MEMORANDUM

Date: 2019-07-08
Permit: PE-7613

RE: Nickel Plate Mine/Barrick Gold Inc. Proactive Review

Submitted By: Barrick Gold Inc.
Reviewed by Leilane Ronqui, Environmental Impact Assessment Technician – Biologist (Auxiliary), Mining Operations

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1. Introduction

The intent of this memo is to provide an assessment of the receiving water quality and aquatic health information provided by Barrick Gold Inc. (Barrick) in relation to the Nickel Plate Mine (NPM) operations. Recommendations from this review may be used to inform future permit amendments, Ministry of Environment and Climate Change Strategy (ENV) field monitoring programs and ENV compliance action. This memorandum assessed the *NPM Annual Water Quality Report 2018* (Barrick, 2019) which covers the 2018 reporting requirements of Permit PE-7613(most recently amendment: April 1, 2014).

In addition to the *NPM Annual Water Quality Report 2018*, my review has been informed by the following documents:

Reports:

- The *Nickel Plate Mine Annual Water Quality Report 2016*. Prepared by Barrick Gold Inc. Submitted to ENV. (Barrick, 2016).
- The Memorandum*: Impact Assessment for the Flow out of the Spillway/Rock Quarry into Cahill Creek-Nickel Plate Mine* dated March 7, 2019. Prepared by: Abhirosh Chandran, EIA Biologist - ENV. (MoE, 2019).
- The *Impact Assessment for the Flow out of the Spillway/Rock Quarry into Cahill Creek* dated February 15, 2019. Prepared by: Golder Associates Ltd. (Golder). Submitted to ENV. (Barrick, 2019).

Permits:

- The *Permit PE-7613* dated April 1, 2014. Ministry of Environment (ENV), Environmental Protection Division (MoE, 2014).

Ambient Water Quality Objectives:

- The *Ambient Water Quality Objectives For The Similkameen River Okanagan Area* dated July 18, 1990. Ministry of Environment and Climate Change Strategy, Water Protection and Sustainability Branch (MoE, 1990).

- The *Okanagan Area Cahill Creek and its Tributaries Water Quality Assessment and Objectives (Technical Appendix)* dated February 1987. Prepared by: Swain, L. G. (P. Eng.) to the Ministry of Environment and Parks Province of British Columbia (MoE, 1987).

2. Project & Receiving Environment Monitoring Description

Nickel Plate Mine is authorized to discharge effluent from a gold mine and mill operation to a tailings impoundment and to the environment, located at Nickel Plate Mountain, near Hedley, BC. The authorization is subject to the conditions of Permit PE 07613, first issued by the Ministry of Water, Land, and Air Protection, under the provisions of the *Environmental Management Act* (Barrick, 2019).

The mine effluent discharges from the wastewater treatment plant and seepage are authorized under a Ministry of Environment *Environmental Management Act* effluent discharge permit (PE-7613). Currently, the seepage water is collected and treated at the water treatment plant and then discharged to Hedley Creek via pipeline (Barrick, 2019).

The Nickel Plate Mine is located on the Aberdeen Ridge on the East side of the Similkameen River Valley near Hedley in South Central British Columbia. Historical mining at the site occurred between 1904 and 1952 and was inactive from 1952 until the mine operation was restarted in 1987. Active mining was completed at Nickel Plate in July 1996 and milling was completed in October of the same year (Barrick, 2014). Currently, the site is in active closure with activities limited to water treatment, reclamation, and remediation (Barrick, 2019).

This memorandum assessed the *NPM Annual Water Quality Report 2018,* which covers the reporting requirements of Permit PE-7613, amended April 1, 2014, including the last quarter of 2018. The report encompasses water quality monitoring data, periphyton and benthic invertebrate community composition, and toxicity tissue analysis for benthic invertebrates. The site and sampling locations for the 2018 monitoring program from the *NPM Annual Water*

Quality Report 2018 and the *2018 Benthic Invertebrate Monitoring Program* can be found in the Appendices A, B and C.

3. Impact Assessment

3.1 Ambient Guidelines and Objectives

The *Ambient Water Quality Objectives (AWQOCCT) for Cahill Creek* was published on February 2nd, 1987 (MoE, 1987) and includes objectives for Cahill Creek and its tributaries (Nickel Plate Mine Creek, Sunset Creek and Red Top Gulch Creek). In addition, Hedley Creek has its own AWQOCCT (*Ambient Water Quality Objectives For The Similkameen River Okanagan Area*) dated July 18, 1990 (ENV, 1990). The Water Quality Objectives (WQO's) limits for Cahill Creek and its tributaries can be found in the *NPM Annual Water Quality Report 2018* (pages 3 to 11, Barrick, 2019) and the WQO's for Hedley Creek can be verified in the PE-7613 (Appendix I - page 26, MoE, 2014).

