the genus or species level does not improve bioassessment (Bailey et al. 2004; EC 2002).

Fish stomachs were removed and weighed and preserved for identification of dietary items in the lab. In the lab, stomach contents were removed, blotted with filter paper to remove excess moisture, and weighed to the nearest milligram. Recognisable prey items were identified to Order, enumerated, and weighed by group to the nearest milligram.

6.7.5.6 Detailed Baseline for Benthic Macro-Invertebrates

6.7.5.6.1 Density and Relative Abundance in Streams

In 2009, mean BMI density was higher at the Patsy Creek (PC2) site (3,910 individuals/m^2) than at the upper Lime Creek (LC3) and in the two lower Lime Creek sites (LC0 and LC1) (803, 586 and 445 individuals/m^2, respectively) (Table 6.7.5-1). The denser riparian vegetation and the large amount of woody debris at PC2 likely contributed to the higher BMI densities at this site (Rescan 2010b).

Table 6.7.5-1: Sampling Precision, Mean Density, And Community Metrics For Stream BMI Sites Sampled in The Lime Creek Watershed In 2009

Community Metric	Statistic	LC0	LC1	LC3	PC2
Sampling Precision	D_p	0.20	0.18	0.31	0.16
Density (organisms/m^2)	Mean	586	445	803	3,910
	SD	266	215	565	1,427
Family richness	Total	21	23	21	28
EPT (%)	Mean	63.27	85.40	86.95	75.49
Pielou's Evenness (*J*)	Mean	0.69	0.72	0.68	0.74
	SD	0.66	0.13	0.44	0.33
Simpson's Diversity (*D*)	Mean	0.74	0.75	0.74	0.83
	SD	0.10	0.09	0.07	0.03
Shannon's Diversity(*H'*)	Mean	1.75	1.76	1.75	2.14
	SD	0.25	0.28	0.22	0.10

Note: EPT - Ephemeroptera, Plecoptera, and Trichoptera; SD - standard deviation
Source: Rescan (2010a)

Plecoptera (stoneflies) and ephemeroptera (mayflies) larvae comprised between 63% and 84% of the total BMI present at all four sites sampled in 2009. Even though Tricoptera (caddisfly) larvae contributed <5% to the total BMI communities at these four sites in 2009, EPT taxa comprised between 63 and 87% of the total BMI organisms present at these four sites. Dipteran (true flies and midges) larvae comprised 23% of the BMI community at the Patsy Creek site (PC2) and 34% of the BMI community at the lowest Lime Creek site downstream of the Kitsault Townsite (LC0). Dipteran larvae comprised only 12% and 8% of the BMI communities at the upper Lime Creek site (LC3) and the lower Lime Creek site above the Kitsault Townsite (LC1). Together, stoneflies, mayflies, and dipteran larvae comprised over 90% of all organisms present in the samples.

In 2010, mean BMI densities were significantly ($p<0.001$) higher at the sites in the Clary Creek watershed than at the sites in the Lime Creek Watershed. The Clary Lake outlet site (19,577 organisms/m^2) had the highest mean BMI density of any of the sites sampled in 2010 and was significantly higher than the density of BMIs at the Lake 901 inlet and outlet (6,698 and 9,037 organisms/m^2, respectively). By comparison, the mean BMI densities at the three Lime Creek sites ranged from 1,388 to1.871 organisms/m^2 (Table 6.7.5-2).

Table 6.7.5-2: Sampling Precision, Mean Density, And Mean Community Metrics For Stream BMI Sites Sampled In 2010

Metric	Statistic	Lime Creek Watershed			Clary Creek Watershed		
		LC1-10	**LC3-10**	**PC**	**L901-I**	**L901-O**	**CL-O**
Sampling Precision	D_p	0.09	0.14	0.20	0.27	0.30	0.16
Density (organisms/m^2)	Mean	1,640	1,871	1,388	6,698	9,037	19,577
	SD	347	571	613	4,093	6,139	6,845
Family richness	Total	20	19	23	32	28	22
EPT (%)	Mean	98	99	91	40	45	20
Pielou's Evenness	Mean	0.38	0.55	0.62	0.69	0.63	0.55
	SD	0.38	0.15	0.26	0.58	0.41	0.20
Simpson's diversity index	Mean	0.38	0.66	0.74	0.79	0.79	0.62
	SD	0.08	0.03	0.04	0.07	0.02	0.15
Shannon's Diversity	Mean	0.92	1.41	1.67	2.10	1.87	1.47
	SD	0.18	0.11	0.10	0.24	0.10	0.34

Note: SD - standard deviation

Similar to 2009, Plecoptera and Ephemeroptera larvae comprised over 90% of the BMI communities at the three sites in the Lime Creek watershed. Replicates from the lower Lime Creek site (LC1-10) were dominated by plecopteran larvae from the family Taeniopterygidae (winter stoneflies). They accounted for >70 % of individuals in each replicate. Taeniopterygidae are from the “shedder” functional feeding group and are typically found in leaf packs or snags at the edges of streams. They are also indicative of well oxygenated, unpolluted waters (Howell et al. 1998).

In contrast, EPT taxa comprised no more than 45% of the BMI communities at the three Clary Creek watershed sites. Instead of EPT taxa, dipteran larvae (predominantly chironomids [midges] and Simulidae [blackfly] larvae) were the dominant taxa at the Lake 901 inlet and outlet, comprising 49% and 31% of the total BMI community at these sites

The BMI community at the Clary Lake outlet site was the most different of the six sites sampled in 2010. Here, the BMI community was dominated by bivalves (67%), EPT taxa comprised only 20% of the total organisms present and dipteran larvae comprised only 11% of the total organisms present.

6.7.5.6.2 Richness and Diversity Indices for Streams

In addition to having the most dense BMI community, the Patsy Creek site had the most even distribution of organisms among families present and was the most taxonomically diverse (28 families) of the four stream sites sampled in the Lime Creek watershed in 2009 (Table 6.7.5-3). The Patsy Creek site had a mean Pielou’s evenness index of 0.74, a mean Simpson’s diversity index of 0.83, and a Shannon’s diversity index of 2.14. Family richness at the upper and lower Lime Creek sites ranged from 21 to 23 families in 2009. Pielou’s evenness, Simpson's diversity, and Shannon's diversity indices at the three Lime Creek sites were similar but lower than the Patsy Creek site. This indicated that the BMI communities at the Lime Creek sites had fewer taxa present and fewer taxa comprised the greatest proportion of the total individuals present.

Family richness was generally higher at the three Clary Creek sample sites than at the three Lime Creek watershed sample sites in 2010. Family richness ranged from 22 families at the Clary Lake outlet to 32 families at the Lake 901 inlet site in 2010. In comparison, family richness ranged from 19 families at the upper Lime Creek site to 23 families at the Patsy Creek site.

6.7.5.6.3 Density and Relative Abundance in Lakes

Mean BMI density in Patsy Lake in 2009 was 153 organisms/m^2 (Table 6.7.5-3). In comparison, mean BMI density in Lake 901 was 95 organisms/m^2 while no BMI were found in any of the 15 replicate sampled collected from the profundal zone of Clary Lake in 2010. Variability was high between replicates in Patsy Lake and Lake 901 in both years.

Table 6.7.5-3: Sampling Precision, Mean Density, And Community Metrics For Lake BMI Sites Sampled In 2009 And 2010

Community Metric	Statistic	Patsy Lake	Lake 901	Clary Lake
Sampling precision	D_p	0.77	0.32	n/a
Density (organisms/m^2)	Mean	153	95	0
	SD	204	68	0
Family richness	Total	3	4	0
Pielou's Evenness (*J*)	Mean	0.75	0.36	n/a
	SD	0.04	0.08	n/a
Simpson's Diversity (*D*)	Mean	0.34	0.15	n/a
	SD	0.02	0.16	n/a
Shannon's Diversity(*H'*)	Mean	0.52	0.25	n/a
	SD	0.03	0.25	n/a

Note: D_p - sampling precision; SD - standard deviation; SE - standard error

Dipteran larvae (chironomids predominantly) comprised the majority of the BMI communities in Patsy Lake in 2009 (78%) and Lake 901 in 2010 (69%). These were followed by oligochaetes (round worms) and bivalves (3% and 19%, respectively in Patsy Lake in 2009 and 28% and 3% in Lake 901, respectively in 2010).

6.7.5.6.4 Richness and Diversity Indices for Lakes

BMI density and family richness in Patsy Lake (3 families), Lake 901 (4 families), Clary Lake (no families) were significantly lower than in the three wetland sites sampled in 2009. BMI densities ranged between 2,600 individuals/m^2 and 6,500 individuals/m^2 and between 9 and

11 families in the three wetland sites where dipteran larvae, oligochaetes, and bivalves were also the most abundant taxa present. The lower BMI densities and lower family richness in Patsy Lake compared to the wetland sites and the absence of BMI in Clary Lake was likely due to the cold water temperatures and low dissolved oxygen concentrations near the bottom at the depths samples (approximately 25 m and 37 m, respectively). It is unclear why the density and diversity of BMI in Lake 901 was lower compared to wetlands given that samples collected in Lake 901 were collected from relatively shallow depths (< 3 metres), however it may be due to differences in water quality, water temperature, nutrient levels, trophic structure (lack of fish predator in wetlands), and/or bottom substrate composition.

Patsy Lake had higher Pielou's evenness (0.75), Simpson's diversity (0.34), and Shannon's diversity (0.52) indices than Lake 901 (0.36, 0.15, and 0.25, respectively). Although family richness was low in both lakes, the higher evenness and diversity indices in Patsy Lake indicates that the BMI community of Patsy Lake was more balanced than in Lake 901 where the BMI community was dominated by fewer taxa. Both lakes had lower community metrics than the three wetlands sampled in 2009 because they had low family richness and the BMI communities in the two lakes were dominated by fewer families.

6.7.5.6.5 BMI Composition in Fish Diets

6.7.5.6.5.1 Lime Creek Dolly Varden

Dipteran (true flies) larvae comprised the largest proportion (34%) of identifiable prey items found in the 12 Dolly Varden stomachs analyzed in 2009. This was followed by, in order of abundance, fish eggs (20%), tricopteran (caddisflies) larvae (13%), adult and larval hymenopterans (ants, bees, and wasps) (9%), adult lepidopterans (moths and butterflies) (7%), ephemeropteran (mayflies) larvae (5%), and plecopteran (stoneflies) larvae (4%). All other prey items comprised <4% of the total prey items consumed.

Of the 339 prey items consumed, only 53% were adults or larvae of freshwater origin (i.e., insects on the bottom or drifting in Lime Creek). The other 47% were adults or larvae of terrestrial origin that were eaten when they fell into Lime Creek, presumably from the riparian vegetation and tree canopy. These included 68% of all hymenopterans, 89% of all dipterans, 93% of all coleopterans, and 100% of all lepidopterans consumed.

Fish eggs comprised the largest proportion (46%) of the total wet weight of prey items eaten. These were followed by, in order of percentage of total wet weight, trichopteran larvae (16%), unidentifiable insect parts (10%), adult lepidopterans (9%), and adult and larval dipterans (5%). All other prey taxa comprised <5% of the total wet weight of prey items consumed.

Although the sample sizes were small, there was a substantial difference in diet between Dolly Varden greater than 180 mm (n=8 fish) and Dolly Varden less than 180 mm (n=4 fish). The diet of the larger fish was comprised largely of terrestrial and aquatic insects: dipterans, trichopterans, hymenopterans, lepidopterans, and plecopterans comprised 83% of total prey items and 81% of the total wet weight of prey items consumed by these larger fish. In contrast, fish eggs were the primary food item of Dolly Varden less than 180 mm in length, comprising 32% of the total prey items and 62% of the total wet weight of prey items consumed. Fish eggs comprised only 6% of the total wet weight of prey items consumed by the larger fish. Such a difference in diet between these two size groups of Dolly Varden suggests that the smaller fish were juveniles that had not yet migrated to Alice Arm, who began opportunistically feeding on fish eggs as the larger adult spawners returned to Lime Creek. The different diet, larger size, older age (all eight fish were 3+ or 4+ years old) suggests that the other eight fish were adults returning to Lime Creek to spawn and had likely been in the creek for only a short period.

6.7.5.6.5.2 Clary Lake Rainbow Trout

Zooplankton comprised approximately 85% of the total wet weight of all prey items found in the 17 rainbow trout stomachs from Clary Lake with identifiable prey items. Aquatic dragonfly (Odonata) nymphs (12%) and terrestrial Hemipterans (3%) comprised the remainder of identifiable prey items in these 17 rainbow trout stomachs. The other four rainbow trout stomachs were either empty or contained unidentifiable material.

Zooplankton were found in all 17 stomachs analyzed. In contrast, only three of the 17 rainbow trout stomachs contained Odonata nymphs and only one rainbow trout stomach contained Hemipterans. Interestingly, this one fish was feeding on Hemipterans exclusively. These data suggest that although zooplankton are the primary prey item of Clary Lake rainbow trout, they feed opportunistically on aquatic insect larvae and terrestrial insects. These preys are larger and have a higher lipid content than the smaller zooplankton and, therefore, provide higher energy meals for rainbow trout. These fish likely take advantage of these higher energy prey items whenever they are available on the bottom in the littoral areas or on the surface of the lake.

The opportunity for rainbow trout to eat these higher energy prey items is likely limited in Clary Lake due to its bathymetry and shoreline characteristics. Clary Lake has a steep shoreline gradient around most of its perimeter and cobbles are the most common littoral substrate type. These two features limit the amount and suitability of Clary Lake's littoral habitat for aquatic insect production. Coupled with the absence of benthic invertebrate prey in the profundal (>20 m) areas that comprise most of the Clary Lake and the absence of other prey fish species, it is not unexpected that rainbow trout in Clary Lake feed primarily on zooplankton.

6.7.5.7 Cultural Ecological or Community Knowledge

Desk-based research was conducted to identify Nisg̲a'a Nation's and Aboriginal groups' rights, interests, and values related to stream flow and BMI. However, no information was available from public, secondary sources. Ongoing future consultation and engagement activities and data collection efforts in collaboration with the Nisg̲a'a Nation and Aboriginal groups may result in additional information and understanding of the importance of BMI in streams and lakes within the Kitsault area during the Application Review period.

6.7.5.8 Past, Present or Future Projects / Activities

Tables 6.7.5-4, 6.7.5-5 and 6.7.5-6 below identify the historical land use, present land use and reasonably foreseeable projects, respectively, which have the potential to interact in time and/or space with potential residual effects on BMI due to the proposed Kitsault Project. These land uses and projects were selected from the final Project Inclusion List for the cumulative effects assessment (CEA) based on their potential to affect BMI in the Lime Creek or Clary Creek watershed due to their potential indirect effects on stream flows, lake levels, or water quality. Included projects were restricted to the Lime Creek and Clary Creek watersheds because these are the two watersheds in which potential residual effects to BMI from the Kitsault Project could occur and because freshwater life stages of BMI in these watersheds would not move into other watersheds in the Alice Arm area where other past, present and future projects are known to exist.

Table 6.7.5-4: Historical Land Use Activities in Biophysical Cumulative Effects Assessment Study Area

Project / Activity	Description
Kitsault Mine and exploration	Exploration, which appears to have begun in the area in 1911, identified the presence of an ore body in late 1964. The mine was owned by B.C. Molybdenum, a subsidiary of KEL from 1963 to 1972 and by Climax Molybdenum Company of British Columbia (CMC) and affiliates from 1973 to 1998. Between January 1968 and April 1972, approximately 9.3 million tonnes of ore were produced with about 22.9 million pounds of molybdenum recovered. CMC returned the mine to production in 1981 but production was terminated again because of low metal prices in 1982.
Kitsault Town site	The Kitsault Town site, built in the 1970s and opened in 1981 to support the Kitsault Mine, was occupied for less than two years. The Kitsault Town site, which is located approximately 5 km from the proposed Project, was purchased by Kitsault Resort Ltd. in 2005 and has been, and continues to be, maintained by caretakers.

Note: B.C. - British Columbia; CMC - Climax Molybdenum Company of British Columbia; KEL - Kennco Exploration (Western) Ltd.

The historical land use with the greatest potential to cumulatively affect BMI is the past mining activities at the Kitsault Mine site. During the first mining operation, between 8 and 11 milllion tonnes of mine tailings were deposited directly into Lime Creek Watershed between 1963 and 1972. During the second mining operation, waste rock dumps were located adjacent to Patsy Creek and in the upper headwaters of the Patsy Creek watershed. While the high discharge and energy of Lime Creek Watershed has likely removed all or most of these tailings from Lime Creek and deposited them in Alice Arm, any residual effects of this past deposition and any residual effects of the former waste rock dumps is reflected in the baseline characterisation of the BMI communities in Patsy and Lime Creeks presented in the Appendix 6.7-A and summarised in Section 6.7.5.6 above.

Table 6.7.5-5: Present Land Use Activities in Biophysical Cumulative Effects Assessment Study Area

Project / Activity	Description
Mining exploration	Mining exploration activities are ongoing in the CESA. These include exploration of the Bell Moly in the upper Clary Creek watershed. A number of private claims are surrounded by the proponent's Kitsault mineral tenure area.

Note: CESA - Cumulative Effects Study Area; FSR - Forest Service Road; RSA - Regional Study Area

Exploration in the Bell Moly deposit in the Clary Creek watershed has the potential to alter water quality and stream flows that may cumulatively affect any BMI. Modern exploration operations must follow strict government permit requirements which include best management practices to reduce or eliminate potential effects to fish-bearing habitat downstream. Thus, an interaction is possible but this is not considered a key interaction (Table 6.7.1-2).

Table 6.7.5-6: Reasonably Foreseeable Projects in Biophysical Cumulative Effects Assessment Study Area

Project / Activity	Construction	Operation	Area and Rationale
Northwest Transmission Line Project	Spring 2011 - 2013	Unknown – with routine maintenance it would operate into the foreseeable future	The Northwest transmission line is a 287 KV 335 km transmission line between the Skeena substation (near Terrace) and Bob Quinn Lake.

Note: KV - Kilovolts

There are no potential interaction to BMI from residual effects from the Northwest Transmission Line Project and residual effects from the Kitsault Project. This is because the Northwest Transmission Line Project does not the Lime Creek or Clary Creek watersheds.

Table 6.7.5-7 summarises potential interactions between BMI and historic, present, and reasonably foreseeable land use activities.

Table 6.7.5-7: Assessment of Linkages Between Other Projects, Human Activities and Reasonable Foreseeable Projects With Benthic Macro-Invertebrates

	Historical Land Use					Representative Current and Future Land Use					Reasonably Foreseeable Projects
Freshwater Aquatic Resources VC	**Kitsault Mine and Exploration**	**Kitsault Town Site (on-going)**	**Alice Arm Town Site (on-going)**	**Previous Mine Operations**	**Previous Mine Exploration**	**Transportation and Access**	**Mining Exploration**	**Trapping and Guide Outfitting**	**Nisga'a Nation hunting, trapping, fishing, and other uses**	**Aboriginal hunting, fishing, and other uses**	**Northwest Transmission Line Project**
Benthic macro-invertebrates	-	-	NI	NI	NI	NI	o	NI	NI	NI	NI

Note: Interaction definitions: o - interaction; - - key interaction; + - benefit; NI - no interaction

6.7.5.9 Potential Effects of the Proposed Project and Proposed Mitigation

This section identifies and presents the likelihood that different Project components and activities would have a direct, indirect, or combined effect on BMI during the construction, operations, closure / decommissioning and post-closure phases of the Kitsault Project. It does so by:

- Identifying each potential direct, indirect, and combined effect that may occur to BMI during each phase of the Project;
- Identifying any direct, indirect, or combined effects on BMI that may indirectly effect other Valued Components, including other Freshwater Aquatic Resource VCs;
- Identifying any potential direct, indirect, or combined effects on BMI that are eliminated through implementation of changes to the Project design; these potential effects were not carried forward in the assessment; and
- Identifying and rating the likelihood of mitigation measures that would be implemented to reduce or eliminate potential direct, indirect, or combined effects on BMI; potential effects where mitigation measures are determined to completely break the linkage between the Project component or activity and the VC were not carried forward in the assessment.

Those direct, indirect, and combined effects carried forward in the effects assessment are presented and rated for their significance to the health, growth, survival, and / or recruitment of BMI in Section 6.7.5.9.1.4.

6.7.5.9.1 Identification and Analysis of Potential Project Effects

6.7.5.9.1.1 Potential Direct Effects on Benthic Macro-Invertebrates

For the purposes of this assessment, direct effects to BMI were considered to occur from those Project components or activities that would result in the direct mortality of BMI or the direct loss of their habitat under the Project footprint. Based on this definition, only one potential direct effect has been identified, that is the loss or destruction of habitat or mortality of BMI as a result of the development of the mine pit, the TMF and the south and northeast embankments and tailings beaches as summarised in (Table 6.7.5-8).

Table 6.7.5-8: Potential Direct Project Effects on Benthic Macro-Invertebrates

Project Component	Project Phase	Potential Direct Project Effect	Likelihood of Occurrence
Development of mine pit, TMF, and TMF embankments and tailings beaches	Construction, operations, closure & post-closure	Potential change in abundance and composition of BMI community due to loss of habitat	Likely

The footprint of the proposed TMF lies primarily within the non-fish-bearing Patsy Creek Watershed, a headwater tributary of the Lime Creek watershed. The Kitsault Pit would also be located in the lower reaches of Patsy Creek. However, the TMF would encroach into the headwaters of the adjacent fish-bearing Clary Creek watershed. Specifically, the northeast embankment, tailings beach, and northeast water management ponds and collection ditches would be located on fish-bearing headwater tributaries of Lake 901, a fish-bearing headwater lake in the Clary Creek watershed. As a result, potential direct effects of the Project on BMI could occur in both the Lime Creek and Clary Creek watersheds.

In the Lime Creek watershed, the development of these mine components would result in the destruction BMI habitat and the loss of BMI communities in Patsy Creek and in Patsy Lake. This in turn would result in a reduction in downstream BMI drift in Lime Creek. As a result, the potential exists for an indirect effect to Dolly Varden and coho salmon in lower Lime Creek as both of these fish species are known to feed on BMI drift. These potential indirect effects to Dolly Varden and coho salmon due to the direct effect of the Project on BMI are addressed in Sections 6.7.2 and 6.7.3 respectively.

In the Clary Lake watershed, the development of the TMF would result in the destruction of BMI habitat and the loss of BMI communities in two Lake 901 headwater tributaries: Stream 76800 and ILP 887. These are the two main inlet tributaries to Lake 901. As a result, development of the TMF would result in a reduction in the downstream BMI drift entering Lake 901. Therefore, the potential exists for an indirect effect to rainbow trout in Lake 901 because rainbow trout are known to feed on BMI prey. This potential indirect effect to rainbow trout due to the direct effect of the Project on BMI is addressed in Section 6.7.4.

6.7.5.9.1.2 Potential Indirect Effects on Benthic Macro-Invertebrates

For the purposes of this assessment, indirect effects to BMI were considered to occur from those Project components or activities that had the potential to indirectly affect the health, growth, or survival of BMI through potential direct Project effects to other VCs. The primary VCs through which indirect effects to BMI could occur are potential changes in surface water quality and potential changes in hydrology (i.e., stream flows).

