5.0 EFFLUENT IMPACT ASSESSMENT

5.1 Water Quality Criteria

The BC Provincial Water Quality Guidelines (BC PWQG) for the protection of freshwater aquatic life was used to evaluate the existing baseline surface water quality. The conclusions of the 2006-2007 baseline water quality are discussed in detail in Section 4.6.2 of this application, or for further evaluation see the Time Series Plots (Figure 3-1 to 3-13) for the various parameters within the document *Yellowjacket Gold Project – Baseline water Quality Conditions (2006-2007 Monitoring), Lorax March 2009* – Appendix D. The Yellowjacket Project surface water sample parameters and detection limits are shown in Table 2-5 of this same report, which are the same as the proposed parameters noted in Table 6.3 of this application.

In overview, the 2006-2007 data highlight the extremely dynamic nature of Pine Creek, on both seasonal and inter-annual time scales. Within a given year, water quality conditions exhibit marked changes largely in accordance with changing flow conditions. On a year-to-year basis, the contrasts between the freshet signatures of 2006 and 2007 show how both sampling methods (weekly sampling in 2007 freshet in comparison to monthly in 2006) and flow can affect the observed distributions of water quality parameters.

In summary of the baseline data, seasonal changes in flow conditions exert the dominant influence on water quality variability in Pine Creek. During the course of a year, the relative proportion of groundwater (more saline) and surface runoff (less saline) changes, resulting in significant variations in the concentrations of major ions. At the onset of freshet (mid April through May), it is predicted that the initial flushing of soluble weathering products from within the extensive alluvial/placer deposits can account for the pronounced seasonal maxima in stream conductivity. During peak freshet flows, the dilutionary effect from snow melt outweighs the effect of this loading mechanism, resulting in pronounced salinity minima.

Seasonal variability in stream flow also governs stream turbidity, as well as the concentrations of parameters which are associated with suspended sediments. TSS/turbidity values during freshet greatly exceed aquatic life guidelines, with station maxima ranging from 411 mg/L (PC-1) to 2,850 mg/L (PC-5). Turbidity/TSS 30-day guidelines are also periodically exceeded outside the freshet period in the downstream reaches of Pine Creek. The highly turbid environment within Pine Creek is predicted to greatly limit habitat values for aquatic biota (*e.g.,* periphyton, fish). The effect of high stream turbidity is also evident for numerous other parameters which are associated with particulate phases, including total phosphate, total cyanide and trace metals.

For most metals, the seasonal distribution of total values follow a pattern similar to that observed for TSS/turbidity, where maximum values are encountered during periods of high flow and high TSS concentrations. The exceptions to this include elements such as uranium and molybdenum which are dominantly associated with filterable (dissolved) phases. Total metals that occasionally exceed maximum BC PWQG values include arsenic, cadmium, chromium, cobalt, copper, iron, lithium, lead, manganese, mercury, nickel, silver, titanium, thallium, vanadium and zinc.

5.1.1 Aquatic Life Impact Criteria

There are several indicator parameters for potential mine-impacted water qualities for this project, which may adversely affect aquatic life at the Yellowjacket Gold Project, especially during high flow periods when there high TSS and high turbidity levels. Baseline water quality assessments indicated that the highly turbid environment within Pine Creek is predicted to greatly limit habitat values for aquatic biota (*e.g.,* periphyton, fish). It is expected at this time to that the protection of benthic invertebrate might become the receiving environment criteria applicable for this project. However, to date no benthic invertebrate studies have been conducted at the Yellowjacket Gold Project, so as part of the 2009 monitoring program the Yellowjacket JV will undertake a benthic invertebrate evaluation downstream of the project area, in order to gather data on the aquatic biota.

As noted in Section 4.6.2, the BC Provincial Water Quality Objectives (BCWQOs) for the protection of aquatic life are typically only exceeded during freshet, when total metal levels are largely governed by the concentration of suspended particulates. Given the reduced bioavailability of particulate metals in comparison to dissolved species, the elevated concentrations during freshet are not predicted to contribute to metal toxicity. Rather, high TSS and high turbidity levels at this time are predicted to pose the greatest limitation on the aquatic biota.