3.1.1 Discharge limits and exceedances downstream of mining-influenced environment

According to the NPM *Annual Water Quality Report 2018* at the end-of-pipe (LT#1), all permit limits were met for all parameters in 2018, although cobalt (Co) concentrations at the downstream location on Hedley Creek consistently exceeded the Working Water Quality Objective[1] (WQO's) of 0.9 µg/L (HDL Creek downstream of the treated water from the water treatment plant: total Co µg/L: min 0.05, max 14.9, average 2.99) for the protection of freshwater aquatic life (MoE, 2014), but not the short-term maximum of the British Columbia Water Quality Guidelines (BC WQG's equal to 110 µg/L). However, exceeded the long-term average BC WQG's limit of 4 µg/L.

Regarding Cahill Creek Watershed, sulphate appears to be increasing at receiving environments Cahill-2, Cahill-3 and Nickel Plate Mine Creek (as documented previously in reporting to the Ministry of Environment; V. Bell, pers comm., **Barrick, 2019**). In addition, a notable increase in cobalt and selenium occur between Cahill-2 and Cahill-3, suggesting input from the Tailings Storage Facility (Barrick, 2019). At Red Top Creek West, ammonia, sulphate, dissolved arsenic; cobalt and selenium appear to be increasing with time.

In Cahill Creek (Cahill-2 and Cahill-3), dissolved sulphate, and total selenium exceeded the WQO's[2] and WQG's (WQG's total Se = 0.002 mg/L), respectively. In Nickel Plate Mine Creek total dissolved solids (TDS) and dissolved sulphate exceeded the WQO's[2]. In Nickel Plate Mine Creek and Red Top Gulch Creek dissolved sulphate, values exceeded the WQO's[2] limits between four to six times the maximum threshold of 150 mg/L.

In Red Top Creek West, dissolved sulphate exceeded the WQO's[2] ten times the limit, min. 1,780.00 mg/L, max. 2,080.00 mg/L, and the average 1,925.7 mg/L.

[1]Water Quality Objectives limits for Hedley Creek (MoE, 1990): Dissolved sulphate - protection of freshwater mosses: max. 100 mg/L. Dissolved sulphate – aesthetic guideline: max. 500 mg/L. Total arsenic: 0.05 mg/L max. Total cobalt – protection of freshwater aquatic life: max. 0.9 µg.L.

[2]Water Quality Objectives limits for Cahill Creek, NPM Creek and Red Top Gulch Creek (MoE, 1987): Total sulphate: max. 150 mg/L, average 50 mg/L. Total arsenic: max. 0.05 mg/L (Cahill Ck and Red Top Ck) and 0.5 mg/L (Nickel Plate Ck). Total dissolved solids: 500 mg/L.

In summary, TDS, sulphate, and selenium concentrations in NPM Creek, downstream of the reclaimed North Waste Rock Dump, exceeded the Ambient Water Quality Objectives for Cahill Creek Watershed. The TDS concentration in NPM Creek was 649 mg/L, compared to the WQO's of 500 mg/L, and continued to be elevated downstream from NPM Creek, but below the Objectives.

The sulphate concentration in NPM Creek was 558 mg/L compared to the Ambient Water Quality Objectives for Cahill Creek Watershed of 150 mg/L. The Objective for sulphate was also exceeded downstream of NPM Creek at Cahill-2 (max. 206 mg/L) and Cahill-3 (max: 207 mg/L). Total selenium at Cahill-3 (0.004360 mg/L) exceeded its Objective of 0.001 mg/L.

According to Barrick (2019), the elevated concentrations of TDS, sulphate and selenium are associated with mine influence on the Cahill Creek watershed.

3.2 *2018* Benthic Invertebrate Monitoring Program

The NPM permit PE-7613 has effluent and receiving environment monitoring requirements including a comprehensive monitoring program and an annual benthic invertebrate monitoring program. NPM has conducted benthic invertebrate monitoring programs to identify potential mine effects on aquatic resources to facilitate mitigation since 1985. The purpose of the *2018 Benthic Invertebrate Monitoring Program* was to continue the monitoring program to meet Permit PE-7613 requirements and to identify potential effects of mine effluent discharge on benthic invertebrate communities and periphyton biomass in receiving watercourses.