Indirect effects to BMI due to potential changes in surface water quality could results from mine effluent discharge and seepage, changes in groundwater quality or quantity, and changes in air quality (e.g., dust deposition and contaminants from burning of fossil fuels). Indirect effects to BMI due to changes in hydrology could result from changes in upstream catchment areas, diversion of streams, capture of run-off for use during operations or closure of the mine, and annual release of excess accumulated run-off.

All potential indirect effects on BMI were identified after review of the residual effects sections of the hydrology (Section 6.5), surface water quality (Section 6.6), vegetation (Section 6.10), and air quality (Section 6.2) effects assessments. Table 6.7.5-9 summarises all of the potential indirect effects of the Kitsault Project, before mitigation, on BMI during all phases of the Project.

Table 6.7.5-9: Potential Indirect Project Effects on Benthic Macro-Invertebrates

Project Component	Project Phase	Potential Indirect Effect	Likelihood of Occurrence
Land clearing, top-soil stripping, and grading of land for mine infrastructure installations, ore stockpiles, and waste rock management facilities (WRMFs)	C	Potential increase in suspended sediments in watercourses adjacent to these activities including Patsy Creek, and Lake 901 headwater tributaries resulting in change in abundance and composition of BMI community	Likely
Soil and till salvage, handling and storage, including locations, volumes and impacted areas	C, O	Potential increase in suspended sediments in watercourses adjacent to these activities Patsy Creek and Lake 901 headwater tributaries resulting in change in abundance and composition of BMI community	Likely
Emissions and dust generation (fugitive emissions, equipment operation and movement)	C,O, D/C, PC	Potential increase in suspended sediments in watercourses adjacent to these activities including Patsy Creek and Lake 901 headwater tributaries resulting in change in abundance and composition of BMI community	Unlikely
Mine infrastructure installations including processing plant, camp, equipment washing facility, and primary crusher, conveyor systems, and pipelines	C	Potential increase in suspended sediments in Patsy Creek resulting in decreases in change in abundance and composition of BMI community	Unlikely
Pre-stripping of Kitsault Pit	C	Potential increase in suspended sediments in Patsy Creek resulting in decreases in change in abundance and composition of BMI community	Likely
Water management including dewatering, diversions, and downstream discharges	C, O, D/C	Potential change in water quality and stream flow in Patsy Creek and Lime Creek and in Lake 901 headwater tributaries resulting in decreases change in abundance and composition of BMI community	Likely
Waste-water and sewage management	C, O, D/C	Potential change in water quality of Patsy Creek and Lime Creek resulting in change in abundance and composition of BMI community	Likely
TMF seepage management and reclamation	O, D/C, PC	Potential change in water quality of Patsy Creek, Lime Creek and Lake 901 headwater tributaries resulting in change in abundance and composition of BMI community	Likely
Ore stockpiles development and reclamation	O, D/C	Potential change in water quality of Patsy Creek and Lime Creek resulting in change in abundance and composition of BMI community	Likely

Project Component	Project Phase	Potential Indirect Effect	Likelihood of Occurrence
Surface water management and diversion systems	O, D/C, PC	Potential change in water quality and stream flow in Patsy Creek and Lime Creek and in Lake 901 headwater tributaries resulting in change in abundance and composition of BMI community	Likely
Groundwater management	O, D/C, PC	Potential change in water quality, and stream flow in Patsy Creek and Lime Creek resulting in change in abundance and composition of BMI community	Likely
Pit dewatering	O	Potential change in water quality, and stream flow in Patsy Creek and Lime Creek resulting in decrease in change in abundance and composition of BMI community	Likely
Storm-water run-off measures	O	Potential change in water quality, and stream flow in Patsy Creek and Lime Creek resulting in change in abundance and composition of BMI community	Likely
TMF surplus and contact water discharge (including blasting residues)	O, D/C, PC	Potential change in water quality and water temperature of Lime Creek resulting in change in abundance and composition of BMI community	Likely
Metal Leaching and Acid Rock Drainage (ML/ARD) management	D/C, PC	Potential change in water quality and water temperature of Lime Creek resulting in change in abundance and composition of BMI community	Likely
Decommissioning and removal of all processing facilities, infrastructure, and ancillary facilities	D/C	Potential increase in suspended sediments in Lime Creek resulting in change in abundance and composition of BMI community	Likely
Kitsault Pit reclamation including Kitsault Pit re-filling and over-flow	D/C, PC	Potential change in water quality, water temperature and stream flow of Lime Creek resulting in change in abundance and composition of BMI community	Likely
Surface water and groundwater management	D/C, PC	Potential change in water quality, and stream flow of Lime Creek and Lake 901 headwater tributaries resulting in change in abundance and composition of BMI community	Likely

Note: C - construction; D/C - decommissioning and closure; O - operations; TMF - Tailing Management Facilities; PC - post-closure; WRMF - waste rock management facilities

The only mine activities during construction, operation, closure/decommissioning phases unlikely to result in indirect, adverse effects on BMI in the Lime Creek Watershed and in the Clary Creek watershed (i.e., Lake 901 and its headwater tributaries) were: 1) emission and dust generation during all Project phases; and 2) installation of mine infrastructure during the construction phase. These two mine activities were not carried forward in this assessment.

Emissions and dust generation was not carried forward in the assessment because, even unmitigated, the amount of dust generated from mine haul roads and blasting and the amount of air-borne emissions entering the stream and lakes was considered to be low enough to have a negligible effect on BMI communities in adjacent lakes and streams.

Installation of the mine infrastructure itself was considered unlikely to adversely affect BMI in Lime Creek Watershed because this activity would only involve the placement of mine infrastructure on the pre-prepared land surfaces and would not be a source itself of potential sediment to surrounding streams or lakes. Activities involving the physical disruption of land in the Patsy Creek watershed and in the headwaters of the Lake 901 required for placement of mine infrastructure and preparation for construction of the TMF embankments could result in such increases in sediment and, for this reason, this activity is carried forward in the assessment.

All other mine components and activities during construction, operations, closure / decommissioning phases of the Project were carried forward in this assessment. This was because, unmitigated, all of these other mine components and activities had the potential to indirectly affect BMI through:

- Direct changes to surface water quality in Patsy or Lime creeks in the Lime Creek Watershed and in Lake 901 headwater tributaries, Lake 901, and Clary Creek in the Clary Creek watershed;
- Direct changes to water temperatures in Patsy or Lime Creeks; and
- Direct changes to stream flow in Patsy or Lime creeks in the Lime Creek watershed and in Lake 901 headwater tributaries or in Clary Creek in the Clary Creek watershed.

Although these components and activities were carried forward into the effects assessment, this does not imply that these mine components or activities would necessarily cause an adverse effect to BMI. It only implies that, without mitigation, these mine component and activities have the potential to adversely affect BMI. The likely effectiveness of the various mitigation measures available to minimise or eliminate these potential effects on BMI were assessed in Section 6.7.6.9.2. The significance of any residual effects to BMI were assessed in Section 6.7.6.10.

6.7.5.9.1.3 Potential Combined Effects

Potential combined effects to BMI were considered those potential direct and indirect effects that would occur simultaneously or through time in the same waterbody or stream to potentially change the growth, survival, health, and / or recruitment of BMI in Patsy Creek and Lime Creek in the Lime Creek watershed and in Lake 901 and Clary Creek in the Clary

Creek watershed. Table 6.7.5-10 summarises the potential combined effects on BMI due to the Kitsault Project.

Table 6.7.5-10: Potential Combined Project Effects by Project Phase on Benthic Macro-Invertebrates

Potential Project Effect	Potential Combined Project Effect	Project Phase	Likelihood of Occurrence
Loss of habitat in Patsy Creek and Patsy Lake	Change in abundance and composition in BMI community of Lime Creek due combined effect of habitat loss and changes in water quality, stream flows, and water temperature	C, O, D/C, PC	Likely
Change in surface water quality, stream flows, and water temperature in Patsy Creek and Lime Creek	Change in abundance and composition of BMI community of Lime Creek due to combined effect of habitat loss and changes in water quality, stream flows, and water temperature	C, O, D/C, PC	Likely
Loss of habitat in Lake 901 headwater tributaries	Change in BMI drift entering Lake 901 due to combined effect of habitat loss and changes in water quality and stream flows	C, O, D/C, PC	Likely
Change in surface water quality and stream flow in Lake 901 headwater tributaries	Change in BMI drift entering Lake 901 and change in BMI community in Lake 901 due to combined effect of habitat loss and changes in water quality and stream flows	C, O, D/C, PC	Likely

Note: C - construction; D/C - decommissioning and closure; O - operations; PC - post-closure

Loss of habitat and changes in surface water quality, stream flow, and water temperature in Patsy Creek and Lime Creek could occur simultaneously as the mine water management plan was enacted and as mine infrastructure in the Patsy Creek watershed was built and operated. Any change in the benthic macro-invertebrate community would be expected to occur soon (i.e., within weeks and months) after these physical and chemical changes occurred. Benthic macro-invertebrates are better indicators of stressors in the aquatic environment than fish and, therefore, any effects on benthic macro-invertebrate due to changes in water quality, stream flows, and water temperatures would be readily evident as precursor to potential impacts of any local fisheries population. Such changes could result in indirect effects to Dolly Varden and coho salmon in lower Lime Creek.

Similarly, habitat loss and changes in surface water quality and stream flows in headwater tributaries of Lake 901 due to construction of the TMF, its northeast embankment and tailings beach, and the water management ponds downstream could result in the reduction of BMI drifting downstream to Lake 901 and to the change in BMI community in Lake 901 itself. Combined, these two effects could result in a change in the BMI community in Clary Creek downstream of Lake 901 and could result in a change in the BMI drifting downstream to Clary Creek and Clary Lake from Lake 901. Again, such changes could result in indirect effects to rainbow trout in Lake 901 and in Clary Creek downstream.

6.7.5.9.1.4 Potential Indirect Effects on Other Valued Components

Potential direct, indirect, or combined effects on BMI have the potential to indirectly affect other Valued Components (Table 6.7.5-10). These include potential indirect effects on other Freshwater Aquatic Resource VCs (e.g., Dolly Varden and Coho salmon in the Lime Creek watershed and rainbow trout in the Clary Creek watershed) that utilise BMI as a portion of their diet, as well as piscivorous wildlife that also eat BMI (e.g., shore birds, frogs and toads, or small mammals that forage on the edges of watercourses),. The potential indirect effects identified in Table 6.7.5-9 represent those that could occur without considering the likely effectiveness of mitigation measures to reduce or eliminate the effect on BMI.

There is no potential interaction between potential changes in BMI growth, survival, abundance, or composition with any other biophysical VC other than those identified and rationalised in Table 6.7.5-11. All other biophysical VCs (e.g., air quality, hydrogeology, soil and vegetation) have the potential to interact indirectly with BMI through changes in surface water quality and hydrology but the reverse linkage from BMI to these other VCs is not valid (e.g., changes in BMI health, growth, and survival cannot affect air quality) (Table 6.7.5-12).

Table 6.7.5-11: Potential Indirect Project Effects on Other Valued Components

Direct Project, Indirect, or Combined Effect (adverse or positive)	Project Phase	Potential Indirect Project Effect	Carried Forward (yes/no)	Rationale
Potential change in abundance and composition of BMI community in Patsy and Lime creeks due to loss of habitat and to changes in water quality, stream flows, and water temperatures in the Lime Creek watershed	Construction, operations, decommissioning, post-closure	Change in growth, survival, and recruitment of Dolly Varden and coho salmon in lower Lime Creek	Yes	Reduced abundance and change in composition of BMI community in the Lime Creek watershed may indirectly reduce the health, growth, survival and abundance of Dolly Varden and coho salmon that utilise BMI for all or part of their dietary needs.
Potential change in abundance and composition of BMI community Lake 901 headwater tributaries due to loss of habitat and to changes in water quality, stream flows in the Clary Creek watershed	Construction, operations, decommissioning, post-closure	Change in growth, survival, and recruitment of rainbow trout in Lake 901 and in the Clary Creek watershed	Yes	Reduced abundance and change in composition of BMI community in the Lake 901 headwater tributaries may indirectly reduce the health, growth, survival and abundance of rainbow trout that utilise BMI for all or part of their dietary needs.
Potential change in abundance and composition of BMI community in Patsy and Lime creeks due to loss of habitat and to changes in water quality, stream flows, and water temperatures in the Lime Creek watershed	Construction, operations, decommissioning, post-closure	Change in growth and survival of wildlife (e.g., shorebirds, frogs and toads) that feed on BMI in Patsy Lake, Patsy Creek, or Lime Creek or on the fish that eat BMI (e.g., otters, mergansers).	Yes	Reduced abundance and change in composition of BMI community in the Lime Creek watershed may indirectly reduce the health, growth, survival and abundance of wildlife that eat BMI in streams or lakes or the fish that eat BMI.
Potential change in abundance and composition of BMI community Lake 901 headwater tributaries due to loss of habitat and to changes in water quality,	Construction, operations, decommissioning, post-closure	Change in growth, survival, and recruitment of wildlife (e.g., shorebirds, frogs and toads) that feed on BMI in Lake 901 or in Clary Creek or on the fish	Yes	Reduced abundance and change in composition of BMI community in the Lake 901 headwater tributaries may indirectly reduce the health, growth, survival and abundance of wildlife that

Direct Project, Indirect, or Combined Effect (adverse or positive)	Project Phase	Potential Indirect Project Effect	Carried Forward (yes/no)	Rationale
stream flows in the Clary Creek watershed		that eat BMI (e.g., otters and mergansers).		eat BMI or the fish that eat BMI.

Table 6.7.5-12: Summary of Potential Interaction Between Project Effects on Benthic Macro-Invertebrates and Other Valued Components

Direct, Indirect, or Combined Project Effect on BMI	Air Quality and Climate Change	Noise and Vibration	Hydrogeology	Groundwater Quality	Freshwater and Sediment Quality	Surface Hydrology	Freshwater Aquatic Resource	Marine Water Quality	Marine Biota	Terrestrial Environment	Wildlife and Their Habitat	Environmental Health	Economic	Social	Heritage	Human Health	Nisga'a Nation Land Use	Aboriginal Groups Land Use
Potential change in abundance and composition of BMI in Patsy Creek, Patsy Lake, and Lime Creek	NI	NI	NI	NI	NI	NI	-	NI	o	NI	-	o	NI	NI	NI	NI	NI	NI
Potential change in abundance and composition of BMI in Lake 901 headwater tributaries and in Clary Creek	NI	NI	NI	NI	NI	NI	-	NI	NI	NI	-	o	NI	NI	NI	NI	NI	NI

Note: Interaction definitions: o - interaction; - - key interaction; + - benefit; NI - no interaction
n/a not applicable; VC - Valued Component

6.7.5.9.1.5 Potential Project Effects Carried Forward in the Assessment

A summary of the potential Project effects on BMI that were carried forward into the assessment is presented in Table 6.7.5-13. These include:

- Potential direct effect on BMI abundance and composition in the Lime and Clary Creek watersheds due to habitat loss;
- Potential indirect effect on BMI abundance and composition in the Lime and Clary Creek watersheds due to changes in surface water quality;
- Potential indirect effect on BMI abundance and composition in the Lime and Clary Creek watersheds due to changes in stream flow;
- Potential indirect effect on BMI abundance and composition in the Lime Creek watershed due to changes in water temperature; and
- Potential indirect effect on BMI abundance and composition in the Clary Creek watershed due to changes in lake levels.

Effects on BMI in the Lime Creek watershed due to potential changes in surface water quality were assessed based on results from a surface water quality model that predicted metal, ion, cation, and nutrient concentrations in Patsy Creek, Lime Creek downstream of the confluence of Lime Creek and Patsy creeks, and in lower Lime Creek downstream of the waterfalls. Results from this same model at Lake 901 and Clary Lake were used to assess effects on BMI in the Clary Creek watershed.

Effects on BMI due to potential changes in stream flows were assessed based on results of a watershed model that predicted annual, monthly, peak instantaneous, and 7-day low flows at these same locations in the Lime Creek watershed and in the Lake 901 inlet and outlet, in Clary Creek downstream of the Lake 901 confluence with Clary Creek, and in the Clary Lake outlet.

Both the water quality and watershed models incorporated all of the various mine activities and components that could potentially affect surface water quality and stream flows in the Lime Creek and Clary Creek watersheds during each phase of the Project. They also included all of the mitigation measures that would be used to reduce or eliminate these potential effects (i.e., diversion of water from Lake 493 to Lake 901). Thus, the assessment of potential changes in surface water quality and stream flow on BMI were based on the likelihood that predicted changes in water quality parameters and predicted changes in stream flow and lake levels would adversely affect BMI at specific points in time during the development of the Kitsault Project. Because neither model explicitly linked any single mine component or activity to a predicted change in water quality or stream flow during any phase of the Project (e.g., increase in watershed area and re-filling of the Kitsault Pit during closure), neither could the explicit direct or indirect effects of any single mine component or activity be linked to BMI. This reality did not limit the credibility or accuracy of the assessment on BMI but it did limit the ability of the assessment to explicitly identify which mine component or activity was most likely to the cause the predicted change in water quality or stream flow, and hence effect on BMI.

Table 6.7.5-13: Summary of Potential Project Effects to be Carried Forward Into the Assessment for Benthic Macro-Invertebrates

Adverse Effects / Positive Effects	Project Phase	Direction
Potential change in abundance and composition of BMI community in Lime Creek and Clary Creek watersheds due to alteration or loss of habitat	C, O, D/C, PC	Negative
Potential change in abundance and composition of BMI community in Lime Creek and Clary Creek watersheds due changes in surface water quality	C, O, D/C, PC	Negative
Potential change in abundance and composition of BMI community in the Lime Creek watershed due to changes in water temperature	C, O, D/C, PC	Negative
Potential change in abundance and composition of BMI community in Lime Creek and Clary Creek watersheds due changes in stream flows	C, O, D/C, PC	Negative
Potential change in abundance and composition of BMI community in Clary Creek watershed due to changes in lake levels	C, O, D/C, PC	Negative

Note: C - construction; D/C - decommissioning and closure; O - operations; PC - post-closure

6.7.5.9.2 Mitigation Measures

Mitigation measures to reduce or eliminate each of the potential direct, indirect, and combined effects of the Project on BMI in the Lime Creek and Clary Creek watersheds are presented in Table 6.7.5-14 and are described in greater detail in the sections below. Where mitigation measures were specific to a potential effect to BMI (e.g., change in water quality due to potential change in suspended sediments due to land clearing) or where unique to either the Lime Creek or Clary Creek watershed, these mitigation measures have been identified separately. These measures include those already included in the Project design plus additional mitigation measures that the proponent would commit to implementing should the Project be approved and permitted.

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Table 6.7.5-14: Potential Project Effects by Project Phase on Benthic Macro-Invertebrates and Mitigation Measures

Project Effect	Project phase	Mitigation / Enhancement Measure	Mitigation Success Rating
Potential change in abundance and composition of BMI community in Lime Creek and Clary Creek watersheds due to alteration or loss of habitat	C, O, D/C, PC	Minimise Project footprint and located major project components in headwaters of Lime and Clary Creek watersheds	Low prevention/reduction
		Implementation of a Fish habitat mitigation and compensation plan that meets DFO's no-net-loss policy and provincial and NLG fisheries management objectives	Medium prevention/reduction
Potential change in abundance and composition of BMI community in Lime Creek and Clary Creek watersheds due changes in surface water quality from land clearing for mine infrastructure installations, ore stockpiles, and waste rock management facilities	C	Implement erosion control measures such as diversion ditches, run-off collection ditches, sediment collection ponds around all areas to be disturbed prior to construction and before any earthworks proceed	High prevention / reduction
		Implement "Best Management Practices" during preparation of land	Medium prevention/reduction
		Sediment collection pond built downstream of Patsy Waste Rock Dump prior to its movement from its current position for use as construction materials for the South Embankment of the TMF	High prevention / reduction
		Seepage control ponds built in the two Lake 901 inlet tributaries prior to construction of the northeast embankment of the TMF	High prevention/reduction
Potential change in abundance and composition of BMI community due to increase in suspended solids in Lime Creek due soil and till salvage, handling and storage	C,O	Implement erosion control measures such as diversion ditches, run-off collection ditches, sediment control ponds around soil and till salvage and storage areas prior to construction and before any earthworks proceed	High prevention/reduction
Potential change in abundance and composition of BMI community in Lime Creek due to increase in suspended solids and blasting residues and change in stream flows in Lime Creek due pre-stripping of Kitsault Pit	C	Sediment control pond built within the Kitsault Pit footprint, down-gradient of the pre-stripping area	Medium prevention / reduction
		Pumping of water in sediment control pond to Patsy Creek (if it meets WQOs) or to the TMF if it is not	Medium prevention / reduction

Project Effect	Project phase	Mitigation / Enhancement Measure	Mitigation Success Rating
Potential change in abundance and composition of BMI community due to change in water quality and stream flows in Lime Creek due to development of the south embankment of the TMF	C,O, D/C	Cofferdams and pumping systems built to store and divert non-contact water from Patsy Creek around south embankment footprint during dewatering	High prevention / reduction
		Construction of a sediment control pond downstream of the south embankment prior to construction (Stage 1A)	High prevention / reduction
		Construction of the South Diversion Channel along the southern part of the Patsy Creek catchment to divert non-contact water to Patsy Creek downstream of embankment construction area.	High prevention / reduction
		Pumping system installed to dewater the embankment footprint in case of large storm event	High prevention / reduction
		Construction of the South Water Management Pond and pumping system downstream of the south embankment prior to construction (Stage 1B and 1C). Water would either be pumped back to the TMF or discharged to Patsy Creek via the Water Box	Medium prevention / reduction
		Construction of Water Box to handle excess water in the TMF prior to discharge to Patsy Creek	Medium prevention / reduction
		Spillway constructed in south embankment to allow TMF surplus water to drain to Kitsault Pit during closure	High prevention/reduction
Potential change in abundance and composition of BMI community in Lime Creek due to change in water quality and stream flow from TMF surplus and contact water discharge (including blasting residues)	C, O, D/C, PC	Surplus water in TMF pumped to Water Box and released to Lime Creek during Years 1 to 13 of operations; dedicated pump system in TMF allows variable pumping rates throughout year to increase dilution capabilities	Medium prevention/reduction
		All contact water in Kitsault Pit collected in sediment control pond and pumped to TMF during Years 1 to 13 of operations	High prevention/reduction
		Surplus water in TMF pumped to Water Box and released to Lime Creek during Years 14 to 16 of operations	Medium prevention/reduction
		South Water Management Pond and pumping system downstream of the south embankment is maintained until monitoring shows that WQOs can be attained.	High prevention/reduction