The fishery studies completed to date indicate only two (2) species of fish; slimy sculpin *(Cottus cognatus)* and Arctic grayling *(Thymallus arcticus)* are confirmed within the upper Pine Creek watershed beyond the Pine Creek Falls. Of these species only slimy sculpin are believed to inhabit the waters of Pine Creek within the project area. For more information see Section 4.5.5 of this application.

5.2 Assimilation Zone Description

The surficial (alluvial) gravels that cover the entire project area with its surface (groundwater) flowing through them, and Pine Creek which flow through the projects will make up the assimilation zone. For Pine Creek the proposed initial boundaries for the assimilation zone, would go between PC-6 a monitoring point (point within 200 m of the effluent discharge point) and PC-2 the proposed receiving environment monitoring point where maximum effluent quality will need to meet criteria.

Based on the baseline water quality data to date for the Yellowjacket Gold Project, there are several parameters that naturally exceed the maximum BCWQOs.

Therefore, the approach to assessing potential water quality impacts for this project will need to consider the anticipated effluent quality and quantity during the appropriate high flows and high TSS conditions that exist during spring freshet and fall rains.

At this time, site specific data is limited, therefore the Yellowjacket JV completed a statistical assessment of the baseline water quality data that has been collected for station PC-2 in Pine Creek from 2006-2007, and will used this evaluation to determine site specific water quality objectives (SSQWOs). The results of this assessment are detailed in the following Section 5.5 of this application.

5.2.1 Initial Assimilation Zone and Proposed Receiving Environment Monitoring Site

Site PC-6 (UTM 6607095 581671) is located 200 m downstream of the mine related effluent discharges; it will be the near field site and will be at the initial edge of the assimilation zone. The water quality monitoring at this site only started in March 2009, so there is insufficient data at this time to make it a standalone monitoring station. Therefore, the Yellowjacket JV is proposing PC-2 (UTM 6606370 580635) as the far field monitoring station for the project receiving environment. This site is downstream of all mine related influences, is well upstream of fish-bearing habitat and is the first monitoring location below PC-6 that was regularly monitored as part of the baseline environmental program.

However there is a potential issue in using PC-2, it is that there is a probability of a placer mining operation being located between the Yellowjacket Gold Project and PC-2 in 2009. It is not known for certain that this activity will occur or that it would impact the water quality results, but there might be questions surrounding the validity of the results from PC-2 during any placer mining activities.

The Yellowjacket JV has decided to continue to use and monitor PC-2 until such time that impacts from other sources (i.e. placer mining) do occur, and will then consider moving the site upstream towards the project area away from the placer mining activities. The Yellowjacket JV does not want to move the site at this time, as there is fifteen (15) months of baseline water quality data results from this particular site and that this site data is being utilized for development of interim SSWQOs for the project.

PC-2 is located approximately 3.1 km upstream of the known fish-bearing habitat (Pine Creek Falls- Fish Barrier) and 2.0 km downstream of the project area, as noted PC-6 is positioned 200 m downstream from the point that is estimated where all mine related impacts will enter Pine Creek via exfiltration from the surficial gravels.

5.3 Explosives Residues

At this time the Yellowjacket JV is not anticipating using any explosives for the mining of the bedrock. Excavation work in 2007 of the bulk sample provided significant evidence that the bedrock material can be easily excavated down to at least 7.5 metres without the use of explosives. However, in the future if explosive use is required then a plan to use and store explosives would need to be developed. As well the Yellowjacket JV would need to evaluate the amount of nitrogen losses from the blasting, so they would use one of the following methods developed by (Pommen (1983), and/or Ferguson and Leask (1988)) that are available to estimate nitrogen (N) losses. These two studies investigated the nitrogen loads present in waters associated with surface mines to formulate empirical relationships between the quantity of nitrogen-bearing explosives used at mine sites and their effect on the quality of the downstream waters. The more conservative Pommen formula for nitrogen loss would probably be selected for the Yellowjacket Gold Project analysis.