3.2.1 Periphyton Biomass and Chlorophyll-a

Five replicate periphyton biomass samples were collected at each site concurrent with water quality and benthic invertebrate samples and analyzed for chlorophyll *a*. Each replicate sample was a composite of three subsamples. However, at Cahill-2 (exposure site, downstream of Cahill-4 and NPM Creek; groundwater recharge from the TSF; historical discharge of NPM Creek treated water from the denitrification treatment plant), Cahill-2A (exposure site, 1.6 Km downstream from Cahill-2), and Cahill-3 (far-field exposure site, 1.6 Km downstream from Cahill-2A and approximately 250 m from the confluence with the Similkameen River), the five periphyton replicate samples were combined in the laboratory into one sample for each site; as a result, reference-exposure site comparisons could not be made for these sites (Barrick, 2019).

3.2.1.1 Hedley Creek

Chlorophyll *a* concentrations ranged from 2.93 to 23.4 mg/m^2 in Hedley Creek and were significantly different (KW, $p<0.05$) between the reference site H1 (reference, 10 m upstream of the Nickel Plate Mine biological treatment plant outfall diffuser) and exposure sites H2 (nearfield exposure site) and HDL CREEK D-S DIFSER (Appendix B). Concentrations were lowest at H1 (reference), highest at H2, and intermediate at HDL CREEK D-S DIFSER, similar to the trend noted in 2017 (Ecoscape 2017). According to Ecoscape 2017, high levels of chlorophyll *a* at H2 have been associated with the presence of Didymo (*Didymosphenia geminata*, a species of diatom that can produce extensive algae mats in streams and form a brown layer on rock substrates) (Barrick, 2019).

3.2.1.2 Cahill Creek Watershed

Chlorophyll *a* concentrations ranged from 0.0995 mg/m^2 (NPM Creek) to 37.8 mg/m^2 (Sunset) in the Cahill Creek watershed (Appendix C). There were no significant differences (KW, $p<0.05$) between the average reference site Cahill-1 (4.3 mg/m^2) and the exposure sites NPM (1.14 mg/m^2) and Cahill-3 (6.42 mg/m^2). The 2017 and 2018 results differed, with significantly higher chlorophyll *a* concentration at NPM Creek than at Cahill-1 (Ecoscape 2017). This difference could be due to mine influence, the random selection of rocks from areas of different sunlight exposure, or a scouring event (Barrick, 2019).

3.2.2 Benthic Invertebrates Analyses

Benthic invertebrate samples were collected at the ten sites concurrently sampled for water and periphyton. The following statistical comparisons were made:

- Hedley Creek A (comparing reference site H1 to exposure sites H2 and HDL CREEK D-S DIFSER),
- Cahill Creek watershed A (comparing reference site Cahill-1 to exposure sites Sunset, NPM Creek, and Cahill-4),
- Cahill Creek watershed B (comparing exposure site Cahill-2 to exposure sites Cahill-2A and Cahill-3),
- Cahill Creek watershed C (comparing site Cahill-2A to exposure sites Sunset, NPM Creek, and Cahill-4).

3.2.2.1 Hedley Creek Comparisons

The Hedley Creek comparisons assessed the effects of mine discharge from the water treatment plant into Hedley Creek. Reference site H1 is upstream of the effluent diffuser, and exposure sites H2 and HDL CREEK D-S DIFSER are downstream of the diffuser.

Regarding the mean benthic invertebrate density results, there was a significant difference in density between site H1 and sites H2 and HDL CREEK D-S DIFSER (KW, $p<0.05$), with mean values at H2 and HDL CREEK D-S DIFSER more than two SD from the reference mean and above the critical effect size (Barrick, 2019).

There were no significant differences in taxonomic richness for reference vs. exposure sites. There were significant differences between the reference and exposure sites for Bray Curtis, Simpson's evenness, and Simpson's diversity indices. At H2 and HDL CREEK D-S DIFSER, the benthic invertebrate communities were dissimilar from the reference mean at H1 (with Bray Curtis index of 0.57 and 0.6, respectively) and were less even (Simpson's evenness of 0.8 and 0.8, respectively) and less diverse (Simpson's diversity 0.75 and 0.76) in composition compared to the community at H1. According to Barrick (2018), these differences were below the critical effect size and do not necessarily indicate a high risk to the environment.