Project Effect	Project phase	Mitigation / Enhancement Measure	Mitigation Success Rating
		Water treatment plant built to reduce concentrations of metals and nutrients that exceed WQOs	High prevention/reduction
Potential change in abundance and composition of BMI community in Lime Creek due to TMF seepage	C, O, D/C, PC	Tailings beaches developed along embankments to create low permeability zone to minimise seepage	Medium prevention/reduction
		Low permeability core incorporated into the design of the starter dam for the South embankment	Medium prevention/reduction
		South Water Management Pond and pumping system downstream of the south embankment is maintained throughout operations and through closure until monitoring shows that WQO can be attained. South WMP is then decommissioned to allow TMF and East WRMP seepage and run-off to drain to the Kitsault Pit	High prevention/reduction
Potential change in abundance and composition of BMI community in Lime Creek due to change in water quality from ore stockpile development	O, D/C, PC	Low Grade Stockpile (LGS) diversion ditches and sediment control pond collect all contact water; pumps convey excess water to Water Box for release to Lime Creek or is pumped to TMF (Years 1 to 13 of operations)	Medium prevention/reduction
		Run-off from LGS diverted to Open Pit during Years 14 to 16 of operations	High prevention/reduction
		Ore in LGS will be processed and tailings placed in TMF; any waste rock will be placed in East WRMF or Kitsault Pit	High prevention/reduction
Potential change in abundance and composition of BMI community in Lime Creek due to change in water quality and stream flows from Kitsault Pit dewatering	O, D/C	Pumping system conveys contact water to TMF or to holding tank before release to Lime Creek during Years 1 to 13 of operations	Medium prevention/reduction
		Pumping system decommissioned in Year 14 of operations to allow Kitsault Pit to fill with water	High prevention/reduction
		Patsy Creek Diversion Ditch built on upper bench of Kitsault Pit to convey non-contact run-off from South Diversion Ditch around Kitsault Pit to Lime Creek	High prevention/reduction
Potential change in abundance and composition of BMI community in Lime Creek due to change in water quality	C, O, D/C, PC	Groundwater collection and monitoring wells used to determine if additional seepage recovery is necessary	Medium prevention/reduction
		Depressurisation wells installed in open pit to improve stability	Medium

Project Effect	Project phase	Mitigation / Enhancement Measure	Mitigation Success Rating
and stream flows from surface and groundwater management		of pit slopes; water from these wells will be pumped to the TMF or to a holding tank, mixed with other contact water and released to Lime Creek if it meets WQOs (Years 1 to 13 of operations)	prevention/reduction
		Groundwater used to fill Open Pit during Years 14 to 16 of operations	High prevention/reduction
		South Diversion Channel and Patsy Creek Diversion Channel diverts non-contact water to Patsy Creek downstream of the south embankment and Open Pit during construction and operations phases	High prevention/reduction
		Groundwater allowed to accumulate in Kitsault Pit; no groundwater released downstream during closure/decommissioning or post-closure phases	High prevention/reduction
		All contact water, TMF overflow, TMF seepage, groundwater seepage, and ML/ARD drainage diverted to Kitsault Pit	Medium prevention/reduction
		Upper portion of South Diversion Channel decommissioned to allow non-contact water to drain into TMF	High prevention/reduction
		Lower portion of South Diversion Channel maintained for perpetuity to divert run-off around East WRMF to the Kitsault Pit	High prevention/reduction
		Patsy Creek Diversion Channel decommissioned to divert non-contact water to the Kitsault Pit	High prevention/reduction
Potential change in abundance and composition of BMI community in Lime Creek due to change in water quality and stream flows due to Kitsault Pit reclamation, re-filling, and overflow	D/C, PC	No release of pit over-flow during closure/decommissioning phase. All contact water from South Water Management Pond, East WRMF, and LGS stockpile used to fill Pit	High prevention/reduction
		Pit filled only with contact water; all non-contact water from upper Patsy Creek catchment diverted around Kitsault Pit to Patsy Creek downstream of Pit via South Diversion Channel and Patsy Creek Diversion Channel	High prevention/reduction
		South Water Management Pond decommissioned in Year 14 of operations to allow run-off from south embankment and East WRMF to fill Open-pit	Low prevention/reduction

Project Effect	Project phase	Mitigation / Enhancement Measure	Mitigation Success Rating
		Pumping system in Kitsault Pit decommissioned in Year 14 of operations to allow Kitsault Pit to fill with contact water and groundwater	Low prevention/reduction
		Spillway constructed in Kitsault Pit to allow end-pit lake overflow to drain to Patsy Creek	High prevention/reduction
Potential change in abundance and composition of BMI community in Lime Creek due to Metal Leaching and Acid Rock Drainage (ML/ARD)	D/C, PC	All Kitsault Pit contact water allowed to fill Kitsault Pit; no release of pit contact water during closure/decommissioning phase	High prevention/reduction
		Placement of low permeability covers over and re-vegetation of East WRMF	Low prevention/reduction
		Water treatment plant built to reduce concentrations of metals and nutrients that exceed WQOs	High prevention/reduction
Potential change in abundance and composition of BMI community in Lime Creek due to change in surface water quality due to waste-water and sewage treatment	C, O, D/C	Modular sewage treatment plant, sized for 700 persons, would be installed for the construction camp	High prevention / reduction
		Sewage treatment plant effluent discharged to TMF	High prevention / reduction
Potential change in abundance and composition of BMI community in Lime Creek and Lake 901 due to change in water quality due to decommissioning and removal of all processing facilities, infrastructure, and ancillary facilities	D/C	All disturbed surfaces will be re-graded, capped with top-soil, fertilised and re-seeded with native species	High prevention/reduction
		All metal contaminated soils will be collected and disposed of in the Kitsault Pit	Medium prevention/reduction
Potential change in abundance and composition of BMI community due to change in water quality in Lake 901 due to development of the northeast embankment of the TMF	C, O, D/C, PC	Construction of seepage control ponds downstream of the northeast embankment of the TMF and pumping of collected seepage back to the TMF during mine operations	Medium prevention/reduction
		Diversion of water from Lake 493 to Lake 901 via a gravity-fed pipeline	Medium prevention/reduction
		Decommissioning of seepage control ponds and pumps only when site-specific water quality objectives are met	High prevention/reduction
Change in surface water quality of Lake 901 and Clary Lake due to seepage	C, O, D/C, PC	Construction of seepage control ponds downstream of the northeast embankment of the TMF and pumping of collected	Medium

Project Effect	Project phase	Mitigation / Enhancement Measure	Mitigation Success Rating
from the northeast embankment of the TMF		seepage back to the TMF during mine operations	prevention/reduction
		Diversion of water from Lake 493 to Lake 901 via a gravity-fed pipeline	Medium prevention/reduction
		Decommissioning of seepage control ponds and pumps only when water quality objectives are met	High prevention/reduction
Potential change in abundance and composition of BMI community due to change in water levels in Lake 901 and Clary Lake	C, O, D/C, PC	Diversion of water from Lake 493 to Lake 901	High prevention/reduction
		Minimise water-withdrawals from Clary Lake to requirements for potable water, firefighting, reagent mixing, and pump gland water	High prevention/reduction
Potential change in abundance and composition of BMI community in Lake 901 and Clary Creek due to change in stream flows caused by change in upstream catchment areas, diversions, Pit dewatering, and surface and groundwater management	C, O, D/C, PC	Decommissioning of seepage control ponds and pumps at closure	Low prevention/reduction
		Diversion of water from Lake 493 to Lake 901	Medium prevention/reduction
		Restriction of diverted flow volumes to only those necessary to offset flow reductions to Lake 901 due to construction of the northeast embankment of the TMF	Low prevention/reduction
		Implementation of a Fish habitat mitigation and compensation plan that meets DFO's no-net-loss policy and provincial and NLG fisheries management objectives	High prevention/reduction

6.7.5.9.2.1 Alteration or loss of BMI habitat

Construction and operation of the TMF, WRMF, and open pit will result in the permanent loss of Patsy Lake and stream habitat in Patsy Creek in the Lime Creek watershed. Construction and operation of the TMF will also result in the permanent loss of stream habitat in the two headwater tributaries of Lake 901 in the Clary Creek watershed.

While these habitat losses and the subsequent losses of BMI production cannot be eliminated, the potential losses in habitat and BMI production were minimised by minimising the Project footprint and locating all major Project components in the headwaters of the Lime Creek and Clary Creek watersheds. This design resulted in a smaller loss of BMI habitat and likely a smaller loss of BMI production than if the Project was larger, effected more lakes and streams, and was located lower down in the watersheds where stream habitat is larger.

In addition, a fish habitat compensation plan will be developed and implemented to increase the productive capacity of fish habitat, and presumably BMI production, through enhancement and restoration of existing habitat and creation of new habitat. This fish habitat mitigation and compensation plan (FHMCP) is described in greater detail in Appendix 11.2-A. The details and final selection of compensation works has yet to be negotiated with DFO, BC MoE, and Nisga'a Fisheries.

Despite, these mitigation/compensation measures, BMI habitat and BMI production will be lost due to the Kitsault Project. As a result, this potential effect is carried forward to the residual effects assessment in Section 6.7.6.10.1.6.

6.7.5.9.2.2 Potential Change in Surface Water Quality in Lime Creek and Clary Creek watersheds

The primary mitigation measures to eliminate or minimise potential effects of changes water quality on BMI in the Lime Creek and Clary Creek watersheds are: 1) implementation of the mine's Water Management Plan; 2) construction and operation of a water treatment facility during the post-closure phase, if required to meet WQOs in Lime Creek; and 3) construction of a diversion channel or pipeline from Lake 493 to Lake 901 in the Clary Creek watershed. The water management plan is presented in detail in Appendix 6.4-B. Details of the proposed water treatment facility are described in the Surface Water Quality assessment Section 6.6. Details of the proposed diversion options to convey water from Lake 493 to Lake 901 are provided in Appendix 6.7-H.

6.7.5.9.2.2.1 Water Management Plan

The water management plan includes strategies and specific design elements at all stages of the Project to minimise potential changes in surface water quality in the Lime Creek and Clary Creek watersheds. Strategies included in the plan include: 1) and operational water management strategy; 2) a sediment and erosion control strategy; and 3) an environmental protection strategy. Specific design elements included within each of these water management strategies include, but are not limited to:

- South diversion channel/Patsy Creek Diversion channel. This diversion is designed to capture and divert non-contact run-off from the upper Patsy Creek watershed around the East WRMF and the Open Pit during construction, operations, and closure phases of the Project;
- Cofferdams and pumping systems. Cofferdams will be built to capture upstream run-off and prevent it from entering the preparation areas of the south and northeast embankments of the TMF during the construction phase. Pumps will be used to pump accumulated run-off around the construction areas downstream to Lime Creek and downstream to Lake 901; and
- Sediment and erosion control elements including:
    - Diversion ditches to route contact water to the TMF and to route non-contact water around the mine area for release to Lime Creek or to Lake 901;
    - Run-off collection ditches to route sediment-laden, contact water to the TMF or to sediment control ponds;
    - Sediment control and seepage collection ponds to capture and hold sediment-laden contact water so that suspended sediments can settle out of suspension. Ponds would be located downstream of the south embankment of the TMF and the East WRMF in Patsy Creek (i.e., south water management pond) and downstream of the northeast embankment of the TMF in the two headwater tributaries of Lake 901 and would collect surface run-off and seepage that would then be pumped back to the TMF;
    - Utilisation of “Best Management Practices” (BMPs) including surface roughening, temporary seeding, sediment traps and sediment basins, and mulching. Surface Water Quality Model Results.

6.7.5.9.2.2.2 Water Treatment Plant

A water treatment plant would be built and operated during post-closure if water quality monitoring in Lime Creek indicated that acid rock drainage had begun in the East WRMF and water quality objectives could not be met. Such a requirement was not anticipated until at least 50 years after the end of mining. If acidic conditions did develop, water treatment of the flow discharging from the toe of the waste rock dump would be implemented.

The water requiring treatment includes the runoff and seepage from the WRMF at the location of the South Water Management Pond (SWMP).

The treatment methods for this volume of water with the water quality parameters predicted by the water quality model all involve lime addition to neutralise acidity and precipitate metals. The primary variants are simple lime addition, and lime addition with high density sludge (HDS) production. Simple lime addition systems are easier to operate but produce much larger volumes of sludge than HDS systems. Given the amount of sludge that is expected to be produced over the long term, the slight additional complexity of an HDS circuit is acceptable. HDS is therefore the preferred system.

The plant would likely operate 365 days per year and would employ four full-time operators. Major equipment would include: insulated steel building; a 32 metre (m) clarifier; two 7.5 m reactor tanks; conditioning tanks; lime silo and shaker; programmable logic controller and motor control center; plant utility circuit; polymer system; plant laboratory; control room; office and dry. A reservoir would be built to equalise the water flowing from the SWMP. Excess thickened sludge would be either pumped to the pit lake or the reclaimed tailings beach area of the TMF.

6.7.5.9.2.2.3 Diversion channel/pipeline from Lake 493 to Lake 901

Once the northeast embankment of the TMF and the two sediment control ponds are built and operating in the two headwater tributaries of Lake 901 downstream of the TMF (i.e., Stream 76800 and ILP 887), over 80% of the inflow to Lake 901 would be lost. Loss of these inflows have the potential to: 1) decrease lake levels in Lake 901; 2) decrease stream flows in the Lake 901 outlet.

To mitigate these potential effects, a diversion would be built to convey water between Lake 493 and Lake 901. Details of this pipeline are presented in Knight Piésold (2011, Appendix 6.7-H). This pipeline would be sized and operated to provide inflows to Lake 901 equal to those lost in Stream 76800 and ILP 887 due to construction of the TMF. Equally important, the outlet of this pipeline would be located such that water from Lake 493 entered Lake 901 as far from the Lake 901 outlet, and as close to the source of TMF seepage, as possible. By doing so, the probability of complete mixing and dilution of any seepage entering the lake would be maximised.

6.7.5.9.2.2.4 Water quality model results

The likely effectiveness of the mitigation measures listed above to eliminate or reduce potential changes to surface water quality, and hence to reduce potential effects to BMI in Lime Creek and Clary Creek Watersheds, was determined by comparing surface water quality concentrations in Lime Creek and in Lake 901 and Clary Lake, predicted from a mass balance mixing model, to provincial and federal water quality guidelines for the protection of aquatic life. Details of the mass balance mixing model are provided in Appendix 6.6-B of the Surface Water Quality assessment. In brief, this model incorporated, at all phases of the Project:

- Baseline surface water quality and groundwater quality source terms;

- All predicted contaminant loading concentrations from all potential sources (e.g., Waste Rock Facilities, ore stockpiles, TMF, exposed Kitsault Pit surface) (SRK 2011);
- All elements of the site water balance (Knight Piesold 20XX, Appendix 6.4-A);
- All potential changes to natural catchment areas and stream discharges; and
- All water management plan mitigation measures list above.

The model output included water quality predictions at four locations in the Lime Creek watershed: 1) within the TMF; 2) at the Patsy Creek discharge point; 3) in Lime Creek immediately downstream of the Patsy Creek confluence; and 4) in lower Lime Creek downstream of the impassable waterfall. In the Clary Creek watershed, the model output included water quality predictions in Lake 901 and in Clary Lake.

Guidelines and standards for comparison with the model output at the Lime Creek and Clary Creek Watersheds nodes were as follows:

- BC MOE water quality guidelines (approved) for the protection of Fresh Water Aquatic Life (BC MOE 2006a, 2006b) including:
- The Maximum Acceptable limits (Max); and
- The 30 Day Average limits (30 Day Average);
- BC MOE ambient aquatic life guideline for iron (BC MOE 2008);
- BC MOE Water Quality Guidelines for Nitrogen (Nitrate, Nitrite, Ammonia) (BC MOE 2009); and
- CCME (2007) guideline for the protection of aquatic life (freshwater).

Table 6.7.5-15 summarises these provincial and federal guidelines. Where specific guidelines are dependent on other water quality parameters (e.g., hardness, pH, temperature), guideline values for lower Lime Creek and for Lake 901 and Clary Lake were calculated using equations provided in the relevant guideline and baseline water quality parameters documented during baseline water quality sampling conducted in 2009 and 2010.

Table 6.7.5-15: Summary of Provincial and Federal Water Quality Guidelines for the Protection of Freshwater Aquatic Life in lower Lime Creek Watershed

Parameter	BC Water Quality Guideline		Canadian Environmental Quality Guideline (mg/L)
	30 day average (mg/L)	Maximum (mg/L)	
Chloride (dissolved)	150	600	
Fluoride (dissolved)		0.3[a]	
Sulphate (dissolved)		100	
Nitrate (as N)		31.3	13.0
Ammonia (total)		1.8 to 2.05[b,c]	6.98 to 23.1 [b,c]

Parameter	BC Water Quality Guideline		Canadian Environmental Quality Guideline (mg/L)
	30 day average (mg/L)	Maximum (mg/L)	
Aluminun (dissolved)	0.05[b]	0.1[b]	0.1[b]
Antimony (dissolved)		0.02	0.005
Arsenic (dissolved)		0.005	0.005
Barium (dissolved)		5.0	
Beryllium (dissolved)		0.0053	
Boron (dissolved)		1.2	
Cadmium (dissolved)		0.000023[d]	0.000023[d]
Chromium III (dissolved)		0.0089	0.0089
Chromium IV (dissolved)		0.001	0.001
Cobalt (dissolved)	0.004	0.11	
Copper (dissolved)	0.002/0.005/0.002/0.004[e,f]	0.008/0.014/0.073/0.12[e,f]	0.002/0.003/0.002/0.003[e,f]
Iron (dissolved)		0.35	0.3
Lead (dissolved)	0.005/0.008/0.005/0.007[e,f]	0.042/0.112/0.039/0.087[e,f]	0.002/0.004/0.002/0.003[e,f]
Mercury (dissolved)	0.00002		0.000026
Molybdenum (dissolved)	1.0	2.0	0.073
Nickel (dissolved)		0.065[d]	0.065[d]
Selenium (dissolved)	0.002		0.001
Silver (dissolved)	0.00005[d]	0.001[d]	0.0001
Thallium (dissolved)		0.0003	0.0008
Uranium (dissolved)		0.3	0.015
Vanadium (dissolved)		0.006	
Zinc (dissolved)	0.008/0.036/0.008/0.019[e,f]	0.033/0.062/0.033/0.044[e,f]	0.03

Note: [a] assumed hardness of > 50 mg/L $CaCO_3$; [b] assumed pH = 7; [c] assumed mid-winter and mid-summer temperatures of 1°C and 12°C, respectively; [d] assumed hardness of 65 mg/L $CaCO_3$; [e] assumed mean hardness during construction, operations, closure, and post-closure of 59, 128, 56, and 105 mg/L $CaCO_3$, respectively; f guideline reported in construction, operations, closure, and post-closure phases, respectively based on average hardness values for each phase

Tables 6.7.5-16 and 6.7.6-17 summarise the water quality parameters that exceed provincial and / or federal water quality guideline for the protection of freshwater aquatic biota for each phase of the Project in lower Lime Creek and in Lake 901, respectively. Summaries of water quality parameter exceedences during each Project phase in Lime Creek, Lake 901, and Clary Lake are provided in the sections below.

Predicted surface water quality exceedences of provincial and federal guidelines during all phases of the Project in both the Lime Creek watershed and in the Clary Creek watershed indicated that the mitigation measures proposed above are insufficient to eliminate all potential effects to BMI due to changes in water quality in Lime Creek and in Lake 901. Because the water quality model factored all loading sources, changes in watershed areas and diversions together, it did not allow the effectiveness of individual mitigation measures to be assessed separately. Regardless, the cumulative change in water quality in Lime Creek and in both lakes and its potential effects on BMI during all phases of the Project were carried forward to the residual effects assessment section below.

Table 6.7.5-16: Summary of Predicted Exceedances of Provincial and Federal Water Quality Guidelines for the Protection of Freshwater Aquatic Life in Lower Lime Creek

Parameter	Construction			Operations			Closure			Post-closure		
	BC WQG 30 day average (mg/L)	BC WQG Maximum (mg/L)	Canadian Environmental Quality Guideline (mg/L)	BC WQG 30 day average (mg/L)	BC WQG Maximum (mg/L)	Canadian Environmental Quality Guideline (mg/L)	BC WQG 30 day average (mg/L)	BC WQG Maximum (mg/L)	Canadian Environmental Quality Guideline (mg/L)	BC WQG 30 day average (mg/L)	BC WQG Maximum (mg/L)	Canadian Environmental Quality Guideline (mg/L)
Fluoride					●			●			●	
Sulphate					●						●	
Aluminum	●			●	●	●	●			●	●	●
Cadmium		●	●		●	●		●	●		●	●
Chromium VI		●	●		●	●		●	●		●	●
Copper				●	●	●				●	●	●
Mercury				●		●				●		●
Molybdenum			●			●			●			●
Selenium						●						●
Zinc	●						●			●		

Note: BC WQG - British Columbia Water Quality Guideline

Table 6.7.5-17: Summary of Predicted Exceedances of Provincial and Federal Water Quality Guidelines for the Protection of Freshwater Aquatic Life in Lake 901 in the Clary Creek watershed

Parameter	Construction			Operations			Closure			Post-closure		
	BC WQG 30 day average (mg/L)	BC WQG Maximum (mg/L)	Canadian Environmental Quality Guideline (mg/L)	BC WQG 30 day average (mg/L)	BC WQG Maximum (mg/L)	Canadian Environmental Quality Guideline (mg/L)	BC WQG 30 day average (mg/L)	BC WQG Maximum (mg/L)	Canadian Environmental Quality Guideline (mg/L)	BC WQG 30 day average (mg/L)	BC WQG Maximum (mg/L)	Canadian Environmental Quality Guideline (mg/L)
Fluoride					■			■			■	
Sulphate								■			■	
Phosphorus									■			■
Aluminum	■	■	■		■	■		■	■		■	■
Arsenic								■	■		■	■
Cadmium					■	■		■	■		■	■
Chromium VI		■	■					■	■		■	■
Copper							■		■	■		■
Iron		■	■									
Lead							■		■	■		■
Mercury							■			■		■
Molybdenum						■			■			■
Selenium						■	■		■	■		■
Zinc				■			■	■	■	■	■	■

Note: BC WQG - British Columbia Water Quality Guideline

6.7.5.9.2.2.4.1 Lime Creek

Water quality predictions in Lime Creek during the construction phase were driven by the seepage through the construction material for the South Embankment (historic Patsy Waste Rock Dump) and runoff within the Open Pit catchment. During the construction phase, predicted water quality results for Lime Creek showed exceedences of guidelines for:

- Aluminum (BC MOE 30-day average only);
- Cadmium (BC MOE maximum and 95th percentile exceedence of CCME guidelines);
- Chromium VI (BC MOE maximum and CCME guidelines);
- Molybdenum (CCME guideline); and
- Zinc (BC MOE 30-day average only).

During operations, water quality predictions were driven by Open Pit dewatering, LGS seepage collection pond water, and surplus TMF water, which is in turn, driven by seepage through the waste rock. All modelled parameters followed an increasing trend through operations Years 1 through 13, with some parameters decreasing in Years 14 through 15, when the SWMP water is directed towards the Open Pit and the Open Pit is no longer being dewatered. During operations, predicted water quality results for Lime Creek showed exceedences of guidelines for:

- Fluoride (BC MOE maximum);
- Sulphate (BC MOE maximum);
- Aluminum (all three guidelines);
- Cadmium (BC MOE maximum and 95th percentile exceedence of CCME guidelines);
- Chromium VI (BC MOE maximum and CCME guidelines);
- Copper (all three guidelines);
- Mercury (BC MOE 30-day average and CCME guidelines);
- Molybdenum (CCME guideline); and
- Selenium (CCME guideline only).