5.4 Water Quality Impact Predictions

It is expected that a site influenced groundwater plume comprised of tailings, open pit and stockpile effluents, will exfiltrate through the surficial gravels in a downstream direction until it eventually enters Pine Creek.

In Section 3 of this application the three (3) effluents associated with the Yellowjacket Gold Project are detailed, and they are specifically:

- Open pit mine water (referred to as "pit water effluent"), allowed to infiltrate into the surrounding surficial materials from a downstream settling pond;
- Tailings pond supernatant (referred to as "tailings supernatant effluent"), which will infiltrate into the surrounding surficial gravels that make-up the containment, and
- Discharge from waste and mineralized stockpiles (referred to here as "stockpile effluent"), which will infiltrate directly into the surrounding surficial materials that make-up their bases.

As indicated previously placer mining is proposed downstream of the Yellowjacket Gold Project, but there is a chance as well that placer mining activities could be initiated upstream, and these would have a potential to impact water quality in Pine Creek downstream of the Yellowjacket site.

However, the 2006 – 2007 baseline water quality monitoring program did not capture any impacts from placer mining, so the current approach to Pine Creek impact predictions resulting from operations at the Yellowjacket Gold Project are based on the case where placer mining operations are not operating on Pine Creek. However, if placer operations commence upstream of PC-2, the impacts from these operations will have to be considered in water quality predictions as well as the water quality monitoring program that is outlined in Section 6.1 of this application.

In March 2009 the Yellowjacket JV initiated water chemistry analysis and monitoring of the pit water (discharge) effluent and the tailings solids which had not been previously characterized are now undergoing ML/ARD characterization and grain size characterization analyses. On project start-up in 2009, the company will initiate water chemistry analysis and monitoring of the tailings supernatant effluent. Additionally, static and kinetic characterization will be conducted on stockpile materials generated during the bulk sample program to obtain data on discharge water quality. These three (3) site source terms will then be combined with water balance calculations and baseline water quality monitoring data to predict the downstream water quality impacts to Pine Creek.

While it is understood that the quality of site affected groundwater entering Pine Creek may be of better quality than process plant discharge water, due to attenuation mechanisms within the surficial (alluvial) gravels, the water quality measured during tailings pond water quality monitoring will be used to conservatively approximate the composition of this site contact water.

As well, it should again be noted that based on the 2006 - 2007 ML/ARD characterization and baseline water quality programs, it is anticipated that all effluent(s) will be of an acceptable water quality for the receiving environment.

5.5 Proposed Effluent Criteria

The information presented in this section comes exclusively from the *Pine Creek Water Quality Impact Predictions and Receiving Environment Monitoring Point Objective Memorandum, Lorax Environmental Service Inc., April 9, 2009* - Appendix J.

Summary statistics for baseline water quality data collected from station PC-2 in Pine Creek from 2006 –

2007 are presented in Table 5.1, including minimum, maximum, 90th percentile, mean, and median values. As well, BCWQOs are included in this table for comparative purposes. These data indicate that the maximum and 90th percentile concentrations of a large number of parameters naturally exceed the maximum BCWQOs during periods of high TSS and high flow. Therefore, site specific water quality objectives (SSWQOs) need to be developed in order to accurately detect impacts to Pine Creek as a result of operations at the Yellowjacket Gold Project.

The methods for deriving SSWQOs published by the BC Ministry of Environment (MacDonald, 1997) recommend that the applicability of SSWQOs for the protection of aquatic life be evaluated in comparison to:

- The background levels of the contaminant;
- The limit of quantification (i.e. analytical detection limit) for the substance;
- The applicability to the site under consideration of the toxicological information that was used to derive the generic WQOs; and,
- The processes and levels of substances that could affect the bioavailability of the contaminant (if these were not accounted for in the derivation of the BCWQOs).