Closure water quality predictions in Lime Creek were driven by TMF water quality. This was because all other mine contact water sources within the Lime Creek were directed towards the Open Pit at this time. Conversely, TMF surplus water is directed to Lime Creek during this phase until the Open Pit is full. During closure, predicted water quality results for Lime Creek showed exceedences of guidelines for:

- Fluoride (BC MOE maximum only);
- Aluminum (BC MOE 30-day average only);

- Cadmium (BC MOE maximum and 95th percentile exceedence of CCME guideline);
- Chromium IV (BC MOE maximum and CCME guideline);
- Molybdenum (CCME guideline); and
- Zinc (BC MOE 30-day average guideline only).

Post-closure water quality in Lime Creek is immediately loaded with water that has been accumulating in the Open Pit during closure. There is an initial peak in concentration of almost every modelled parameter which is directly linked to Open Pit water discharge. There is then a rapid decrease in concentration over the first 13 years of post-closure as the water in the Open Pit reaches a new equilibrium and all parameters appear to completely stabilise by Year 23. During post-closure, predicted water quality results for Lime Creek showed exceedences of guidelines for:

- Fluoride (BC MOE maximum);
- Sulphate (BC MOE maximum);
- Aluminum (all three guidelines);
- Cadmium (BC MOE maximum and 95th percentile exceedence of CCME guidelines);
- Chromium IV (BC MOE maximum and CCME guidelines);
- Copper (all three guidelines);
- Mercury (BC MOE 30-day average and CCME guidelines);
- Selenium (CCME guideline only); and
- Zinc (BC MOE 30-day average only).

Each of these guideline exceedences in Lime Creek are created because there will be an unavoidable release of mine effluent and/or mine contact water during all phases of the Project.

6.7.5.9.2.2.4.2 Lake 901

Water quality predictions in Lake 901 during operations were driven by seepage losses from the NWMP. The NWMP water quality predictions were predominantly driven by seepage through the cyclone sand dam. Model results for Lake 901 showed exceedances for the following parameters during operations:

- Fluoride (BC MOE maximum);
- Aluminum (BC MOE maximum and CCME guidelines);
- Cadmium (95th percentile and maximum predicted concentrations);
- Chromium VI (initial concentrations exceeded BC MOE guidelines);
- Molybdenum (peak concentrations exceed only CCME guideline);

- Selenium (CCME guideline); and
- Zinc (BC MOE 30-day average).

Closure and post-closure model results provide a clear indication as to which parameters are being driven by the seepage through the cyclone sand dam, as there is an immediate increase in concentration of these parameters in Lake 901 when pumps and seepage control ponds are decommissioned during closure. Predicted water quality results for Lake 901 during closure and post-closure phases showed the following exceedences of guidelines:

- Fluoride (BC MOE maximum);
- Sulphate (peak concentrations are 5.2 times higher than guidelines)[16];
- Arsenic (peak concentrations exceed BC MOE maximum and CCME guidelines);
- Cadmium (mean and 95th percentile concentrations exceed BC MOE maximum and CCME guidelines);
- Chromium VI (BC MOE maximum and CCME guidelines)
- Copper (BC MOE 30-day average and CCME guidelines);
- Mercury (BC MOE 30 Day average and CCME guidelines)[17];
- Molybdenum (CCME guideline); and
- Selenium (BC MOE 30 Day average and CCME guidelines).

6.7.5.9.2.2.4.3 Clary Lake

Predicted water quality results in Clary Lake showed fewer guideline exceedences than in Lake 901. This was because Lake 901 would be directly downstream of the northeast embankment of the TMF while Clary Lake is further downstream and would continue to receive the majority of its inflow from unaffected portions of its upstream watershed. Water quality parameters predicted to exceed guidelines in Clary Lake during construction, operations, and/or closure/post-closure phases included:

- Sulphate (BC MOE maximum);
- Fluoride (BC MOE maximum);
- Aluminum (BC MOE maximum and CCME guidelines);
- Cadmium (mean and 95th percentile concentrations exceed BC MOE maximum and CCME guidelines);
- Mercury (BC MOE average and CCME guidelines);

[16] Davies et al. (2004) and Davies (2007) have shown that the BC MOE guideline for sulphate is based on potassium toxicity and not sulphate toxicity. They recommend sulphate guidelines be based on hardness.

[17] The apparent exceedances of mercury are detection limit driven; monitoring during and after mine operation will be required to determine whether any mercury exceedances will in fact occur.

- Molybdenum (CCME guidelines);
- Selenium (BC MOE 30-day average and CCME guidelines); and
- Zinc (BC MOE 30-day average guideline).

Each of the above guideline exceedences in Lake 901 and Clary Lake are created because there will be an unavoidable seepage of TMF supernatant during operations, closure and post-closure phases of the Project. While the northeast seepage control ponds are expected to capture most (approximately 90%) of the TMF seepage during operations, some seepage to Lake 901 is unavoidable due to the topography and geology surrounding the TMF. This seepage will be diluted by the diversion of water from Lake 493, a mitigation measure that will be in place for perpetuity.

6.7.5.9.2.3 Potential Change in Hydrology in Lime Creek and Clary Creek watersheds

6.7.5.9.2.3.1 Lime Creek Watershed

Potential changes in stream flow in Patsy Creek and Lime Creek may occur during all phases of the Kitsault Project. These potential changes would occur primarily due to: 1) changes to the upstream catchment areas; 2) capture of upstream catchment run-off in the TMF for start-up processing requirements and management of mine tailings; 3) diversion of streams; and 4) filling of the Kitsault Pit at closure.

The primary mitigation measures to eliminate or minimise these potential changes in hydrology in Patsy Creek and Lime Creek, and potential effects on BMI communities in both creeks, are:

- Implementing of the mine's Water Management Plan (Appendix 6.4-B);
- Filling the Kitsault Pit over a 15 to 17 year time period during closure instead of filling the pit as quickly as possible (Knight Piesold 2011, Appendix 6.5-C). This mitigation measure minimises the magnitude of flow reductions in Lime Creek by continuing to divert non-contact run-off from the upper Patsy Creek watershed around the TMF, East WRMF, and open pit to Lime Creek Watershed; and
- Re-establishing stream flows in Lime Creek to near baseline conditions during post-closure by allowing all accumulated run-off in the Patsy Creek watershed to again to report to Lime Creek.

The specific mitigation measures included in the water management plan and those listed above are included in Table 6.7.6-14 above across from the potential Project effect they have been designed to mitigate.

The primary mitigation measures included in the mine's water management plan to eliminate or reduce potential changes in stream flows in Lime Creek during the construction phase of the Project are:

- Construction and operation of coffer dams and pumping system to dewater and divert accumulated run-off around the south embankment footprint to Patsy Creek downstream;
- Construction of the South Diversion Channel to divert non-contact water from the upper Patsy Creek catchment around the south embankment footprint; and
- Construction and operation of a Water Box to collect and discharge surplus water in the TMF to Patsy Creek downstream.

The primary mitigation measures to eliminate or reduce potential changes in stream flows in Lime Creek during the operations phase of the Project are:

- Maintenance of the South Diversion Channel to divert non-contact water from the upper Patsy Creek catchment around the south embankment and East WRMF to Patsy Creek downstream;
- Construction and operations of the Patsy Creek Diversion Channel in the upper bench of the Kitsault Pit to convey non-contact run-off from the South Diversion Channel to Patsy Creek downstream; and
- Operation of the Water Box to collect and discharge surplus water in the TMF and run-off from the LGS to Patsy Creek downstream.

The primary mitigation measure to reduce or eliminate changes in hydrology in Lime Creek Watershed during the closure / decommissioning phase is to extend the open pit filling period from a minimum possible filling period of 5 years if all upstream run-off was diverted to the open pit to a maximum possible filling period between 15 and 17 years by maintaining the South Diversion Channel and Patsy Creek Diversion Channel to continue conveying water downstream to Patsy Creek while the pit fills (Knight Piesold 2011). The potential benefits of this mitigation measure to BMI (and other aquatic biota) in Lime Creek are the minimisation of the magnitude of potential flow reductions and the maximisation of Lime Creek's capacity to dilute surplus water from the TMF discharged to Lime Creek via the Water Box. However, this mitigation measure would extend the period of potential flow reductions in lower Lime Creek by 10 to 12 years.

Once the Kitsault Pit has filled with water, all accumulated run-off and groundwater seepage from the reclaimed Patsy Creek watershed upstream of the pit, plus the additional run-off from the small portion of the Clary Creek watershed captured within the TMF footprint, would be conveyed to Lime Creek through a spillway channel in the pit's downstream face. The objective of this post-closure water management plan is to restore the magnitude, duration, frequency, and timing of stream flows in lower Lime Creek, as closely as possible, to pre-mine, baseline conditions.

6.7.5.9.2.3.2 Clary Creek Watershed

Potential changes in stream flows in the Clary Creek watershed would occur during all phases of the Kitsault Project. The magnitude and duration of these potential changes would differ depending on the location in the watershed and the project phase. The sources of these potential changes in stream flow at different locations and Project phases in the Clary Creek watershed include:

- Flow reductions in the two headwater tributaries of Lake 901 (i.e.,Stream 76800 and ILP 887), at the Lake 901 outlet, and in Clary Creek downstream of the Lake 901 and Lake 493 confluence caused by construction and operation of the northeast embankment of the TMF and the two northeast seepage control ponds;

- Flow reductions at the Clary Lake outlet caused by the reduction in run-off from the loss of catchment area in the headwaters of Lake 901 under and upstream of the northeast embankment of the TMF and the northeast seepage management ponds and by the pumping of water directly from Clary Lake for the potable water supply; and

- Flow reductions in the Lake 493 outlet caused by the diversion of water from Lake 493 to Lake 901 through a gravity-fed pipeline used to mitigate flow reductions, lake level changes, and water quality effects in Lake 901 due to loss of inflow from the two main headwater tributaries under and upstream of the northeast embankment of the TMF.

The principle mitigation measure to reduce or eliminate potential changes in stream flows in the Clary Creek watershed is the construction of a pipeline to divert water from Lake 493 to Lake 901. Options include a diversion channel, a buried pipeline and a above ground pipeline.

6.7.5.9.2.3.3 Watershed Modelling Methods

The likely effectiveness of the mitigation measures listed above to eliminate or reduce potential changes to stream flows, and hence to reduce potential effects to BMI in Lime Creek Watershed, was determined by comparing predicted monthly discharges during each phase of the Project to the instream flow guideline threshold as calculated using the BC Instream Flow Guidelines (BCIFG) for Fish (Hatfield et al., 2003). Greater detail on the watershed modelling methods in the Lime Creek and Clary Creek watersheds are provided in the Section 6.7.2 (Dolly Varden) and in Section 6.7.3 (rainbow trout), respectively.

Predicted monthly discharges that exceeded the calculated monthly minimum instream flow threshold were assumed to be protective of BMI in Lime Creek and Clary Creek. Conversely, predicted monthly discharges that fell below the calculated monthly minimum instream flow threshold were assumed to be potentially harmful to BMI and, therefore, were carried forward to the residual effects assessment below (Section 6.7.4).

6.7.5.9.2.3.4 Watershed Modelling Results

6.7.5.9.2.3.4.1 Lime Creek

Although the seasonal distribution of flows were not expected to change from baseline during any phase of the Project, reductions in average monthly discharge were consistently predicted to be greatest during May and June during construction (Phase 2 and 3), operations (Years 13 and 15), and closure phases of the Project (Figure 6.7.5-1). This timing corresponds to the spring freshet in Lime Creek Watershed. On average, monthly May and June flows in lower Lime Creek Watershed were predicted to be approximately 25%, 19%, 26%, and 24% lower during the construction (Phase 2 and 3), operations (Year 13), operations (Year 15), and closure phases, respectively, compared to baseline (Table 6.7.6-22).

Monthly flows during October in lower Lime Creek were predicted to be, on average, 17%, 13%, 21%, and 18% lower than baseline during construction (Phases 2 and 3), operations (Year 13), operations (Year 15), and closure, respectively (Table 6.7.5-18). On average, monthly flows in August were predicted to range between 8% lower during closure to 17% lower during construction (Phase 2 and 3). Monthly flow reductions during the winter low flow period (November to March) were predicted to be greatest during operations (Year 15) and closure phases when the Kitsault Pit is re-filling: 13% to 18% reduction in discharge during operations (Year 15) and 18% to 23% reduction in discharge during closure (Figure 6.7.5-2).

Table 6.7.5-18: Baseline and Predicted Mean, Minimum, and Maximum Monthly and Annual Discharge in Lower Lime Creek During Construction, Operations, Closure, and Post-Closure Phases of the Project

Phase	Flow statistic	Units	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Pre-mine	Average	m^3/s	0.36	0.40	0.74	1.87	4.15	4.18	3.20	2.18	2.17	2.74	1.11	0.49	1.97
	Minimum	m^3/s	0.21	0.18	0.18	0.24	1.28	0.80	0.45	1.11	0.55	0.43	0.33	0.27	0.50
	Maximum	m^3/s	0.75	3.02	2.69	3.8	6.23	7.64	6.47	4.42	5.26	7.90	5.23	1.79	4.60
Construction: Phase 1	Average	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Minimum	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Maximum	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Construction: Phase 2 & 3	Average	%	9%	-19%	-16%	-20%	-25%	-26%	-22%	-17%	-17%	-17%	-9%	2%	-20%
	Minimum	%	-29%	-27%	-29%	-19%	-27%	-19%	-20%	-22%	-22%	-31%	-28%	-28%	-29%
	Maximum	%	-9%	-8%	-10%	-20%	-26%	-18%	-15%	-16%	-15%	-9%	-8%	-13%	-9%
Operations: Year 13	Average	%	-8%	-8%	-9%	-14%	-19%	-18%	-12%	-9%	-11%	-13%	-4%	-5%	-14%
	Minimum	%	-26%	-23%	-9%	-3%	-2%	-6%	-6%	-20%	0%	-28%	-26%	-26%	-21%
	Maximum	%	-7%	-6%	-8%	-8%	-21%	-6%	-6%	0%	-3%	-8%	-7%	-8%	-8%
Operations: Year 15[a]	Average	%	-18%	-18%	-17%	-22%	-26%	-25%	-17%	-13%	-15%	-21%	-13%	-15%	-20%
	Minimum	%	-29%	-27%	-28%	-20%	-9%	-12%	-16%	-22%	-21%	-31%	-28%	-28%	-28%
	Maximum	%	-10%	-16%	-20%	-24%	-28%	-14%	-14%	-6%	-9%	-20%	-17%	-13%	-17%
Closure	Average	%	-18%	-17%	-18%	-21%	-24%	-20%	-13%	-8%	-13%	-18%	-8%	-5%	-17%
	Minimum	%	-28%	-26%	-28%	-19%	-8%	-12%	-15%	-21%	-20%	-30%	-28%	-28%	-32%
	Maximum	%	-9%	-15%	-19%	-11%	-26%	-11%	-11%	-1%	-5%	-19%	-13%	-13%	-14%
Post-closure	Average	%	-8%	-5%	1%	2%	3%	5%	3%	-2%	0%	3%	4%	-4%	2%
	Minimum	%	-9%	-7%	-8%	-5%	0%	-10%	-15%	-8%	4%	-8%	-10%	-10%	-8%
	Maximum	%	-3%	2%	3%	4%	5%	4%	5%	1%	1%	3%	4%	-1%	3%

Note: [a] Kitsault Pit filling scenario A

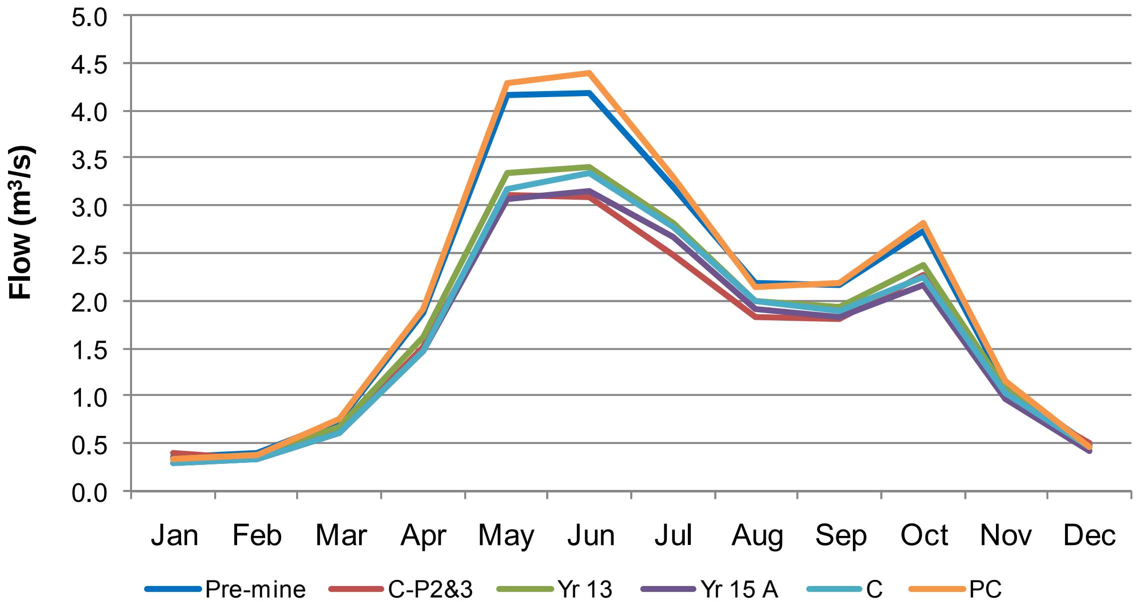

Figure 6.7.5-2: Comparison of Predicted Average Monthly Discharges in Lower Lime Creek During Construction, Operations (Years 13 and 15), Closure, and Post-Closure Phases to Average Pre-Mine Conditions

A comparison of the predicted average monthly flows in lower Lime Creek during each phase[18] of the Project to the calculated monthly instream flow guideline threshold[19] is provided in Figure 6.7.5-3. As can be seen from this graph, predicted monthly discharges in lower Lime Creek Watershed during all phases of the Project were predicted to be below the calculated BC IFG threshold for lower Lime Creek in all months except during May and June.

The largest deviations in discharge from the calculated BC IFG threshold occur in the low flow months of August, December, January, February and March. During these months, the predicted average monthly discharges in lower Lime Creek were predicted to be approximately 0.5 m^3/sec lower than the corresponding BC IFG threshold discharge. These differences are largely an artefact of how the BC IFG threshold is set for low flow months. For lower Lime Creek, the BC IFG threshold was set between the 84th and 90th percentile of median daily flows for each of these months. As a result, predicted mean monthly discharges (i.e., approximately the 50th percentile flows) in lower Lime Creek would always

[18] Average monthly discharges for each Project phase were calculated using the percentage change in monthly flows from baseline predicted by the watershed model. Pre-mine baseline monthly average discharges were calculated from the 20 year daily flow record (1976 to 1996) obtained from the Water Survey of Canada stream gauge (08DB010) in lower Lime Creek Watershed. This was done so that predicted monthly flows could be fairly compared to the BC Instream Flow Guideline threshold; the watershed model only predicts monthly flows but the BC IFG threshold must be calculated from daily flows.

[19] Threshold guideline was calculated from the 20 year daily flow record (1976 to 1996) obtained from the WSC stream gauge (08DB010) in lower Lime Creek Watershed using the methods described in Hatfield et al. (2003)

be below the calculated BC IFG threshold during these low flow months even during pre-mine baseline conditions. Nevertheless, the purpose of the BC IFG threshold is to provide higher protection during low flow months than high flow months (Hatfield et al. 2003).

The fact that the predicted monthly during each phase of the Project were predicted to be below the calculated BC IFG threshold in these months, particularly during the winter low flow months, indicates that the mitigation measures included in the Project's water management plan are insufficient to eliminate the potential indirect effect of predicted changes in hydrology in lower Lime Creek on BMI. As a result, this potential effect is carried forward to the assessment of residual effects (see Section 6.7.5-10).

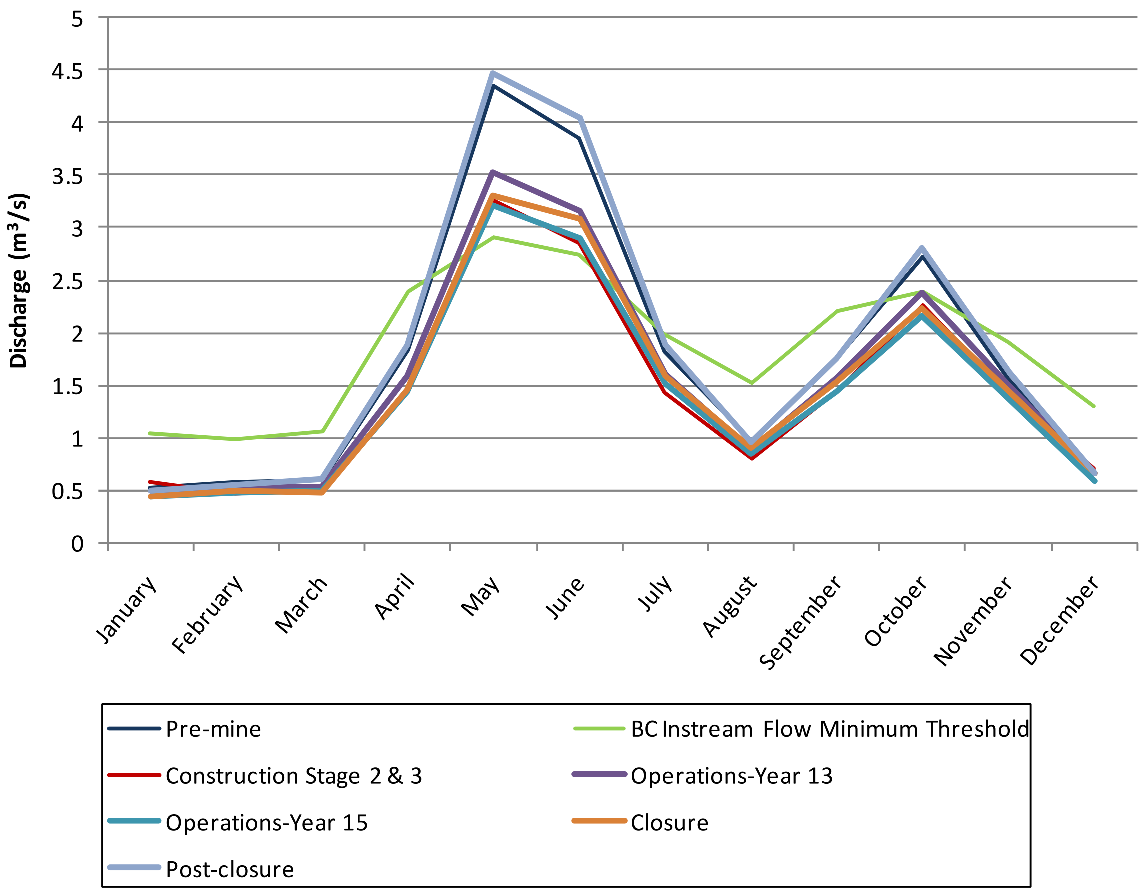

Figure 6.7.5-3: Comparison of Predicted Average Monthly Discharges in Lower Lime Creek During Construction, Operations (Years 13 and 15), Closure, and Post-Closure Phases to Pre-Mine Average Monthly Discharge and the Calculated BC Instream Flow Guideline Threshold

6.7.5.9.2.3.4.2 Clary Creek Watershed

During construction and operations, the loss of run-off in the two headwater tributaries of Lake 901 would result in an approximately 70% reduction in flow in these two inlets downstream of the northeast embankment of the TMF and downstream of the two northeast seepage management ponds (Table 6.7.4-24). More water would be available during closure and post-closure phases when the pumps in the seepage management plans would be decommissioned. However, the loss of run-off from the catchments upstream of the northeast embankment of the TMF would still result in nearly a 50% reduction in flow. Flow reductions of this magnitude are expected to result in changes in channel morphology, instream hydraulics, and substrate composition, and therefore, the quantity and suitability of habitat for rainbow trout and for benthic invertebrate production. While a fish habitat compensation plan would be developed to compensate for this loss of fish habitat, the loss of BMI drift from these two tributaries to Lake 901 is carried forward to the residual effects assessment.

The diversion between Lake 493 and Lake 901 would divert enough water to Lake 901 to offset the loss of inflows from the two Lake 901 inlet tributaries affected by construction of the TMF and northeast seepage control ponds. As a result, no flow reductions would occur at the Lake 901 outlet and no lake level changes would occur in Lake 901 during any mine phase (Table 6.7.5-19). This potential effect was not carried forward in the assessment as a result.

This diversion would not mitigate potential flow reductions in Clary Creek downstream of the Lake 901 confluence (Figure 6.7.5-4) or at the Clary Lake outlet (Figure 6.7.5-5). This is because the diversion would re-distribute water but it would not alleviate the net loss of water entering Clary Creek and Clary Lake downstream of the Lake 493 and Lake 901 confluence because no additional water would be transferred to Clary Creek to offset the net loss of run-off captured in the TMF or removed from Clary Lake by the freshwater supply pumps. As a result, flows in Clary Creek downstream of the Lake 901 confluence was predicted to decrease by 21% during construction and operations and by 14% during closure/post-closure (Table 6.7.4-24). Flows in the Clary Lake outlet were predicted to decrease by 8% during construction and operations and by 4% during closure/post-closure. The potential effects of these predicted flow reductions on BMI were carried forward to the residual effects assessment.

While mitigating potential flow reductions in the Lake 901 outlet, the construction of the diversion would create substantial flow reductions (up to 50% flow reductions in winter and up to 43% flow reductions during the spring spawning period) in the approximately 350 metres of Clary Creek between Lake 493 and the confluence of Clary Creek and the Lake 901 outlet (Table 6.7.5-19). The potential effect of these flow reductions on BMI in this portion of Clary Creek is carried forward in the assessment.

Table 6.7.5-19 Percentage Change in Average Monthly and Average Annual Flows at Different Locations in the Clary Creek Watershed during Construction, Operations, Closure, and Post-Closure Phases

Month	Lake 901 inlets			Lake 901 outlet		Clary Creek[1]			Lake 493 outlet		Clary Lake outlet		
	Construction[2]	Operations[3]	Closure/Post-closure	C[2], O[3]	D/C, PC	Construction[2]	Operations[3]	Closure/Post-closure	C[2], O[3]	D/C, PC	Construction[2]	Operations[3]	Closure/Post-closure
January	-67%	-65%	29%	0%	24%	-21%	-20%	9%	-50%	-50%	-6%	-21%	2%
February	-69%	-65%	40%	0%	39%	-21%	-20%	12%	-33%	-33%	-6%	-24%	3%
March	-79%	-76%	-13%	0%	18%	-23%	-22%	-4%	-50%	-50%	-7%	-17%	-1%
April	-79%	-78%	-51%	0%	1%	-25%	-24%	-16%	-43%	-29%	-8%	-11%	-5%
May	-75%	-75%	-62%	0%	0%	-24%	-24%	-20%	-43%	-37%	-8%	-9%	-6%
June	-71%	-70%	-55%	0%	0%	-22%	-22%	-17%	-37%	-30%	-6%	-7%	-5%
July	-63%	-63%	-41%	0%	0%	-18%	-18%	-12%	-41%	-41%	-5%	-6%	-3%
August	-61%	-60%	-27%	0%	1%	-16%	-15%	-7%	-35%	-35%	-3%	-5%	-2%
September	-66%	-66%	-39%	0%	0%	-18%	--18%	-10%	-30%	-23%	-4%	-6%	-3%
October	-74%	-73%	-54%	0%	0%	-22%	-22%	-16%	-37%	-27%	-7%	-8%	-5%
November	-76%	-76%	-31%	0%	0%	-23%	-23%	-10%	-46%	-47%	-7%	-11%	-3%
December	-69%	-68%	5%	0%	7%	-22%	-22%	2%	-50%	-50%	-6%	-16%	0%
Annual average	-71%	-71%	-46%	0%	1%	-21%	-21%	-14%	-35%	-31%	-6%	-8%	-4%

Note: [1] downstream of the Lake 493 and Lake 901 confluence; [2] Stage 3 of the construction phase; [3] Year 13 and Year 15 of operations.

Project phase: C - construction; O - operations; D/C - decommissioning and closure; PC - post-closure

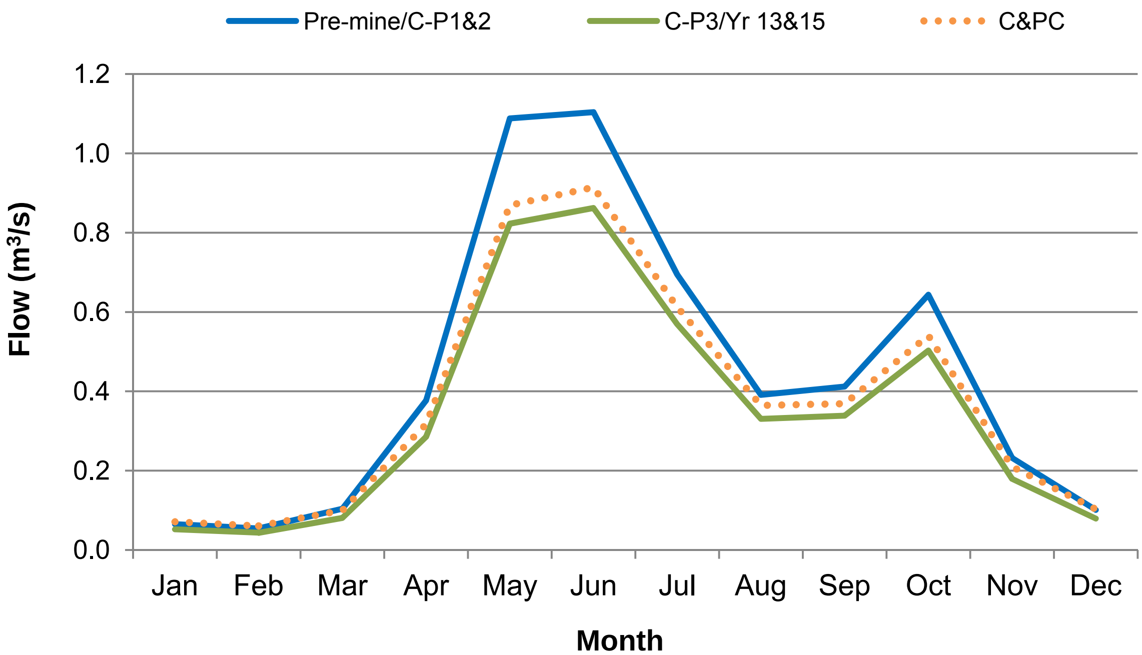

Figure 6.7.5-4: Predicted Average Monthly Discharges in Clary Creek Downstream of the Lake 901 Confluence During Baseline, Construction (Phases 1 and 2), Construction (Phase 3) and Operations, and Closure / Post-closure Phases

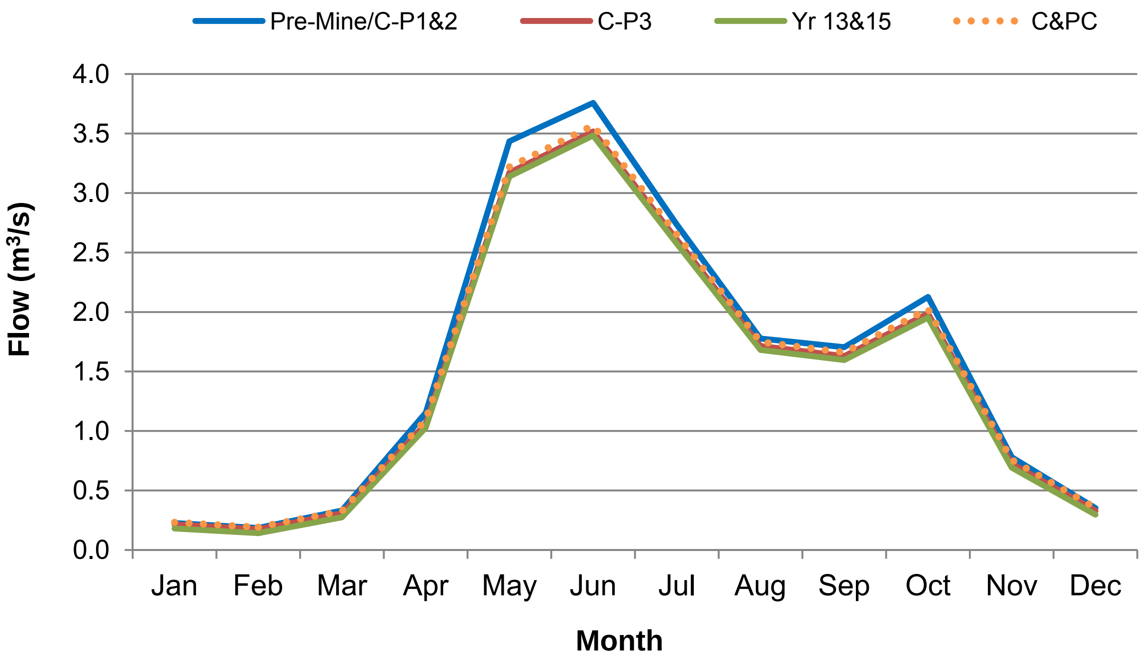

Figure 6.7.5-5: Predicted Average Monthly Discharges in the Clary Lake Outlet During Baseline, Construction (Phases 1 and 2), Construction (phase 3). Operations (Year 13 and 15), and Closure / Post-closure Phases

6.7.5.9.2.4 Potential Change in Water Temperature

Other than the mitigation measures included in the water management plan, there are no mitigation measures specifically designed to eliminate or reduce potential changes in water temperature in Lime Creek during any phase of the Kitsault Project. Therefore, the potential remains for the alteration of water temperatures in Lime Creek due to the release of TMF surplus water to Lime Creek during construction, operations, and closure and from the release of overflow from the Kitsault Pit during post-closure. This potential effect is therefore carried forward to the residual effects assessment.

Potential changes in Lake 901 water temperatures would be mitigated by the diversion of water from Lake 493 to Lake 901. No residual effect would occur and this potential effect to Lake 901 is not carried forward to the residual effects assessment.

6.7.5.9.2.5 Potential Change in Lake Levels in the Clary Creek Watershed

Potential change in lake levels in Lake 901 and Clary Lake could occur during all phases of the Kitsault Project. This potential exists in Lake 901 due to the predicted reduction of inflow in the two headwater tributaries downstream of the northeast embankment of the TMF and the northeast seepage control ponds. In Clary Lake, lake levels during construction and operations would be reduced by the combined effect of reductions in total upstream catchment areas associated with encroachment of the TMF into headwaters of the Lake 901 catchment and from pumping of water for freshwater supply requirements (i.e., potable water, fire suppression, reagent mixing, pump gland water). Lake level changes in Clary Lake during closure and post-closure phase would be limited to the effect of the altered upstream catchment area once the freshwater supply pumps are shut off.

Potential lake level reductions could potential affect BMI communities in these two lakes, particularly in Lake 901 where lake levels reductions would be highest and the lake bathymetry is shallowest (mean depth of 2 metres and maximum depth of approximately 6 m), by reducing the littoral areas available for BMI production.

Potential reduction of the Lake 901 water level would be eliminated by the construction of a pipeline diversion from Lake 493 to Lake 901. As mentioned above, this diversion would be designed and operated to divert water from Lake 493 to Lake 901 in similar magnitude to those normally provided by the combined inflow from Stream 76800 and ILP 887. As a result, no reduction in Lake 901 lake levels would occur during any phase of the Project. This potential effect is not carried forward to the residual effects assessment.

No mitigation measures are proposed specifically to reduce or eliminate potential lake level reductions in Clary Lake. Based on lake level modeling conducted by Knight Piésold (2011, Appendix 6.5-D), it was predicted that annual average lake levels in Clary Lake would be reduced by 5%, 6%, and 2% during the construction, operations, and closure/post-closure phases, respectively (Table 6.7.5-20). These percentage reductions translate into approximately 1 to 3 cm average monthly lake level reductions in Clary Lake. During maximum flow conditions (i.e., 1:70 year flood return period), these lake level reductions were predicted to range from 3 cm to 5 cm (Knight Piésold 2011, Appendix 6.5-D).

Table 6.7.5-20: Predicted Average Lake Level Change in Clary Lake from Baseline, by Depth and by Percentage, during Construction, Operations, and Closure/Post-Closure Phases of the Project

	Construction		Operations		Closure/Post-closure	
Month	**metres**	**% change**	**Metres**	**% change**	**metres**	**% change**
January	0.01	-5%	0.02	-9%	0.00	-1%
February	0.01	-5%	0.03	-12%	0.00	0%
March	0.01	-5%	0.02	-13%	0.00	0%
April	0.01	-5%	0.02	-8%	0.01	-2%
May	0.03	-4%	0.03	-4%	0.02	-3%
June	0.03	-4%	0.03	-4%	0.03	-3%
July	0.03	-5%	0.02	-4%	0.02	-4%
August	0.02	-5%	0.02	-5%	0.02	-4%
September	0.02	-5%	0.02	-5%	0.01	-3%
October	0.02	-4%	0.02	-4%	0.01	-3%
November	0.02	-4%	0.02	-4%	0.01	-3%

	Construction		Operations		Closure/Post-closure	
Month	**metres**	**% change**	**Metres**	**% change**	**metres**	**% change**
December	0.02	-5%	0.02	-6%	0.01	-2%
Annual average	0.02	-5%	0.02	-6%	0.01	-2%

These predicted lake levels reductions in Clary Lake are sufficient to warrant that this potential effect to the BMI community in Clary Lake is carried forward to the residual effects assessment.

6.7.5.10 Potential Residual Effects and Their Significance

6.7.5.10.1 Potential Residual Effects after Mitigation

Only those potential effects that would not be eliminated by mitigation measures incorporated in the Project design or committed to in Section 6.7.6.9.2 above were carried forward to this assessment of potential residual effects on BMI. An assessment of the potential residual effects to BMI of each of these direct or indirect effects is presented in the sections below. The significance of each of these potential effects is assessed in Section 6.7.6.10.2.

6.7.5.10.1.1 Loss or Alteration of Habitat

The Kitsault Project will result in the loss of Patsy Lake and Patsy Creek in the Lime Creek watershed and the loss of the two headwater tributaries of Lake 901 (Stream 76800 and ILP 887) in the Clary Creek watershed. These potential losses of habitat cannot be mitigated because they would result due to the construction and operation of the TMF, mining in the Kitsault Pit, and construction and operation of the East WRMF in the Lime Creek watershed and construction and operation of the TMF in the Clary Creek watershed. Each of these mine components is necessary for the development of the Kitsault Project. The potential residual effects of these unavoidable losses of habitat on BMI in the Lime Creek and Clary Creek watersheds are assessed in the sections below.

6.7.5.10.1.1.1 Lime Creek Watershed

Construction and operation of the TMF would result in the permanent loss of the benthic macro-invertebrate and plankton communities in Patsy Lake. Because Patsy Lake is non-fish-bearing, predaceous benthic macro-invertebrates such as dragonfly nymphs and predaceous diving beetles are the top-predators in the lake, and the density of these benthic macro-invertebrate communities is presumably higher than would be expected in a lake with fish as the top-predators.

The BMI community in the profundal zone of Patsy Lake is comprised of dipteran larvae (chironomids largely), bivalves (of the family Pelecypoda) and oligochaetes each comprising 78%, 19%, and 3% of the total profundal BMI community, respectively. These taxa are typically adapted to the low oxygen concentrations found in the hypolimnion of lakes. While the littoral BMI community of Patsy Lake was not sampled in 2009, the littoral BMI community in Patsy Lake likely would be more diverse and more dense than the profundal BMI community because water temperatures would be warmer and dissolved oxygen concentrations above the thermocline would be higher. Dragonfly nymphs, mayflies, caddisflies, and aquatic beetles are likely present in this nearshore habitat.

The BMI community of Patsy Creek was comprised of largely (>75% in 2009 and >90% in 2010) by mayflies and stoneflies. Cladocerans and copepods were also present in samples collected in 2009 and 2010 and were emigrants from Patsy Lake.

The loss of Patsy Lake and Patsy Creek represents a loss of 100% of the lake habitat and 28% of the stream habitat in the Lime Creek watershed. While the loss of BMI production from Patsy Lake and Patsy Creek cannot be quantified, such losses in habitat are assumed to have a not significant (moderate) effect on BMI in the Lime Creek watershed because the habitat losses would be limited in geographic extent to Patsy Lake and Patsy Creek and because the ecological context of the loss of BMI from Patsy Lake and Patsy Creek is assumed to be low (Table 6.7.5-31). This was because it was unlikely that Patsy Lake provides habitat or produces any BMI taxa not found elsewhere in the Kitsault area and because Patsy Lake and Patsy Creek are non-fish-bearing. Loss of BMI production in Patsy Lake and Patsy Creek would be considered more ecologically important if they supported a fish community, particularly if it contained a fish species used or valued by humans.

6.7.5.10.1.1.2 Clary Creek Watershed

Construction of the TMF would result in the permanent loss habitat and BMI production in the two headwater tributaries of Lake 901. In 2010, the BMI community of these streams was found to be comprised of blackfly and chironomid larvae (49%), caddisflies, mayflies and stoneflies (40%), oligochaetes (6%), and Ostracoda (3%). The loss of this habitat and its effect on BMI communities in these streams would result in a not significant (minor) affect on BMI in the Clary Lake watershed (Table 6.7.5-21). This was because: 1) these two streams represent a small fraction of the total stream habitat area of the Clary Creek watershed; 2) some of this lost habitat and BMI production would be compensated for by enhancing, restoring, or creating habitat; and 3) based on diet analysis of rainbow trout in Clary Lake, zooplankton and not BMI appear to form the majority of the rainbow trout diet in lakes in the Clary Creek watershed.

6.7.5.10.1.2 Potential Change in Surface Water Quality in Lime Creek and Clary Creek Watersheds

Results of the water quality model predicted various exceedences of provincial and federal water quality guidelines for the protection of freshwater aquatic biota in Lime Creek and Lake 901 and Clary Lake during construction, operations, closure, and post-closure phases of the Project. However, as discussed in the Dolly Varden, coho salmon, and rainbow trout sections of this assessment, some or all of these guideline exceedences may not necessarily result in acute or chronic effects to freshwater aquatic biota. This was due to a number of reasons including:

- The conservative assumptions in the various models used to predict water quality parameters in Lime Creek and in the lakes of the Clary Creek watershed (e.g., dissolved metals do not interact with other water quality parameters that would make them biologically unavailable);
- Detection limits were used as input concentrations for those parameters where the actual concentrations were below laboratory detection limits (e.g., mercury);
- Baseline water quality concentrations exceeded guidelines for a number of parameters yet fish and BMI communities including sensitive pollution intolerant species continue to be present; and
- Provincial and/or federal guidelines were conservative in that they often:
  - were developed to protect the most sensitive life stage of the most sensitive taxa available in the published literature and many of these taxa are not present at Kitsault;
  - Did not take into account more recent data or dose-response relationships for taxa more closely related to the fish species and BMI communities present at Kitsault since the guidelines were originally developed; and
  - Did not take into account the likelihood of potential reductions in the acute and/or chronic toxicity of metals that are known to interact with other water quality parameters (e.g., hardness, pH, dissolved organic carbon).

As a result, the proponent would work with Environment Canada, the BC Ministry of Environment, and the NLG to develop water quality objectives for freshwater during all phases of the Project. Follow-up monitoring would be conducted in Lime Creek and in Lake 901 as part of environmental effect monitoring (EEM) required under the *Metal Mine Effluent Regulations (MMER)* of the *Fisheries Act*. This would include water quality monitoring, BMI sampling, and fish tissue sampling as required by the MMER. Results of this monitoring program would be used to indicate whether additional mitigation (e.g., water treatment plant) is necessary to meet SSWQOs that may be developed for the Kitsault Project.

While the proponent would commit to this monitoring and additional mitigation necessary to ensure that fish and BMI continued to persist at or near pre-mine levels, several lines of evidence further suggest that the guideline exceedences predicted by the water quality model may not necessarily create acute or chronic toxicity effects in BMI communities present in Lime Creek and Lake 901. These lines of evidence include:

- Based on acute toxicity data (for which there is more research than for chronic toxicity data on BMI), BMI taxa present at Kitsault are less sensitive to most dissolved metals than rainbow trout and coho salmon. In order to evaluate whether or not this trend holds true for the chemicals of concern that are likely to exceed BC or CCME guidelines at some point over the life of the Project, a review of laboratory test results was conducted using the PAN Pesticide Database (Kegley et al., 2011)[20]. The toxicity comparison presented in Table 6.7.5-21 indicates that fish were more likely to exhibit a mortality response than invertebrates at lower concentrations for nearly all of the chemicals of concern in Lime Creek and Lake 901. Exceptions were selenium and lead. Therefore, WQOs, developed to protect Dolly Varden and coho salmon in Lime Creek and rainbow trout in Lake 901 are likely to protect the BMI communities present;

- A study completed on BMI communities in north-central B.C. streams affected by drainage from another molybdenum mine and processing mill (Whiting et al, 1994) indicated that the BMI communities downstream of the mine and mill were taxonomically similar to the control streams. In fact, BMI richness and diversity were higher in streams receiving open pit drainage than in control streams;
- All of the water quality parameters with exceedences of provincial or federal guidelines are naturally occurring metals and in some instances the background concentrations measured in baseline studies are present in concentrations that are at or near guideline concentrations (Table 6.7.5-21). Therefore, it is likely that the benthic invertebrate communities in Lime Creek and Lake 901 are already adapted to waters with elevated dissolved metals concentrations. Although no BMI data exists for Lime Creek before mining began at Kitsault in the 1960's for comparison, the dominance of stoneflies and mayflies in the BMI community in 2009 and 2010 suggests that even these pollution-sensitive taxa are able to survive in or adapt to elevated metals. In the study completed by Whiting et al (1994), they included a reference stream with naturally elevated levels of metals and found that the benthic invertebrate community composition was shifted toward more pollution-tolerant taxa. Native species naturally adapted to elevated metals concentrations can and do live in area streams that are metal-rich; and
- Highly conservative "risk screening" of maximum predicted surface water quality concentrations in Lime Creek and in Lake 901 against pre-mine background concentrations and BC 30-day guidelines for protection of freshwater aquatic biota (Table 6.7.5-22) identifies that more than half of the chemicals in Lime Creek and all but two of the chemicals in Lake 901 drop off the list as being of potential concern in this scenario.