The baseline data for PC-2, summarized in Table 5.1, show that background concentrations of numerous total metals are greater than the BCWQO values during periods of high suspended sediment loads, including aluminum (dissolved), arsenic, cobalt, copper, lead, manganese, nickel, silver, vanadium, and zinc (Figure 1; *Yellowjacket Gold Project – Baseline Water Quality Conditions (2006—2007) Monitoring), Lorax Environmental Services Inc., March 2009* – Appendix D. When 90th percentile values are considered, this list is reduced to aluminum (dissolved), cobalt, copper, nickel, silver, vanadium, and zinc (Table 5.1). Therefore, SSWQOs are required for these elements that would apply during periods of elevated TSS (freshet and storm events).

Table 5.1
2006 – 2007 Pine Creek Baseline Water Quality Data at PC-2 compared to BC Water Quality Guidelines for the protection of aquatic life

				Baseline Summary (May-06 to June-07)					Guideline[1]	
Parameters	units	#	#<DL	min	max	90th Percentile	mean	median	30-day mean	Max
Physical Parameters										
Hardness	mg $CaCO_3$/L	19	0	46.2	104	101.2	66.5	56.8		
pH	pH	19	0	7.81	8.21	8.2	8.02	8.02	6.5-9	NP
TSS	mg/L	19	3	<3	620	110.2	63.7	11.6		
Turbidity	NTU	17	0	0.97	419	91.72	45.6	8.33		
Anions										
Chloride	mg/L	19	18	<0.5	1.29	<0.5	<0.5	<0.5	150	600
Sulphate	mg/L	19	0	3.53	6.66	6.34	4.85	4.64	NP	100
Fluoride	mg/L	12	0	0.271	0.722	0.71	0.545	0.568	NP	0.3
Nutrients										
Ammonia Nitrogen[2]		19	16	<0.005	0.028	0.0068	0.00653	<0.005	0.37	1.9
Nitrate Nitrogen	mg/L	19	2	<0.005	0.0471	0.044	0.0242	0.0244	40	200
Nitrite Nitrogen[3]	mg/L	19	18	<0.001	0.0019	<0.001	0.00105	<0.001	0.02	0.06
Cyanides										
WAD Cyanide	mg/L	5	5	<0.001	<0.001	<0.001	<0.001	<0.001	5	10
Total Metals										
Aluminum - Dissolved	mg/L	19	0	0.0044	**0.586**	**0.156**	**0.0776**	0.0207	0.05	0.1
Antimony	mg/L	19	14	<0.0001	0.0004	0.00032	0.00015	<0.0001	NP	0.02*
Arsenic	mg/L	19	1	0.0005	0.00894	0.0033	0.00168	0.00087	NP	0.005*
Boron	mg/L	19	19	<0.01	<0.1	<0.01	<0.01	<0.01	NP	1.2
Cadmium[4]	mg/L	19	10	<0.000017	0.000298	0.000117	0.0000584	0.000023	NP	0.000018*
Chromium	mg/L	19	2	<0.0005	0.0887	0.031	0.0122	0.00219	NP	0.001*
Cobalt	mg/L	19	4	<0.0001	**0.0203**	**0.0059**	0.00255	0.00078	0.004	0.11
Copper[4]	mg/L	19	0	0.00058	**0.0335**	**0.0105**	**0.00504**	0.00175	0.002	0.007
Iron	mg/L	19	0	0.063	20.3	4.94	2.41	0.432	NP	0.3*
Lead[4]	mg/L	19	3	<0.00005	**0.00685**	0.00157	0.000833	0.000278	0.005	0.034
Lithium	mg/L	19	18	<0.005	0.0102	0.00604	0.00529	<0.005	NP	0.014*
Manganese[4]	mg/L	19	0	0.0033	0.419	0.1138	0.0561	0.0212	0.825	1.09
Mercury	mg/L	18	17	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00002	0.0001
Molybdenum	mg/L	19	0	0.00127	0.00315	0.00296	0.0024	0.00241	1	2
Nickel[4]	mg/L	19	0	0.00266	0.25	0.0778	0.0338	0.0112	NP	0.025
Selenium	mg/L	19	10	<0.0005	0.001	0.000858	0.000624	<0.0005	0.002	NP
Silver[4]	mg/L	19	12	<0.00001	**0.000126**	**0.0000664**	0.0000284	<0.00001	0.00005	0.0001
Thallium	mg/L	19	18	<0.0001	0.00015	0.00011	0.000103	<0.0001	NP	0.0003*
Titanium	mg/L	19	11	<0.01	0.614	0.178	0.0796	<0.01	NP	2*
Uranium	mg/L	19	0	0.00213	0.00309	0.00306	0.0026	0.00253	NP	0.3*
Vanadium	mg/L	19	8	<0.001	0.0358	0.01096	0.00552	0.0013	NP	0.006*
Zinc[4]	mg/L	19	7	<0.001	**0.0426**	**0.01102**	0.00633	0.0019	0.0075	0.033

Notes:
* Indicates Working Guideline
[1]BC Provincial Guidelines for Protection of Aquatic Life (BC MOE, 2006a);
[2]Guideline based on pH = 8.5 and temperature= 15°
[3]Guideline based on [chloride] <2 mg/L
[4]Guidlines based on a hardness of 50 mg $CaCO_3$/L;
- NP denotes 'None Proposed'; **bold** values indicate exceedences of 30 day mean BC PWQO, shaded values indicate exceedences of maximum BC PWQO,
- Statistics were calculated assuming undetectable values equal to the detection limit.
- DL = detection limit

A comparison of Pine Creek baseline water quality data from 2006 to 2007 have been used to develop SSWQOs for aluminum (dissolved), cobalt, copper, nickel, silver, vanadium, and zinc based on the following criteria (Table 5.2):

- If the 90th percentile value exceeds the maximum BCWQO, as outlined in Table 5.1, the proposed SSWQO is based on the 90th percentile baseline value between May 2006 and June 2007 plus 20%. The additional 20% provides a reasonable estimate of the maximum variation in concentrations that would be measured under typical natural high-flow and high suspended load conditions;
- If the 90th percentile value is less than the maximum BCWQO, but greater than the 30-day chronic BCWQO, the maximum BCWQO is adopted during high-flow and high suspended load conditions;
- If the 90th percentile value is less than both the maximum and 30-day BCWQOs, the BCWQOs are applied; and
- During clear flow periods (i.e. low flow and low TSS), the SSWQOs for these metals will be equal to the generic BCWQOs listed in Table 5.1.

Additionally, there are a number of other parameters that appear to exceed BCWQOs throughout the year, including fluoride, cadmium, chromium, and iron (Figure 5.2). Site specific water quality objectives were developed for these parameters using the following criteria (Table 5.2):

- For fluoride, the proposed SSWQO is set at the 90th percentile value plus 20% to account for natural variation due to high-flow and high TSS conditions. This SSWQO is applicable all year as the high fluoride concentrations are observed during clear flow periods (Figure 5.2).

For cadmium, the proposed SSWQO is based on the USEPA (2001) hardness dependent guideline

$$=0.938[e^{(0.7409[\ln(\text{hardness})]-4.719}]$$

  - During high flow and high TSS conditions, it is proposed that the SSWQO be based on a hardness value of 100 mg CaCO3/L; and
  - During clear flow periods, it is proposed that a hardness value of 60 mg CaCO3/L be used.
- For iron and chromium, the proposed SSWQO is equal to:
  - the 90th percentile value + 20% during high-flow and high TSS conditions; and
  - The median (50th percentile) value + 20% during clear flow periods.