These lines of evidence, coupled with the commitment by the proponent to develop and adhere to SSWQOs throughout the life of the Project, indicates that no significant adverse effect to BMI communities in Lime Creek or in the Clary Lake watershed would occur (Table 6.7.5-22).

[20] When available, 96-hour survival tests were compared for chironomids, rainbow trout (the most commonly tested salmonid fish species), and another freshwater invertebrate. Where it was not possible to find 96-hour survival tests for each of these species, substitutions were made as indicated in Table 6.7.5-21.

Table 6.7.5-21: Comparison of Toxicity Test Responses of Benthic Macro-invertebrates and Fish to Chemicals of Potential Concern Predicted to Exceed BC and / or CCME Guidelines for the Protection of Freshwater Aquatic Biota in Lime Creek and / or Lake 901

Analyte	Chironomid LC_{50} (mg/L)	Test	Other invertebrate LC_{50} (mg/L)	Test conditions and species	Fish LC_{50} (mg/L)	Test conditions and species
Aluminum	NA	[1]	0.4	96 hour; *Enallagma* sp.(damselfly)	0.12	96-hour; rainbow trout
Arsenic	NA		0.426	7-day chronic test; *Hyallela azteca*	0.17	28-day chronic; rainbow trout
Cadmium	0.08	96-hour[1]	26.0	96-hour; *Luectra* sp. (stonefly)	0.0021	96-hour;rainbow trout
Chromium	0.8	96-hour	43.1	96-hour; damselfly	0.17	28-day chronic; rainbow trout
Copper	0.03	96-hour[1]	4.6	96-hour; damselfly	0.052	96-hour; rainbow trout
Fluoride	NA		NA		125.0	48-hour; brown trout
Iron	NA	28-day	1.0	7-day chronic test; *Hyallela azteca*	0.56	96-hour carp
Lead	0.728	[3]	0.001	7-day chronic test; *Hyallela azteca*	1.0	96-hour; rainbow trout
Mercury	0.02	96-hour[2]	1.2	96-hour; damselfly	0.16	96-hour; carp
Molybdenum	NA		1.0	7-day chronic test; *Hyallela azteca*	0.73	28-day chronic test; rainbow trout
Selenium	NA		0.041	7-day chronic test; *Hyallela azteca*	11.5	96-hour; rainbow trout
Sulphate	NA		NA		NA	
Zinc	9.5	96-hour	26.2	96-hour; damselfly	0.00272	96-hour; rainbow trout

Note: [1] criteria are pH or hardness based; [2] criterion varies based upon proportion of total mercury that is methylated; [3] growth end-point; LC50 lethal concentration at which 50% of individual are killed; NA not available;

Table 6.7.5-22: Screening of Predicted Surface Water Quality Concentrations Against Background and Toxicological Benchmark Concentrations

Watercourse / Waterbody	Chemical of Concern	Background Concentrations (mg/L)[1]	Maximum Predicted Concentration (mg/L)[2]	BC Freshwater Aquatic Life Criteria (ALC) 30-day Average Concentration (mg/L)	MPC > BC 30-day Average Concentration and Background Concentration?
Lime Creek	Aluminum	0.0646	0.255	0.05	YES
	Cadmium	0.00042	0.00083	0.00001	YES
	Chromium	0.0005	0.0012	NA	NO
	Copper	0.0015	0.0056	0.002	YES
	Fluoride	ND	0.92	0.4	YES
	Mercury	0.00001	0.00004	0.00002	YES
	Molybdenum	0.214	0.354	<1	NO
	Selenium	0.0006	0.0016	0.002	NO
	Sulphate	ND	225.4	<100	NO
	Zinc	0.008	0.023	0.0075	YES
Lake 901	Aluminum	0.137	0.147	0.05	YES
	Arsenic	<0.0001	0.0005	0.005	NO
	Cadmium	<0.000015	0.00009	0.00001	YES
	Chromium	<0.0003	0.0014	NA	NO
	Copper	0.0003	0.0006	0.002	NO
	Fluoride	<0.02	0.18	0.4	NO
	Iron	0.248	0.3	1.0	NO
	Lead	<0.00005	0.0003	NA	NO
	Mercury	<0.000008	0.000009	0.00002	NO
	Molybdenum	<0.00005	0.049	<1.0	NO
	Selenium	<0.0006	0.0008	0.002	NO
	Sulphate	0.5	29.4	<100	NO
	Zinc	0.0013	0.005	0.0075	NO

Note: [1] maximum dissolved concentration for Lime Creek from 2009 and 2010 sampling at Station LC1; [2] predicted concentrations during Year 13 of operations

6.7.5.10.1.3 Potential Change in Hydrology in Lime Creek and Clary Creek Watersheds

Potential reductions in stream flow in Lime Creek downstream of Patsy Creek and in Clary Creek downstream of Lake 493 and downstream of Clary Lake have the potential effect the abundance and composition of BMI communities in these streams due to:

- Change in channel morphology and wetted widths (Gore 1977; Cowx et al. 1984);
- Change in water depths and water velocities (Dewson et al. 2007);
- Change in water temperatures and dissolved oxygen concentrations (Rader and Belish 1999; Jowett 1997); and
- Change in substrate composition (Castella et al., 1995; Wood and Armitage 1999).

Potential changes in channel morphology and substrate composition in these streams are unlikely to occur and are not assessed further because the channel banks and instream substrates in Lime Creek and in Clary Creek are largely comprised of large, angular boulders and cobbles with significant bedrock outcrops. Therefore, the likelihood that channel morphology would change in Lime and Clary creeks due to predicted reductions in stream flow is low; the likelihood would be greater if discharges were increased not decreased. Additionally, although estimates of bedload composition were unknown, both watersheds appear to have a paucity of sources of gravel or sand or fine silt substrates. Therefore, it is unlikely that there would be any significant deposition of these finer substrates in the creeks at the lower predicted discharges. Potential effects on BMI due to potential water temperature changes are discussed below.

Potential changes in water depth on BMI were not assessed because it was assumed that BMI in Lime Creek are not sensitive to changes in water depth. Instead, changes in wetted perimeter (i.e., the cross-sectional distance of the stream bottom under water) and water velocity were assessed because these hydraulic parameters were assumed to have a greater influence on BMI community abundance and composition than water depth.

6.7.5.10.1.3.1 Assessment Methods

Potential effects of changes in wetted perimeter and water velocities on BMI communities in Lime Creek and in Clary Creek were assessed in two ways: 1) by comparing the wetted width of potentially affected streams in summer under baseline conditions and with discharges predicted during different phases of the Project; and 2) by comparing predicted average water velocities in riffles and pool-out habitats in summer to the water velocity preference criteria for benthic invertebrate families as reported in Armanini et al. 2010. The summer period (July and August) was selected because this is the time of year when BMI production is greatest.

Both methods required: 1) collection of hydraulic habitat data (e.g., water depths, substrate types, water velocities) over a range of at least three different discharges at transects placed in riffles crests in Lime Creek and in Clary Creek downstream of Lake 493; and 2) development of hydraulic relationships between discharge and wetted perimeter and between discharge and water velocity in each of these locations using calibrated hydraulic models developed for each mesohabitat type from the collected transect data. Details of the data collection and assessment methods are provided in the Dolly Varden effects assessment.

6.7.5.10.1.3.2 Lime Creek

Hydraulic relationships between discharge and wetted perimeter and between discharge and water velocity in riffle crests and pool tail-outs in lower Lime Creek are presented in Figures 6.7.5-6 and 6.7.5-7, respectively. These relationships were used to predict the wetted perimeter and average water velocity in riffle crests and pool-tail out habitats during average and 10% low flow conditions in July and August at pre-mine discharges and at predicted discharges during construction and operations phases (Table 6.7.5-23). Although both of these habitat types were selected specifically to assess potential changes in hydraulic parameters in habitats used by Dolly Varden for spawning, these habitats do represent a significant portion of the available habitat in lower Lime Creek and are likely some of better BMI producing habitats in the creek. As such, it was assumed that hydraulic habitat in these habitats would be suitable for assessing potential changes in stream flow in Lime Creek on BMI community abundance, composition and drift. Similar relationships are not available for upper Lime Creek upstream of the impassable waterfalls due to the safety risks of trying to collect similar data in the steep, highly canyonised section of Lime Creek between the waterfalls and the confluence of Lime and Patsy Creeks.

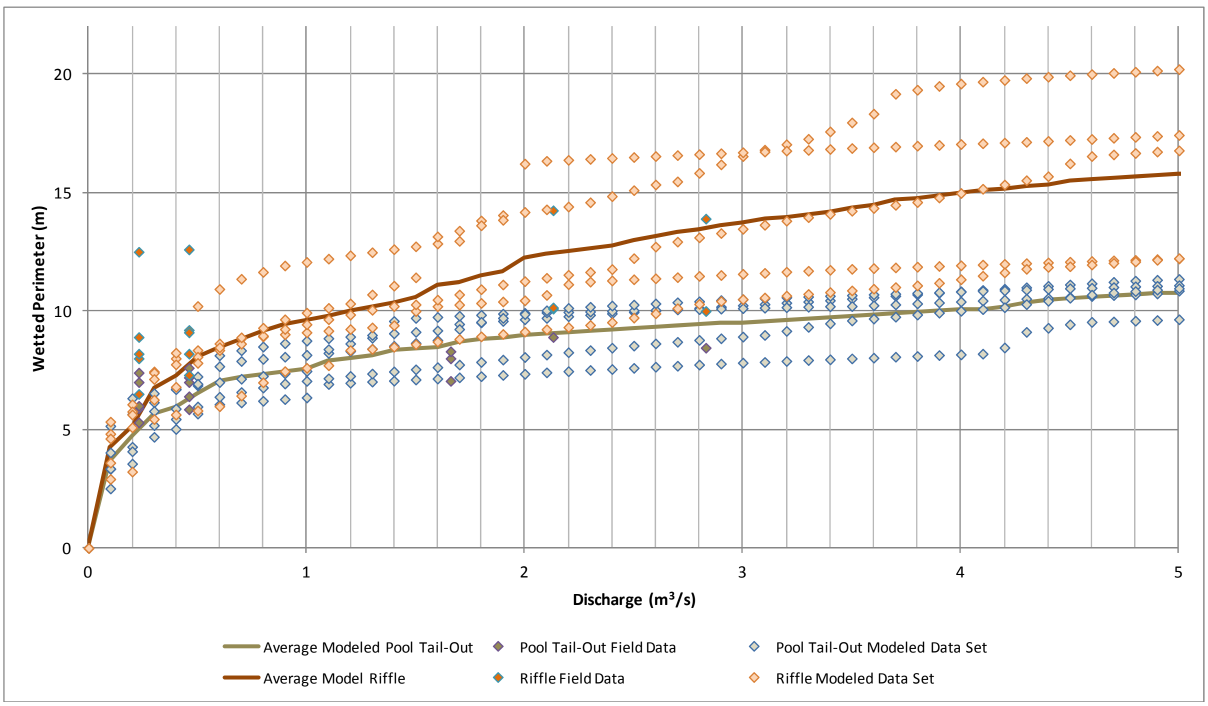

Figure 6.7.5-6: Hydraulic Relationship Between Discharge and Average Water Depth at Riffle Crests and Pool Tail-Outs in Lower Lime Creek Watershed

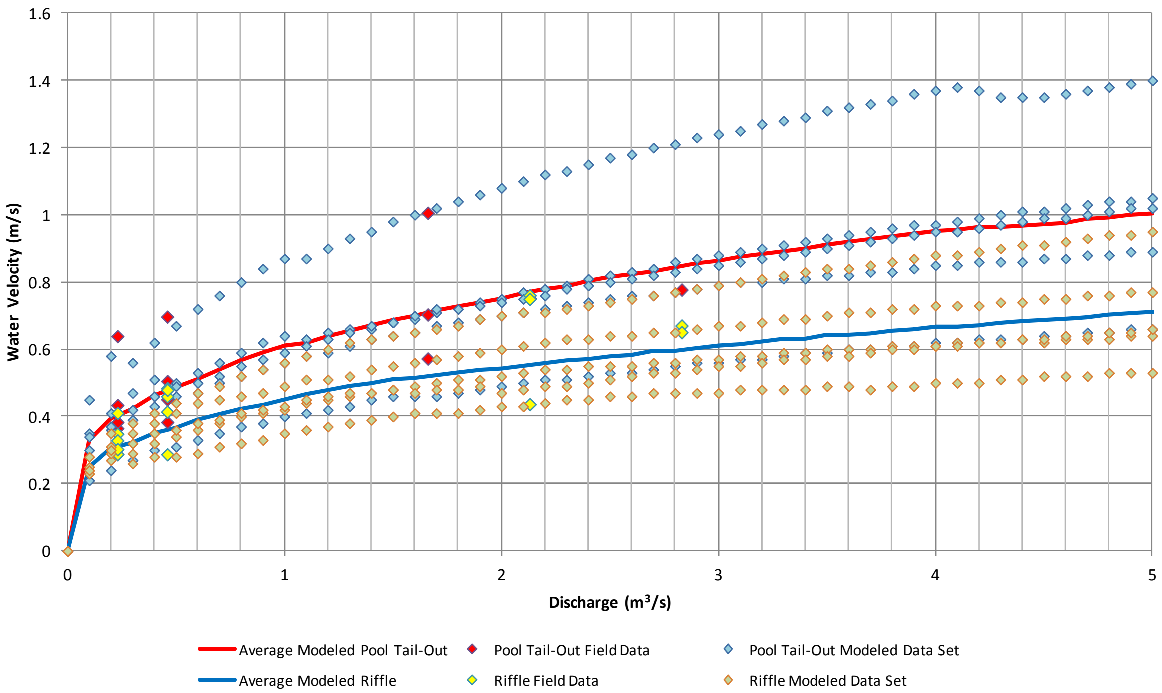

Figure 6.7.5-7: Hydraulic Relationship Between Discharge and Average Water Velocity at Riffle Crests and Pool Tail-Outs in Lower Lime Creek Watershed

Under mean monthly flow conditions, the average wetted perimeter of lower Lime Creek in pool tail-outs was predicted to decrease between 3% and 5% during July and August during construction and operations phases of the Project. This would increase to between a 5% and 9% decrease in average wetted width during a 10th percentile low flow (Table 6.7.5-23). Changes in average wetted width in riffles was also predicted to be small during construction and operations. Under mean monthly flow conditions, the average wetted perimeter if riffles was predicted to decrease between 7% and 9% during construction and operations and between 6% and 7% during a 10th percentile low flow (Table 6.7.5-23). These relatively small changes in wetted perimeter are due the relatively flat relationships between discharge and wetted perimeter in lower Lime Creek in these two habitat types at discharges >1 m^3/sec (Figure 6.7.5-7).

If it is assumed, that BMI production is homogenous across the stream channel, the small predicted changes in wetted perimeter of lower Lime Creek would likely result in a similarly small decrease in stream habitat available for BMI and a similarly small decrease in BMI production in lower Lime Creek. Although similar relationships are not available for the Lime Creek upstream of the impassable waterfalls, it is assumed that the predicted flow reductions would also have a relatively small effect on wetted width and BMI habitat and production in the Lime Creek canyon.

Similarly, the predicted decreases in average water velocities in riffle and pool tail-out habitats are unlikely to decrease the suitability of these habitats for the BMI community present in lower Lime Creek nor was it expected that the abundance or composition of the BMI community would change. Average water velocities in pool tail-outs and riffle crest habitat in lower Lime Creek were predicted to decrease <8% and <7%, respectively, in July and August during construction and operations phases of the Project under mean monthly flow conditions (Table 6.7.5-23). These predicted reductions in water velocity are unlikely to affect the abundance and composition of the lower Lime Creek BMI community because:

- Predicted average water velocities in both habitat types would remain at or slightly above the preferred water velocities for the two most abundant BMI taxa in the creek. The stonefly family Taeniopterygidae comprised over 45% of the BMI community in upper Lime Creek and over 75% of the BMI community of lower Lime Creek. This family has a preferred water velocity of 0.50 m/sec (Armanini et al. 2010), the second highest water velocity preference of any of the stonefly families. The mayfly family Heptageniidae comprised over 35% and 7% of the upper and lower Lime Creek BMI communities, respectively (the second most abundant BMI taxa at both sites). This family has a preferred water velocity of 0.48 m/sec (Armanini et al., 2010), the highest water velocity preference of any of the mayfly families. Average water velocities were predicted to range between 0.52 and 0.59 m/sec in riffles and between 0.74 and 0.83 m/sec in pool-tail outs during construction and operations, down from between 0.56 and 0.62 m/sec in riffles and between 0.78 and 0.88 m/sec in pool-tail outs under pre-mine conditions. The naturally high water velocities in Lime Creek during pre-mine conditions is likely one of the main reasons that Taeniopterygidae and Heptageniidae dominate the Lime Creek BMI communities;
- The relatively small reduction in water velocity would likely have a small effect on the ability of the two dominant BMI taxa in Lime Creek to acquire food. Species of Taeniopterygidae stoneflies and Heptageniidae mayflies generally occupy the "shredders" and "scrapers" functional feeding groups, respectively (Merritt and Cummins, 1996). Both of these functional feeding groups rely on gathering detritus or scraping algae off of rocks. The relatively small reduction in water velocity predicted to occur during construction and operations is unlikely to affect the availability of detritus in Lime Creek or the production of periphyton on the rocks. A potentially greater effect on the density and composition of BMI in Lime Creek would be expected if the BMI community was dominated by "filter-feeding" taxa which rely on the delivery of detritus and nutrients in the water current; and
- Although both of the two dominant BMI taxa in Lime Creek are likely more sensitive to flow changes than other taxa present in the stream such as oligochaete worms, chironomid larvae, and Sphaeriidae molluscs, the predicted change in water velocities are likely insufficient to make habitat in Lime Creek more suitable for these other "less sensitive" taxa. Dewson et al., (2007) found that the abundance and composition of EPT taxa in decreased and the abundance of oligochaetes and chironomids increased in response to flow reductions in small pristine streams in

New Zealand. However, the change in discharge and water velocities in their experiments were up to 85% and between 50% and 90%, respectively. These are up to 10 times greater flow reductions than predicted to occur in Lime Creek.

Table 6.7.5-23: Comparison of Predicted Wetted Perimeters and Water Velocities at Pool Tail-Outs and Riffle Crests in Lower Lime Creek Watershed During July and August Under Average and Low Flow Conditions During Pre-Mine, Construction (Stage 2 & 3), and Operations (Year 15) Phases of the Project

Project Phase	Month	Flow condition	Predicted Discharge (m^3/sec)	Pool tail-outs		Riffle crests	
				Average Wetted Perimeter (m)	Average Water Velocity (m/sec)	Average Water Depth (m)	Average Water Velocity (m/sec)
Pre-mine	July	Mean monthly discharge	3.20	9.63	0.88	13.99	0.62
		10th percentile monthly discharge	1.53	8.43	0.69	10.61	0.51
	August	Mean monthly discharge	2.18	9.12	0.78	12.55	0.56
		10th percentile monthly discharge	1.40	8.34	0.67	10.36	0.50
Construction (Stage 2 & 3)	July	Mean monthly discharge	2.48	9.28 (-4%)	0.81 (-8%)	12.98 (-7%)	0.58 (-7%)
		10th percentile monthly discharge	1.22	8.02 (-5%)	0.64 (-7%)	10.02 (-6%)	0.48 (-6%)
	August	Mean monthly discharge	1.82	8.80 (-3%)	0.73 (-7%)	11.53 (-8%)	0.53 (-5%)
		10th percentile monthly discharge	1.10	7.91 (-5%)	0.62 (-8%)	9.77 (-6%)	0.47 (-6%)
Operations (Year 15)[a]	July	Mean monthly discharge	2.66	9.17 (-5%)	0.83 (-6%)	12.66 (-9%)	0.59 (-5%)
		10th percentile monthly discharge	1.25	8.02 (-5%)	0.65 (-6%)	10.02 (-6%)	0.49 (-5%)
	August	Mean monthly discharge	1.90	8.89 (-3%)	0.74 (-5%)	11.69 (-7%)	0.54 (-4%)
		10th percentile monthly discharge	1.05	7.55 (-9%)	0.61 (-9%)	9.63 (-7%)	0.45 (-10%)

Note: [a] Kitsault Pit filling Scenario A

Note: Colour coding: within the preferred water velocity range for common Ephemeroptera (mayfly) taxa (0.26 m/sec to 0.48 m/sec); within the preferred water velocity range for common Plecoptera (stonefly) taxa (0.38 m/sec to 0.54 m/sec); XXXXX within the preferred water velocity range for common Diptera (true flies) taxa (0.21 m/sec to 0.42 m/sec); XXXXXX within the preferred water velocity range for common mayfly and stonefly taxa

Source: Armanini et al. (2010)

6.7.5.10.1.3.3 Clary Creek Watershed

Potential flow reductions may occur in the Clary Creek watershed in four locations during all phases of the Project: 1) in the two headwater tributaries of Lake 901; 2) in Clary Creek downstream of the natural Lake 493 outlet; 3) in Clary Creek downstream of confluence of the Lake 493 and Lake 901 outlets; and 4) in the Clary Lake outlet. Flow reductions in the two Lake 901 inlets would be due to loss of run-off to the TMF. Flow reductions in Clary Creek downstream of the Lake 493 outlet would be due to the diversion of flows to Lake 901 while flow reductions in Clary Creek downstream of the Lake 901 confluence would be due to the loss of run-off from the catchment area affected by the TMF. Flow reductions in the Clary Lake outlet would be due to the combined effect of the loss of upstream run-off and water withdrawal for potable water during construction and operations.

Flow reductions at these locations would be greatest during construction and operations as freshwater supply pumps would be shut off in Clary Lake during closure and some of the upstream run-off in the headwaters of Lake 901 would be allowed to flow into Lake 901 when the pumps in the northeast seepage control pumps are decommissioned. However, flow reductions at all four sites would persist into post-closure (due to the reduction in upstream catchment area caused by the TMF) with the largest flow reductions predicted to occur in the 350 metres of Clary Creek between the Lake 493 outlet and the Lake 901 outlet confluence. The effect of predicted flow reductions of BMI communities at each of these locations is assessed in the section below.

6.7.5.10.1.3.3.1 Lake 901 Inlet Tributaries

During construction and operations, flows in Stream 76800 and ILP 887 were predicted to decrease by up to 70%. These reductions in flow would be smaller (approximately 50% reduction) during the closure/post-closure phases when the pumps in the northeast seepage control ponds are decommissioned.

Flow reductions of this magnitude would reduce the wetted perimeter, depth, and water velocities in these streams. This in turn, would likely alter the channel geometry, sediment composition, and water quality (e.g., temperature and dissolved oxygen concentrations) and would likely reduce the availability and suitability of these streams for the most of the BMI taxa that comprise the BMI communities in these streams. However, unlike Lime Creek, more flow sensitive mayfly, stonefly and caddisfly taxa comprise less than 50% of the BMI community of these streams. Instead, these communities are dominated by less flow sensitive taxa such as chironomids, blackfly larvae, and oligochaete worms. Of the EPT taxa present, the dominant taxa are Leptophlebiidae mayflies and Capniidae and Leuctridae stoneflies. These taxa generally have the lowest water velocity preferences of the mayfly and stonefly families (Armanini et al., 2010). As a result, it would be expected that chironomids, blackfly larvae and oligochaete would form an even greater proportion of the BMI communities in the remaining habitat in these two streams at the expense of the mayfly, stonefly, and caddisfly taxa that exist at present.

The loss of flow in the lower reaches of these two streams, and its resulting change in the abundance and composition of the BMI community would be, at least partially offset by habitat enhancements proposed in the Lake 901 oultet as part of the FHMCP (see the rainbow trout section and Appendix 11.2-A for details of this plan).

6.7.5.10.1.3.3.2 Clary Creek Downstream of Lake 493

Diversion of water from Lake 493 to Lake 901 to mitigate lake level changes in Lake 901, flow reductions at the Lake 901 outlet, and potential water quality effects in Lake 901, was predicted to reduce flows in Clary Creek downstream of Lake 493 by 35% during construction and operations and by 31% during closure/post-closure (Table 6.7.5-24). On a monthly percentage basis, the flow reductions were predicted to be greatest in the winter low flow months (November to March) and lowest during the spring and fall high flow month (May and June and September and October, respectively).

Table 6.7.5-24: Predicted Average Monthly and Annual Flow Reductions in the Lake 493 Outlet due to Water Diversions to Lake 901 through the Gravity-Fed Pipeline

Month	Baseline	Construction/Operations		Closure / Post-closure	
	(m^3/sec)	(m^3/sec)	% change	(m^3/sec)	% change
January	0.04	0.02	-50%	0.02	-50%
February	0.03	0.02	-33%	0.02	-33%
March	0.06	0.03	-50%	0.03	--50%
April	0.21	0.12	-43%	0.15	-29%
May	0.60	0.34	-43%	0.38	-37%
June	0.64	0.40	-37%	0.45	-30%
July	0.44	0.26	-41%	0.26	-41%
August	0.26	0.17	-35%	0.17	-35%
September	0.27	0.19	-30%	0.21	-23%
October	0.38	0.24	-37%	0.28	-27%
November	0.13	0.07	-46%	0.07	-47%
December	0.06	0.03	-50%	0.03	-50%
Annual average	0.26	0.17	-35%	0.18	-31%

The relationships between discharge and wetted perimeter and water velocity in riffle habitat in the Lake 493 outlet are presented in Figures 6.7.5-8, and 6.7.5-9 respectively.

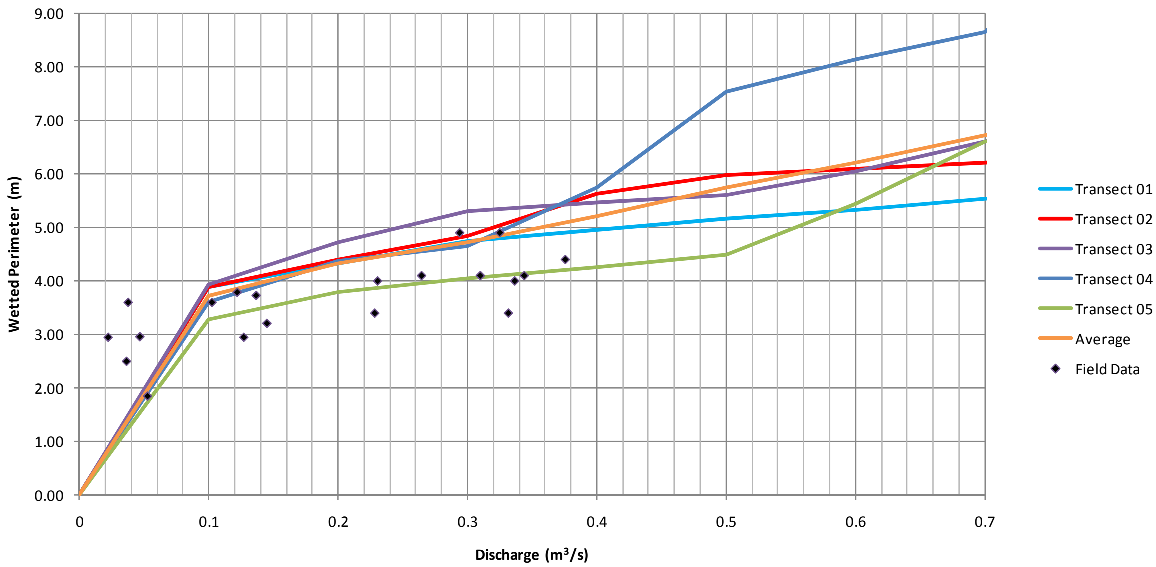

Figure 6.7.5-8: Relationship Between Discharge and Wetted Perimeter in the Lake 493 Outlet

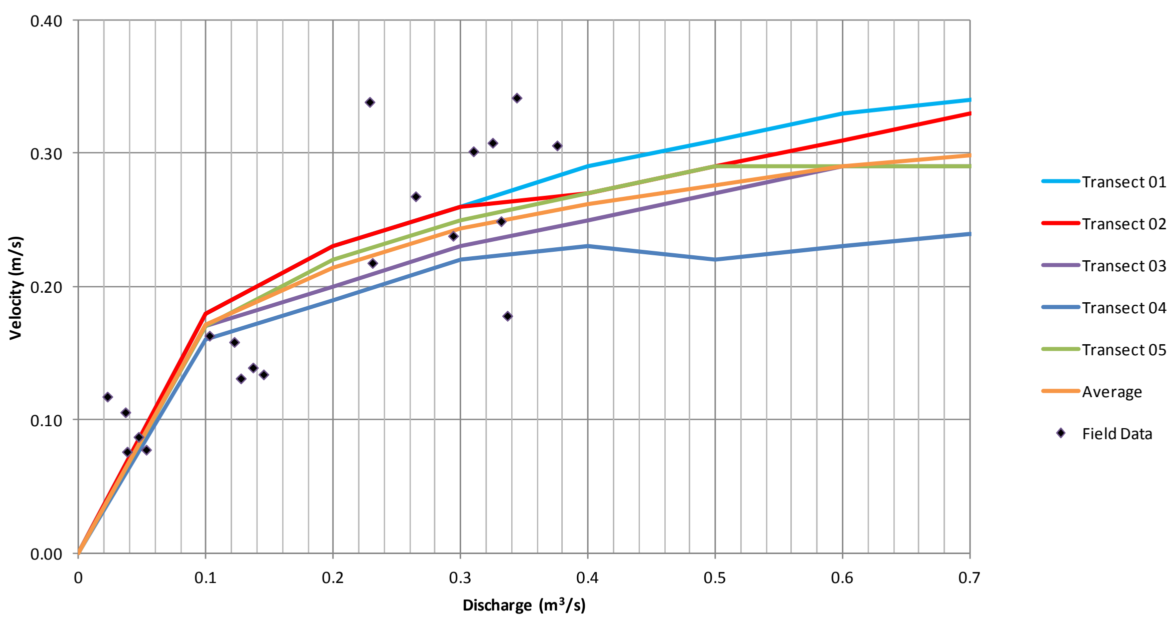

Figure 6.7.5-9: Relationship between Discharge and Water Velocity in the Lake 493 Outlet

Based on these relationships, the wetted perimeter of the channel is predicted to decrease by 19% in May and 9% in August during the construction and operations phases and by 14% in May and August during the closure and post-closure phases Table 6.7.5-25. This amounts to approximately a 1.0 m decrease in wetted perimeter in May and an approximately 0.4 m decrease in the wetted perimeter in August during all Project phases. Such a decreases in wetted perimeter are not expected to have a significant effect on the availability of habitat for BMI production in this section of Clary Creek.

Table 6.7.5-25: Predicted Wetted Perimeter, Water Depth, and Water Velocity in the Lake 493 Outlet during May and August during Pre-Mine Baseline Conditions and during Construction/Operations and Closure/Post-Closure Phases of the Project

Project phase	May			August		
	Wetted perimeter (m)	Water depth (m)	Water velocity (m/sec)	Wetted perimeter (m)	Water depth (m)	Water velocity (m/sec)
Baseline	6.0	0.71	0.29	4.5	0.50	0.23
Construction/operations	4.9	0.56	0.24	4.1	0.42	0.20
Closure/post-closure	5.2	0.59	0.25	4.1	0.42	0.20

Under baseline conditions, the average water velocity in the Lake 493 outlet in August was predicted to be approximate 0.23 m/sec. During construction and operations and during closure and post-closure phases, average water velocities were predicted to decrease by 0.03 m/sec. Although the BMI community of this section of Clary Creek is unknown, it can be assumed that the BMI community present is adapted to the rocky, relatively low velocity habitats that dominate this section of stream. This community would be unlikely to change given the relatively small change in water velocities expected following diversion of flows to Lake 901.

6.7.5.10.1.3.3.3 Clary Creek Downstream of the Lake 901 Outlet Confluence

Flow reductions in Clary Creek downstream of the confluence of the Lake 901 and Lake 493 outlets are predicted to be 16% lower than average baseline flows in August (summer low flow period) and 24% lower than average baseline flows in May (spring freshet period) during the construction and operations phases of the Project (Table6.7.6-28). During closure and post-closure phases, flow reductions during these months are predicted to be smaller (7% and 20%, respectively). The source of these flow reductions is the TMF and northeast seepage control ponds during construction and operations phases and the reduced upstream catchment area in the Lake 901 watershed during closure and post-closure phases.

Although hydraulic habitat data similar to those collected at transects in lower Lime Creek or in the Lake 493 outlet were not collected and, therefore, it was not possible to predict the change in wetted perimeter or water velocity in Clary Creek downstream of the Lake 901 outlet confluence, it is unlikely that the predicted flow reductions in this section of Clary Creek would have a significant adverse effect on the availability or suitability of habitat for the BMI community present. This is because the flow reduction in Clary Creek downstream of the Lake 901 outlet confluence would be smaller than in Clary Creek immediately downstream of the Lake 493 outlet due to the return of diverted flow to Clary Creek via the Lake 901 outlet. Habitat and channel morphology in this section of Clary Creek is relatively similar to habitat in Clary Creek immediately downstream of Lake 493. Therefore, it can be expected that the change in wetted width and average water velocities, nor the BMI community present, in this rocky, canyonised section of Clary Creek would not be substantially changed during any phase of the Project.

6.7.5.10.1.3.3.4 Clary Lake Outlet

Flow reductions in the Clary Lake outlet are not expected to have a significant adverse effect on the BMI community present. The rationale for this assessment is two-fold: 1) the magnitude of predicted flow reductions are unlikely to be insufficient to significantly reduce the wetted perimeter or reduce the average water velocity of habitat downstream of the lake; and 2) the BMI community immediately downstream of the lake is dominated by relatively insensitive BMI taxa.

Flow reductions were predicted to be only 7% to 9% in May and June during the spring freshet, and only 5% or 6% during July and August during construction and operations (Table 6.7.5-26). These reductions were predicted to be smaller during closure and post-closure phases. Flow reductions were predicted to be relatively higher during the winter months but not in terms of absolute discharge. Such changes in flow are likely within the range of natural variability at this location. Clary Lake receives most of its inflow (and hence most of its outflow) from the northeastern portion of its watershed. This portion of the watershed would not be affected by the Kitsault Project therefore any flow reduction created by the TMF in the southwestern portion of the watershed would be largely attenuated.

The BMI community in the Clary Lake outlet is largely comprised of Sphaeriidae molluscs (50%), other bivalves (17%), and chrionomid larvae (11%). These taxa are relatively insensitive to flow changes in comparison to stonefly and mayfly larvae. The two dominant stonefly (Nemouridae) and mayfly (Leptophlebiidae) larvae present at this site have water velocity preferences (0.44 m/sec and 0.26 m/sec, respectively; Armanini et al., 2010) generally in the lower range of water velocity preferences for other stonefly and mayfly families. For these reasons, the predicted flow reductions at the Clary Lake outlet is not predicted to have a significant adverse effect on the abundance or composition of the BMI community present at this site.

Table 6.7.5-26 Percentage Change in Average Monthly and Average Annual Flows at Different Locations in the Clary Creek Watershed During Construction, Operations, Closure, and Post-Closure Phases

Month	Lake 901 inlets			Lake 901 outlet		Clary Creek[1]			Lake 493 outlet		Clary Lake outlet		
	Construction[2]	Operations[3]	Closure / Post-closure	C[2], O[3]	D/C, PC	Construction[2]	Operations[3]	Closure/Post-closure	C[2], O[3]	D/C, PC	Construction[2]	Operations[3]	Closure/Post-closure
January	-67%	-65%	29%	0%	24%	-21%	-20%	9%	-50%	-50%	-6%	-21%	2%
February	-69%	-65%	40%	0%	39%	-21%	-20%	12%	-33%	-33%	-6%	-24%	3%
March	-79%	-76%	-13%	0%	18%	-23%	-22%	-4%	-50%	-50%	-7%	-17%	-1%
April	-79%	-78%	-51%	0%	1%	-25%	-24%	-16%	-43%	-29%	-8%	-11%	-5%
May	-75%	-75%	-62%	0%	0%	-24%	-24%	-20%	-43%	-37%	-8%	-9%	-6%
June	-71%	-70%	-55%	0%	0%	-22%	-22%	-17%	-37%	-30%	-6%	-7%	-5%
July	-63%	-63%	-41%	0%	0%	-18%	-18%	-12%	-41%	-41%	-5%	-6%	-3%
August	-61%	-60%	-27%	0%	1%	-16%	-15%	-7%	-35%	-35%	-3%	-5%	-2%
September	-66%	-66%	-39%	0%	0%	-18%	--18%	-10%	-30%	-23%	-4%	-6%	-3%
October	-74%	-73%	-54%	0%	0%	-22%	-22%	-16%	-37%	-27%	-7%	-8%	-5%
November	-76%	-76%	-31%	0%	0%	-23%	-23%	-10%	-46%	-47%	-7%	-11%	-3%
December	-69%	-68%	5%	0%	7%	-22%	-22%	2%	-50%	-50%	-6%	-16%	0%
Annual average	-71%	-71%	-46%	0%	1%	-21%	-21%	-14%	-35%	-31%	-6%	-8%	-4%

Note: [1] downstream of the Lake 493 and Lake 901 confluence; [2] Stage 3 of the construction [3] Year 13 and Year 15 of operations

Project phase: C - construction; O - operations; D/C - decommissioning and closure; PC - post-closure

6.7.5.10.1.4 Potential Change in Water Temperature in Lime Creek

Loss of Patsy Lake under the TMF and replacement of Patsy Lake discharge and thermal loading to Patsy Creek with discharge and thermal loading from the TMF during construction and operations and with discharge and thermal loading from the overflowing Kitsault Pit during closure and post-closure has the potential to alter water temperatures in Lime Creek. This is because the TMF and the Kitsault Pit would be larger and deeper than Patsy Lake and would therefore take longer to heat up in spring and longer to cool down in fall due to their larger thermal mass and thermal inertia. The larger surface area of both the TMF and Kitsault Pit may also cause summer winter temperatures to increase higher than those in Patsy Lake.

During construction and operations, potential increases in summer and winter water temperatures in Patsy Creek due to discharges from the TMF are unlikely to have a significant effect on water temperatures in Lime Creek. This is because:

- The relative proportion of monthly discharge in Lime Creek from the TMF compared to discharge from upper Lime Creek will be smaller during the construction and operations phases (due to predicted flow reductions) than during pre-mine conditions. Thus, any increase in water temperatures released to Patsy Creek from the TMF will be more attenuated by the larger proportion of the unaffected discharge from the upper Lime Creek watershed and from the unaffected Lime Creek tributaries downstream of the Patsy Creek confluence. Under current conditions, Patsy Creek provides approximately 30% of the total average annual run-off to lower Lime Creek. With smaller discharges predicted during construction and operations, the average annual contribution of flows from the TMF to lower Lime Creek are expected to decrease between 24% and 26% during construction, operations, and closure phases;
- Cooler water from the Patsy Creek tributaries downstream of Patsy Lake will be diverted around the TMF, the East WRMF, and the Kitsault Pit and will serve to moderate any increase in water temperatures discharged to Patsy Creek from the TMF;
- Discharge and thermal loadings from Lime Creek tributaries downstream of the Patsy Creek confluence will continue to attenuate water temperatures in lower Lime Creek. These tributaries contribute approximately 31% of the total annual run-off of lower Lime Creek. This tributaries will be unaffected by the Project; and
- Climatic conditions along the north coast of British Columbia are cool and wet with a relatively short summer (July and August). Maximum mean monthly ambient air temperatures in July are approximately 12°C (Knight Piésold 2011, Appendix 6.4-A). Mid-summer air temperatures can exceed 20°C but the number days when air temperatures exceed 15°C is low. The number of days without cloud (i.e., when solar radiation inputs are maximum) is lower. As a result, even with the larger surface area of the TMF compared to Patsy Lake, it is unlikely that water

temperatures discharged from the TMF to Patsy Creek would be more than 1°C or 2°C warmer than those discharged from Patsy Lake.

During post-closure, potential increases in summer and winter water temperatures in Patsy Creek due to over-flow from the Kitsault Pit are unlikely to have a significant effect on water temperatures in Lime Creek. This is because:

- The proportional increase in run-off volume provided by the end-pit lake to lower Lime Creek at post-closure is small (<1% increase on an annual basis);
- Run-off from upper Lime Creek run-off and Lime Creek tributaries downstream of the Patsy Creek confluence will continue to attenuate any increases in summer temperatures entering Lime Creek from the end-pit lake over-flow; and
- Climatic conditions in the Kitsault area are insufficiently warm, dry, or cloudless to cause water temperatures in the end-pit lake to increase much higher than those normally discharged from Patsy Lake under pre-mine conditions.

For these reasons, it is unlikely that water temperatures in Lime Creek will increase outside the range of natural variability during any phase of the Project. As a result, no significant residual effect on BMI in Lime Creek was expected to occur.

6.7.5.10.1.5 Potential change in lake levels in the Clary Lake

No significant residual effect to the BMI community in Clary Lake was predicted to occur due to predicted changes in lake levels in Clary Lake. Any residual effect on rainbow trout in Clary Lake is expected to be negligible (Table 6.7.5-27). This assessment was based on the following lines of evidence:

- The average percent change in littoral area of Clary Lake would decrease by only 6 to 7% (Table 6.7.5-27) even during maximum flow conditions during the operations phase when lake level reductions were predicted to be greatest (3 to 5 cm reduction);
- The littoral zone (i.e., habitat <6 m deep) comprises <25% of the entire area of Clary Lake due to the steep gradients along most of the shoreline (Figure 6.7.4-12). In addition, substrates in most littoral zone areas (65%) are comprised of course gravel, cobble and boulder substrates which are generally less productive for benthic invertebrates than fine, depositional substrates (Figure 6.7.4-13). Thus, the small predicted change in littoral zone area is unlikely to have a measurable effect on the littoral BMI community present in Clary Lake; and
- The predicted change in lake levels would have no effect on the profundal BMI community of Clary Lake.

Based on the above, no significant effect on rainbow trout would occur in Clary Lake due to predicted changes in lake levels

Table 6.7.5-27: Predicted Percent Change in Littoral Area of Clary Lake from Baseline, during Construction, Operations, and Closure/Post-Closure Phases of the Project

Month	Construction	Operations	Closure/Post-closure
January	-6%	-7%	-6%
February	-6%	-7%	0%
March	-6%	-7%	0%
April	-6%	-7%	-6%
May	-7%	-7%	-7%
June	-7%	-7%	-7%
July	-7%	-7%	-7%
August	-7%	-7%	-7%
September	-7%	-7%	-6%
October	-7%	-7%	-6%
November	-7%	-7%	-6%
December	-7%	-7%	-6%
Annual Average	**-7%**	**-7%**	**-6%**

6.7.5.10.1.6 Residual Effects Summary

A summary of the potential residual effects of the Project on the BMI communities in Lime Creek and Clary Creek is provided in Table 6.7.5-28. All of these potential effects are indirect effects on BMI through potential direct changes to water quality, stream flows, water temperatures, and benthic macro-invertebrate prey in the Lime Creek and Clary Creek Watershed

Table 6.7.5-28: Summary of Residual Effects for Benthic Macro-Invertebrates

Project Phase	Residual effect	Direction
C, O, D/C, PC	Alteration or loss of habitat	Negative
C,O,D/C, PC	Change in surface water quality in Lime Creek and Clary Creek Watersheds	Negative
C,O, D/C, PC	Change in hydrology in Lime Creek and Clary Creek Watersheds	Negative
C, O, D/C, PC	Change in water temperature in Lime Creek	Negative
C,O, D/C, PC	Change in lake level in Clary Lake	Negative

Legend: C - construction; O - operations; D/C - decommissioning and closure; PC - Post-closure

6.7.5.10.2 Significance of Potential Residual Effects

Based on the residual effects assessments above, an assessment of the significance of potential residual effects on BMI due to the potential changes in habitat, surface water quality, hydrology, water temperature, and lake levels is provided in Table 6.7.5-29 below.