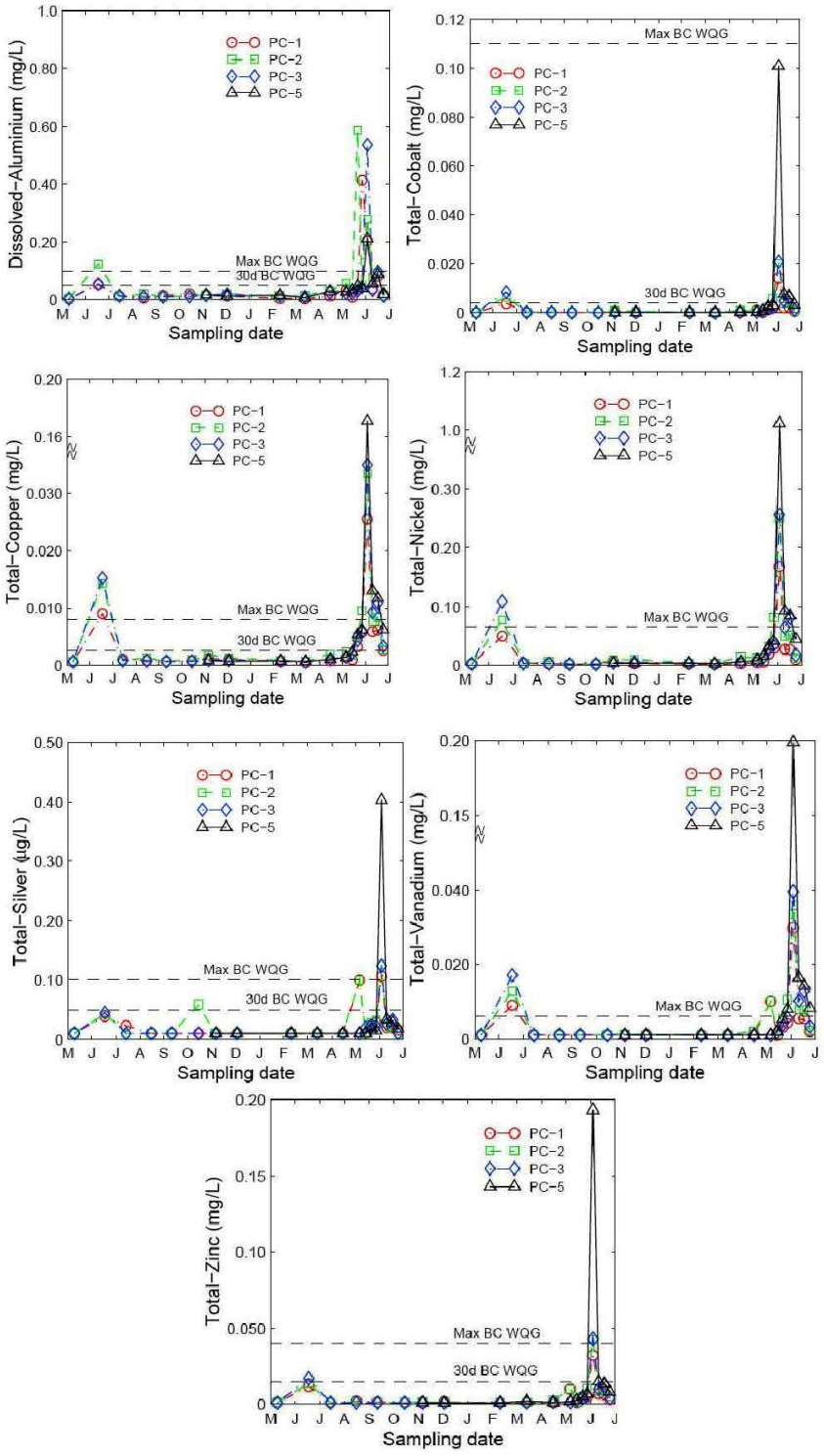

Figure 5.1 - Time series plots for aluminum (dissolved), total cobalt, total copper, total nickel, total silver, total vanadium and total zinc at station PC-2 in Pine Creek from May 2006 to June 2007