Table 6.7.5-29: Residual Effects Assessment by Project Development Phase for Benthic Macro-Invertebrates

Parameter	Stage of Development / Rating			
	Construction	**Operations**	**Decommissioning and Closure**	**Post-Closure**
Residual Effect				
Alteration or loss of habitat				
Effect Attribute				
Direction	Negative	negative	negative	negative
Magnitude	Medium	Medium	Medium	Medium
Geographic extent	Local	Local	Local	Local
Duration	Medium-term	Long-term	Long-term	Chronic
Frequency	Continuous	Continuous	Continuous	Continuous
Reversibility	No	No	No	No
Ecological Context	Low	Low	Low	Low
Probability of occurrence	High	High	High	High
Certainty	Medium	Medium	Medium	Medium

Parameter	Stage of Development / Rating			
	Construction	Operations	Decommissioning and Closure	Post-Closure
Residual Effect Significance	Not significance (moderate)	Not significant (moderate)	Not significant (moderate)	Not significant (moderate)
Level of Confidence	High	High	High	High
Change in surface water quality in lower Lime Creek and Clary Creek Watersheds				
Effect Attribute				
Direction	Negative	negative	negative	negative
Magnitude	Low	Low	Low	Low
Geographic extent	Local	Local	Local	Local
Duration	Medium-term	Long-term	Long-term	Chronic
Frequency	Continuous	Continuous	Continuous	Continuous
Reversibility	No	No	No	No
Ecological Context	High	High	High	High
Probability of occurrence	High	High	High	High
Certainty	Medium	Medium	Medium	Medium
Residual Effect Significance	Not significance (moderate)	Not significant (moderate)	Not significant (moderate)	Not significant (moderate)
Level of Confidence	Medium	Medium	Medium	Medium
Change in hydrology in lower Lime Creek and Clary Creek Watersheds				
Effect Attribute				
Direction	Negative	Negative	Negative	Negative
Magnitude	low	low	low	Low
Geographic extent	local	local	local	Local
Duration	Medium-term	Long-term	Long-term	Chronic
Frequency	continuous	continuous	continuous	continuous
Reversibility	no	no	no	Yes
Ecological context	Medium	Medium	Medium	Medium
Probability of occurrence	high	high	high	High
Certainty	medium	medium	medium	Medium
Residual Effect Significance	Not significant (minor)	Not significant (minor)	Not significant (minor)	Not significant (minor)
Level of Confidence	High	High	High	High
Change in water temperature in Lime Creek				
Effect attribute				
Direction	Negative	negative	negative	Negative
Magnitude	low	low	low	Low
Geographic extent	local	Local	local	Local
Duration	short-term	Long-term	Long-term	Long-term
Frequency	continuous	continuous	continuous	Continuous
Reversibility	no	no	no	yes

Parameter	Stage of Development / Rating			
	Construction	Operations	Decommissioning and Closure	Post-Closure
Ecological context	low	low	low	Low
Probability of occurrence	unknown	unknown	unknown	unknown
Certainty	low	low	low	low
Residual Effect Significance	Not significant (negligible)	Not significant (negligible)	Not significant (negligible)	Not significant (negligible)
Level of confidence	low	Low	Low	low
Change in lake level in Clary Lake				
Effect attribute				
Direction	Negative	Negative	Negative	Negative
Magnitude	Low	Low	Low	Low
Geographic extent	Local	Local	Local	Local
Duration	Medium-term	Long-term	Long-term	Chronic
Frequency	Continuous	Continuous	Continuous	Continuous
Reversibility	No	No	No	No
Ecological context	Low	Low	Low	Low
Probability of occurrence	High	High	High	High
Certainty	High	High	High	High
Residual Effect Significance	Not significant (negligible)	Not significant (negligible)	Not significant (negligible)	Not significant (negligible)
Level of confidence	Medium	Medium	Medium	Medium

6.7.5.11 Cumulative Effects Assessment

6.7.5.11.1 Rationalisation for Carrying Forward Project Related Residual Effects Into the Cumulative Effects Assessment

Only potential minor or moderate residual Project effects on BMI were carried forward into the cumulative effects assessment. These included the potential moderate residual effect on BMI due to alteration or loss of habitat in the Lime and Clary Creek watersheds, the potential moderate residual effect on BMI due to potential changes in surface water quality in Lime Creek and in Lake 901, and the potential minor residual effect on BMI due to potential changes in hydrology in Lime Creek and Clary Creek (Table 6.7.6-30).

Table 6.7.5-30: Project Related Residual Effects - Rationale for Carrying Forward Into the Cumulative Effects Assessment

Project Component	Project Phase	Residual Effect	Rationale	Carried Forward in CEA
Development of the TMF, Kitsault Pit, East WRMF, and northeast embankment of TMF and northeast seepage control ponds	C, O, D/C, PC	Potential change in abundance and composition of BMI community in Lime Creek and Clary Creek watersheds due to alteration or loss of habitat	Loss of Patsy Lake and Patsy Creek in the Lime Creek watershed and loss of Lake 901 headwater tributaries in the Clary Creek watershed would result in loss of BMI production	Yes
TMF surplus water, surface water and groundwater management, TMF seepage, and Klitsault Pit over-flow	C, O, D/C, PC	Potential change in abundance and composition of BMI community in Lime Creek and Clary Creek watersheds due changes in surface water quality	Potential increases in the concentration of metals in Lime Creek and Lake 901 may have acute or chronic effects on BMI taxa	Yes
TMF surplus water, surface water and groundwater management, and Klitsault Pit over-flow	C, O, D/C, PC	Potential change in abundance and composition of BMI community in the Lime Creek watershed due to changes in water temperature	Potential water temperature changes in Lime Creek tempered by cool wet climate and attenuating effects of diverted headwater tributaries and natural run-off from the upper Lime Creek watershed	No
TMF surplus water, surface water and groundwater management, diversions, and Klitsault Pit over-flow	C, O, D/C, PC	Potential change in abundance and composition of BMI community in Lime Creek and Clary Creek watersheds due changes in stream flows	Reduction in stream flows may change the hydraulic conditions in Lime Creek and Clary Creek and alter the availability and suitability of instream habitat for the existing BMI communities present	Yes
Development of the TMF, seepage control ponds, and freshwater supply pipeline and pumps	C, O, D/C, PC	Potential change in abundance and composition of BMI community in Clary Creek watershed due to changes in lake levels	Predicted lake level changes are small and the resulting reduction in littoral area is also small due to steep sided bathymetry of the lake. Littoral BMI community of Clary Lake is likely limited by course substrates and steep gradient.	No

Note: C - construction; O - operations; D/C - decommissioning and closure interaction

6.7.5.11.2 Interaction Between Benthic Macro-Invertebrates and Other Past, Present or Future Projects / Activities

As mentioned in Section 6.7.5.8, the only past, present or reasonably foreseeable Projects with the potential to create potential cumulative effects on BMI communities in the Lime and Clary Creek watersheds are the past mining activities at Kitsault during the 1960's and 1970's and again during the early 1980s and the past and on-going mine exploration activities at the Bell Moly deposit (Table 6.7.5-31).

During the first mining operation, between 8 and 11 milllion tonnes of mine tailings were deposited directly into Lime Creek Watershed between 1963 and 1972. During the second mining operation, waste rock dumps were located adjacent to Patsy Creek and in the upper headwaters of the Patsy Creek watershed. While the high discharge and energy of Lime Creek has likely removed all or most of these tailings from Lime Creek, any residual effects of this past deposition and any residual effects of the former waste rock dumps would be reflected in the current BMI community of Lime Creek. This historic tailings deposition is considered a potential key interaction on the BMI community of Lime Creek.

Exploration of the Bell Moly deposit in the Clary Creek watershed has the potential to alter water quality and stream flows that may cumulatively affect BMI communities in Clary Lake. Clary Lake is the location where any potential residual effects from the Kitsault Project due to changes in water quality and stream flows would interact with any potential residual effects from mine exploration activities at the Bell Moly deposit. This is because the Bell Moly deposit is located in the headwaters of the northeast portion of the Clary Creek watershed and Clary Lake is where flows from the northeastern and south-eastern (i.e., including flows from Lake 901 and Lake 493) portions of the Clary Creek watershed meet.

Table 6.7.5-31: Assessment of Interaction Between Other Projects, Human Activities and Reasonable Foreseeable Projects with Benthic Macro-Invertebrates

	Historic land use					Representative current and future land use					Reasonably foreseeable projects
Potential effect	**Kitsault Mine and exploration**	**Kitsault Town site (on-going)**	**Alice Arm town site (on-going)**	**Previous mine operations**	**Previous mine exploration**	**Transportation and access**	**Mining exploration**	**Trapping and guide outfitting**	**Nisga'a Nation hunting, trapping, fishing and other uses**	**Aboriginal hunting, trapping, fishing and other uses**	**Northwest Transmission Line Project**
Potential change in abundance and composition of BMI community in Lime Creek and Clary Creek watersheds due to alteration or loss of habitat	-	o	NI	NI	NI	NI	o	NI	NI	NI	NI
Potential change in abundance and composition of BMI community in Lime Creek and Clary Creek watersheds due changes in surface water quality	-	o	NI	NI	NI	NI	-	NI	NI	NI	NI
Potential change in abundance and composition of BMI community in Lime Creek and Clary Creek watersheds due changes in stream flows	o	o	NI	NI	NI	NI	o	NI	NI	NI	NI

Note: Interaction definitions: o - interaction; - - key interaction; + - benefit; NI - no interaction

An assessment of the potential spatial and temporal overlap between potential residual effects of the Kitsault Project on BMI and other past, present, or reasonably foreseeable future Projects with potential residual effects that could cumulatively affect BMI is provided in Table 6.7.5-32.

Table 6.7.5-32: Assessment of Spatial and Temporal Overlap Between the Project and Other Projects and Human Actions with Benthic Macro-Invertebrates

	Human Activity	Residual Environmental Effect	Extent	Duration	Rationale	Cumulative Effect (Contribution from Project or Overlap)
Historical land use	Kitsault Mine and exploration	Potential change in habitat and water quality in Lime Creek due to deposit of mine tailings in the creek	Local	Chronic	Mine tailings potentially affected the BMI population in Lime Creek	Potential change in the abundance and composition of BMI in Lime Creek
	Kitsault Town site (on-going)	Channelisation of lower reaches of Lime Creek	Local	Chronic	Alteration of BMI habitat in lower Lime Creek potentially altered the abundance and composition of the BMI community	Potential change in the abundance and composition of the BMI community of Lime Creek
Representative current and future land use	Mining exploration	Potential change in water quality and stream flows entering Clary Lake	Local	Medium-term	Changes in water quality and stream flows may cumulative effect BMI community in Clary Lake	Potential change in the abundance and composition of the BMI community of Clary Lake

6.7.5.11.3 Mitigation Measures

There are no mitigation measures specifically proposed to eliminate potential cumulative effects of the Kitsault Project on BMI with residual effects from other past, present, or reasonably foreseeable future projects or land uses. The likely effectiveness of each of the mitigation measures that would be used to reduce Project effects on BMI have already been assessed above and it is only those Project effects with potential residual effects to BMI that are being assessed here for their potential interaction with potential residual effects from other past, present, or future projects in the Lime Creek or Clary Creek watershed.

Although not strictly a mitigation measure, an environmental effect monitoring program would be developed in consultation with Environment Canada, the BC MOE, and the NLG prior to construction of the Project. This monitoring program would be designed and implemented with two-fold purpose of: 1) assessing whether predictions made during the impact assessments are accurate; and 2) determining whether any unanticipated effects are occurring, and if so, to trigger the implementation of additional mitigation, adaptive management, and/or compensation as required.

Modern exploration operations must follow strict government permit requirements which include best management practices to reduce or eliminate potential effects to fish habitat downstream. This mitigation measure was likely to be highly effective at reducing the potential effect of changes in stream flows and water quality due to exploration at the Bell Moly deposit.

Table 6.7.5-33: Potential Cumulative Effect by Project Phase on Benthic Macro-Invertebrates and Mitigation Measures

Project Cumulative Effect	Project Phase	Mitigation / Enhancement Measure	Mitigation Success Rating
Loss of habitat in Patsy Lake and Patsy Creek in the Lime Creek watershed and in headwaters of Lake 901 in the Clary Creek watershed	C,O, D/C, PC	Minimise project footprint, limit footprint to headwaters of Lime and Clary creek watersheds, implement fish habitat mitigation and compensation plan	Low
Change in hydrology in Lime Creek and in Clary Creek	C,O, D/C, PC	Water management plan, diversion of water from Lake 493 to Lake 901, BMPs for mine exploration activities	Medium
Change in water quality in Lime Creek and in Lake 901	C,O, D/C, PC	Water management plan, water treatment plant at closure (if required), adherence to site-specific water quality objectives, BMPs for mine exploration activities	Medium

Legend: C - construction; O - operations; D/C - decommissioning and closure; PC - post-closure

6.7.5.11.4 Potential Residual Cumulative Effects and Their Significance

6.7.5.11.4.1 Historic mining at Kitsault

Although no pre-mining data exists, deposition of mine tailings in Lime Creek during the first mining operation at Kitsault likely had a significant effect on the BMI community of Lime Creek. This effect would likely have been caused by changes in stream flows but more significantly, by the increase in sedimentation and the increase in metal concentrations in the water and sediments.

There is no obvious physical evidence of these tailings in Lime Creek today. It has been over 40 years since this deposition occurred and, given the high discharge and energy of Lime Creek, most, if not all, of these tailings have likely been carried downstream to Alice Arm. Nevertheless, residual effects on the BMI community may remain and these would be reflected in the current baseline condition of the BMI community in Lime Creek. As indicated in Section 6.7.5.6, this community is currently dominated (>90% of the total BMI community in upper and lower Lime Creek) by stonefly and mayfly larvae. These taxa are generally indicative of habitat with good water quality as they are more generally more sensitive to elevated metals, increased sediments, and lower dissolved oxygen concentrations than other taxa such as chironomids and oligochaetes. Therefore, while it is impossible to know what the BMI community of Lime Creek was before mine began in the 1960's and what potential residual effects on the BMI community of Lime Creek remain, the current BMI community suggests that any past residual effects are negligible. This is because the current BMI community of Lime Creek is not substantially different from one that would be expected in a similarly steep, high energy, north coastal stream with course substrates. Potential cumulative effects on the BMI community of Lime Creek due to past mining activities at Kitsault are expected to be not significant (minor) as a result (Table 6.7.6-33).

6.7.5.11.4.2 Kitsault town site

Channelisation of the lower 270 metres of Lime Creek in the 1970s likely reduced the amount of habitat available for BMI production. This is because the number of channels in the former Lime Creek delta was reduced to one single channel. This channel was armoured with rip-rap along its banks and the channel now conveys water straight to Alice Arm. Water depths and water velocities in this channel are likely higher than they were in braided channels of the former delta.

The residual effect from channelisation of the lower reach of Lime Creek is unlikely to create a significant residual cumulative effect on BMI in Lime Creek. This is because the amount of habitat lost during channelisation was relatively small in comparison to the habitat remaining in the Lime Creek watershed and because the remaining channel provides suitable habitat for many BMI taxa and, therefore, likely offsets some of the lost habitat due to channelisation. A negligible, not significant cumulative effect was expected as a result (Table 6.7.5-34).

6.7.5.11.4.3 Mine exploration in the Bell Moly deposit

Potential cumulative effects on BMI in Clary Lake due to the Kitsault Project and on-going exploration activities at the Bell Moly deposit are unlikely to occur. This is because the amount of water needed for modern drilling is negligible in comparison to the volume of run-off entering Clary Lake at any given time of year and because modern drilling guidelines and best management practices would effectively eliminate potential deposits of hydrocarbons, drill cuttings, and other contaminants into the upper Clary Creek watershed. Any potential residual effect to BMI in Clary Lake would be not significant (negligible) as a result.

Table 6.7.5-34: Summary of Residual Cumulative Effects for Benthic Macro-Invertebrates

Project Phase	Residual Cumulative Effect After Mitigation or Enhancement	Direction	Likelihood of Occurrence
C,O, D/C, PC	Change in abundance and composition of BMI community due to alteration of habitat in the Lime Creek watershed due to the Kitsault Project and past habitat alteration in lower Lime Creek during previous Kitsault mine operations	Negative	Likely
C,O, D/C, PC	Change in abundance and composition of BMI community due to potential change in water quality in Lime Creek due to the Kitsault Project and past mine tailings deposit during previous Kitsault mine operations	Negative	Likely
C,O, D/C, PC	Change in abundance and composition of BMI community due to potential change in hydrology in Lime Creek due to the Kitsault Project and past mine tailings deposit during previous Kitsault mine operations	Negative	Likely
C,O, D/C, PC	Change in abundance and composition of BMI community in Clary Lake due to changes in water quality and stream flows due to the Kitsault Project and from on-going mine exploration at the Bell Moly deposit	Negative	Unlikely

Legend: C - construction; O - operations; D/C - decommissioning and closure; PC - post-closure

An assessment of the significance of potential cumulative effects on BMI communities in Lime Creek and in Clary Lake due to past, present, or reasonably foreseeable projects and land uses is provided in Table 6.7.5-35 below. All three potential sources of cumulative effects on BMI in Lime Creek due to past mining and the town of Kitsault were assessed to have a negligible effect on Lime Creek BMI. The Kitsault Project was assessed to have a not significant minor cumulative effect on BMI in Lime Creek due to changes in water quality, stream flow, and habitat.

Table 6.7.5-35: Residual Cumulative Effects Assessment on Benthic Macro-Invertebrates by Project Development Phase

Parameter	Current / Future Cumulative Environmental Effect(s) Without Project	Project Contribution Cumulative Environmental Effect	Project Phase
Change in abundance and composition of BMI community due to alteration of habitat in the Lime Creek watershed due to the Kitsault Project and past habitat alteration in lower Lime Creek during previous Kitsault mine operations			C,O,D/C, PC
Effect Attribute			
Direction	Negative	Negative	

Parameter	Current / Future Cumulative Environmental Effect(s) Without Project	Project Contribution Cumulative Environmental Effect	Project Phase
Magnitude	Low	Low	
Geographic extent	local	Local	
Duration	chronic	Chronic	
Frequency	continuous	Continuous	
Reversibility	no	No	
Probability of occurrence	Unknown	High	
Certainty	low	High	
Residual Effect Significance	Not significant (negligible)	Not significant (minor)	
Level of Confidence	Low	High	
Change in abundance and composition of BMI community due to potential change in water quality in Lime Creek due to the Kitsault Project and past mine tailings deposit during previous Kitsault mine operations			C,O,D/C, PC
Effect Attribute			
Direction	Negative	Negative	
Magnitude	Low	Moderate	
Geographic extent	local	Local	
Duration	chronic	Chronic	
Frequency	continuous	Continuous	
Reversibility	no	No	
Probability of occurrence	Unknown	High	
Certainty	low	High	
Residual Effect Significance	Not significant (negligible)	Not significant (minor)	
Level of Confidence	Low	High	
Change in abundance and composition of BMI community due to potential change in hydrology in Lime Creek due to the Kitsault Project and past mine tailings deposit during previous Kitsault mine operations			C,O,D/C, PC
Effect Attribute			
Direction	Negative	Negative	
Magnitude	Low	Low	
Geographic extent	local	Local	
Duration	chronic	Long-term	
Frequency	continuous	Continuous	
Reversibility	no	Yes	
Probability of occurrence	Unknown	High	
Certainty	low	High	

Parameter	Current / Future Cumulative Environmental Effect(s) Without Project	Project Contribution Cumulative Environmental Effect	Project Phase
Residual Effect Significance	Not significant (negligible)	Not significant (minor)	
Level of Confidence	Low	High	

Note: C - construction; D/C - decommissioning and closure; O - operations; PC - post-closure

6.7.5.12 Limitations

Like the salmonid species in Lime Creek and Clary Creek watersheds, the assessment of potential project-specific and cumulative effects on BMI is dependent on results of quantitative modelling conducted to determine the potential changes in surface water quality and stream flows and on qualitative assessment of the potential effects of changes in water temperatures and benthic invertebrates in Lime Creek Watershed. Models are predictions of future events. They are useful because they provide a means of predicting future conditions that would otherwise not be possible without actually imposing the effect on the environment and monitoring changes in the receptors. As such, the accuracy of any model's predictions are dependent on the quality of the input data, the accuracy of calibrated model to predict existing conditions, and the number and validity of the assumptions included in the model.

Although all of the models used to predict changes in surface water quality and stream flows were calibrated using real data, each model had limitations on the available input data (e.g., using regional data sets to calibrate site-specific watershed models) and had necessary assumptions (e.g., all the dissolved metals remain in solution and do not form more complex compounds that would make them biologically unavailable) that may have affected the accuracy of the models to predict future conditions. The limitations and assumptions for each of these models are described in greater detail in Section 6.5 (Hydrology) and Section 6.6 (Surface Water Quality).

Most critically to the assessment of potential effects of the Project on BMI, was the uncertainty regarding the effect of the predicted exceedences of existing provincial and federal water quality guidelines for the protection of freshwater aquatic biota for a number of potential chemicals of concern (e.g., selenium, arsenic) in Lime Creek and Clary Watersheds. Taken at face value, these predicted exceedences would result in significant adverse effects to BMI health, growth, and survival, and to the aquatic food-webs upon which they depend. However, as the assessment above explains, some of these guidelines may be overly protective and site-specific water quality guidelines may be more appropriate. Methods to arrive at some these alternative site-specific water quality guidelines have been provided in this assessment. The BC MOE and the CCME acknowledge that site-specific water quality guidelines for certain chemicals of concern may be more appropriate than existing provincial and federal guidelines depending on site-specific conditions. Both agencies provide guidance on how these guidelines could be derived (McDonald et al. 1997; CCME 2007).

The proponent is committed to working with Environment Canada, the BC Ministry of Environment, and the NLG to derive more appropriate site-specific water quality objectives where warranted and to develop any additional mitigation measures necessary to avoid potential changes in surface water quality in Lime Creek and Clary Creek Watersheds downstream of the pit and TMF.

6.7.5.13 Conclusion

Potential effects to the abundance and composition of BMI communities in Lime Creek and Clary Creek watersheds exist because of potential changes to habitat, predicted changes in surface water quality and stream flows, and potential changes in water temperature.

The TMF, East WRMF, and Open Pit would result in the loss of Patsy Lake and Patsy Creek in the Lime Creek watershed and the two headwater tributaries of Lake 901 in the Clary Creek watershed. These losses will affect the BMI production and benthic invertebrate drift entering Lime Creek and Lake 901. Some of this lost production and drift may be partially offset by habitat enhancement in the Clary Creek watershed. However, some loss of BMI production and drift can be expected. Such losses would not be expected to have a significant effect on the overall BMI community or drift in the Lime Creek or Clary Creek watersheds.

Mitigation measures to reduce or eliminate potential indirect effects on BMI due to changes in water quality and stream flows include implementation of the mine water management plan, potential water treatment during post-closure, and adherence to any site-specific water quality objectives that may be promulgated by the proponent during consultations with Environment Canada, the BC Ministry of Environment and the Nisga'a Lisims Government. Additionally, a diversion channel would be constructed between Lake 493 and Lake 901 in the Clary Creek watershed to mitigate potential flow reductions, lake level fluctuations and water quality effects in Lake 901 caused by construction and operation of the TMF.

While the mitigation measures proposed would not likely eliminate all potential effects to the BMI communities in both watersheds, the significance of any residual effects were assessed to be not significant. These significance ratings were based on the facts that each direct or indirect potential effect would likely have a local effect, a low ecological context, and/or a low magnitude.

Potential cumulative effects to BMI due to potential residual effects of the Project and potential residual effects of other past, present, or reasonably foreseeable future project or land uses were considered negligible or low. This included potential cumulative effects from past mining at Kitsault and its potential residual effect on habitat, water quality and stream flows and the Kitsault townsite and its potential residual effect on habitat in the lower Lime Creek delta. Potential residual effects from these to past projects were determined to be negligible and therefore the potential cumulative effect on BMI from the Kitsault Project was determined to be minor. No potential cumulative effects from on-going exploration of the Bell Moly Project would occur.