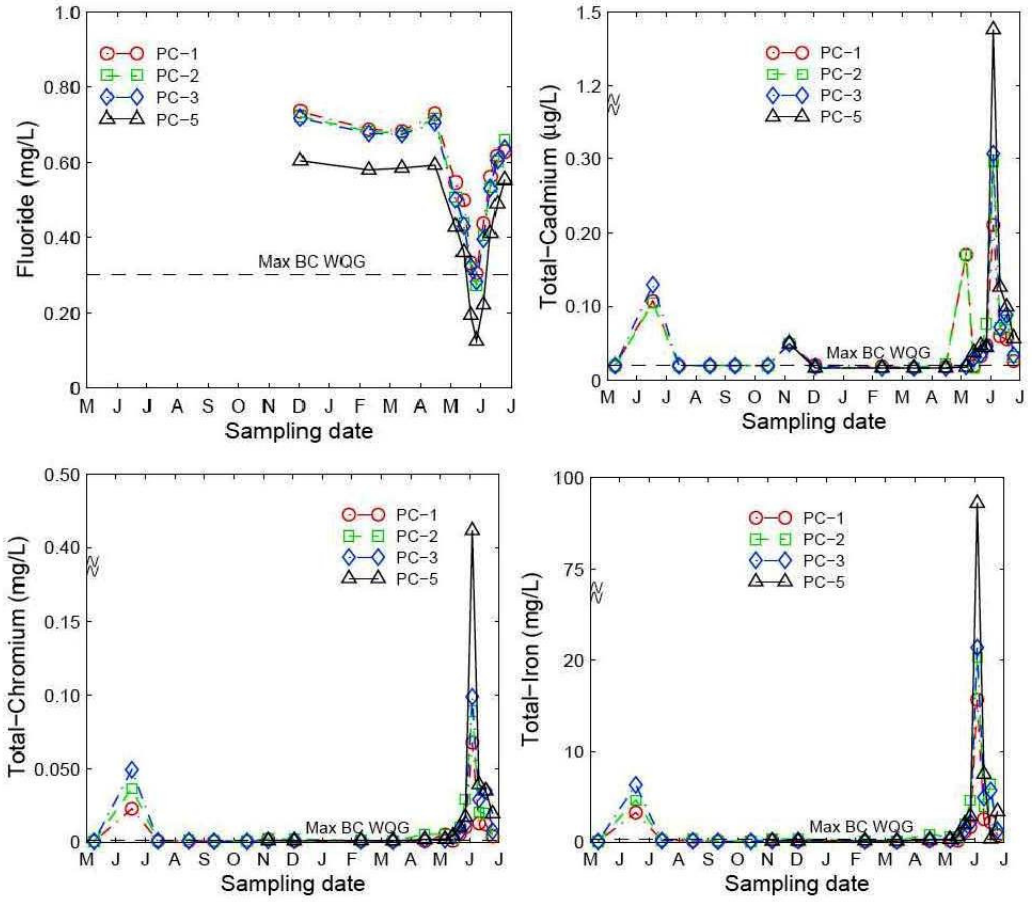

Figure 5.2 - Time series plots for fluoride, total cadmium, total chromium, and total iron at station PC-2 in Pine Creek from May 2006 to June 2007

Although the proposed preliminary SSWQOs are intended to cover a majority of flow conditions and concentrations encountered within Pine Creek, extremely high sediment loads occur naturally during peak flows due to entrainment of fine grained material from the alluvial gravels comprising the stream bed. Therefore, it is expected that during periods of high flow within Pine Creek, the proposed SSWQOs will be exceeded as a result of elevated TSS concentrations. This, however, will not necessarily indicate impacts from mining activity at the Yellowjacket Gold Project and care should be taken to properly interpret elevated concentrations during high-flow and high TSS conditions and ensure that the context of the increases is understood. As well, it should be noted that these preliminary SSWQOs have been proposed in the absence of water quality impact predictions. Once impact predictions are available, the proposed SSWQOs should be reevaluated, through discussions with MOE, to ensure that they appropriately detect mining related impacts while ensuring the protection of Pine Creek water quality.

Table 5.2:
Proposed preliminary site-specific water quality objectives for station PC-2 in Pine Creek

Parameters	units	Baseline 90th Percentile	Baseline Median Value	High Flow/TSS SSWQO[1]	Clear flow/low TSS SSWQO[2]	
					30-day Mean	Max
Anions						
Fluoride	mg/L	0.71	0.568	0.852[A]	NP	0.852[A]
Total Metals						
Aluminum - Dissolved	mg/L	0.156	0.0207	0.187[A]	0.05[D]	0.1[C]
Cadmium	mg/L	0.000117	0.000023	0.00026[B]	NP	0.00017[E]
Chromium	mg/L	0.031	0.00219	0.0372[A]	NP	0.0026[F]
Cobalt	mg/L	0.0059	0.00078	0.113[C]	0.004[D]	0.11[C]
Copper	mg/L	0.0105	0.00175	0.0126[A]	0.002[D]	0.007[C]
Iron	mg/L	4.94	0.432	5.93[A]	NP	0.52[F]
Nickel	mg/L	0.0778	0.0112	0.0934[A]	NP	0.025[C]
Silver	mg/L	0.0000664	<0.00001	0.0001[C]	0.00005[D]	0.0001[C]
Vanadium	mg/L	0.01096	0.0013	0.0132[A]	NP	0.006[C]
Zinc	mg/L	0.01102	0.0019	0.033[C]	0.0075[D]	0.033[C]

[1] Applicable during naturally high flow and high TSS conditions
[2] Applicable during clear flow and low TSS conditions
[A] = 90th percentile value * 1.2
[B] = based on USEPA (2001) using Hardness = 100 mg $CaCO_3$/L
[C] = Maximum BC WQO from Table 1
[D] = 30-day mean BCWQO from Table 1
[E] = based on USEPA (2001) using Hardness = 60 mg$CaCO_3$/L
[F] = median value * 1.2
NP = none proposed

6.0 PROPOSED MONITORING

The proposed monitoring and surveillance programs have been designed to ensure that all regulatory permitting requirements are met by the Yellowjacket JV. Information in this section is exclusively from *2009 Yellowjacket Water Quality and Waste Sampling Program Memorandum, Lorax Environmental Inc., March 10, 2009* - Appendix I.

The 2009 proposed environmental monitoring and surveillance programs will include:

- Surface Water Quality - Sampling and Analysis;
- ML/ARD – Mineralized, waste rock, and tailings -Sampling and Analysis;
- Field leach bin - Construction and sampling; and
- Benthic Invertebrate studies

Additional hydrology and hydrogeology assessment(s) are planned for in 2009 by the Yellowjacket JV as part of the water balance program. Following the water balance work, there may be a requirement to initiate a monitoring program for the data collection. In Sections 4.3 and 4.6 of this application there is some detailed information on both hydrology and hydrogeology.

6.1 Surface Water Quality Monitoring

The Yellowjacket Gold Project currently has in place all infrastructural components required for development of this deposit, including stockpiles, tailings (sedimentation) pond, settling pond, process plant and an a small open pit. Future developments will not involve a significant increase in the mine footprint area or have extensive volume of waste materials which are eventually planned to be stored sub-aerially at site. Previous geochemical characterization of Yellowjacket Zone lithologies indicates that waste materials are non-acid generating (NAG), but neutral-drainage metal leaching may be an issue so additionally characterization and monitoring will be required for the site. Due to the2006-2007 ML/ARD results, mine site drainage is not expected to be significantly impacted as a result of the proposed development plans for the site. Further, the current discharges from site are largely indicative of what will be encountered from future development. Therefore, quantifying the current level of impact from the bulk sample pit, small stockpiles and tailings/sediment ponds will provide robust information in support of the effects assessment required for this Effluent Discharge Permit Application.

Therefore, it is proposed that the 2009 surface water quality monitoring program involve collection of surface water samples from the following locations:

- Pine Creek (4 stations: PC-1, PC-2, PC-6 - located approximately 200 m downstream of mine site, and PC-5);
- Existing Bulk Sample Pit effluent discharge (BS Pit); and
- Tailings facility effluent discharge (TSF)

Collection of water from these three (3) source locations will help to characterize site source water, as well as determine the degree of impact (or lack thereof) associated with current drainages from the Yellowjacket Gold Project.