However, for the supporting endpoints Hilsenhoff's Biotic Index (HBI) and Ephemeroptera, Plecoptera, Trichoptera (EPT) abundance, there was significant difference between H1 and the exposure sites. H2 and HDL CREEK D-S DIFSER both had higher HBI values (4.9 and 5.0, respectively) than H1 (3.3), which indicate the presence of more pollution-tolerant taxa. H2 and HDL CREEK D-S DIFSER also had significantly lower proportions of the pollution-intolerant EPT taxa (22% and 27%, respectively) than H1 (69%), which indicates lower water quality (Figure 1, below – figure 3.13 Barrick, 2018). In summary, The HBI and EPT metrics indicated poorer water quality downstream from the diffuser than upstream for Hedley Creek.

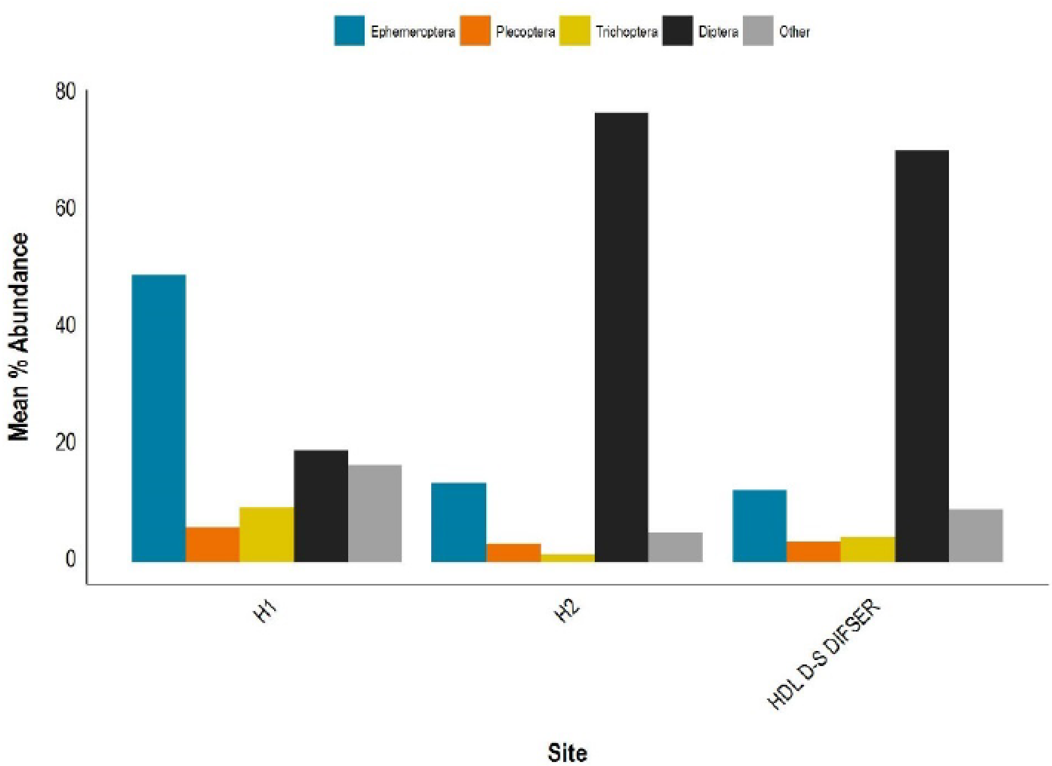

Figure 1: EPT Index (A) and Relative Abundance (B) for Benthic Invertebrate Communities at Sites in Hedley Creek (figure 3.13 Barrick, 2018).

In summary, an effect of mine discharges on the benthic invertebrate community in Hedley Creek was identified through the significant difference in density between reference and exposure sites, above the critical effect size, and significant differences in composition (Bray Curtis, evenness, diversity, HBI, and EPT abundance), below the critical effect size (Barrick, 2019).

The top three dominant benthic invertebrates at each site also indicate a change to poorer water quality downstream of the diffuser (e.g. =100 times more cobalt, ~30% more TSS, and ~30% less DO). At the reference site H1, the dominant taxa were all mayflies (39%) including Heptageniidae (recognized as indicators sensitive to metals in streams (Barrick, 2019)). At H2 and HDL CREEK D-S DIFSER, the communities were dominated by chironomids (recognized as robust taxa that tolerate a range of environmental stresses, including temperature, low oxygen, organic matter, sediment and contaminants).

3.2.2.2 Cahill Creek Watershed Comparisons

The Cahill Creek watershed comparisons assessed the effects of seepage discharge into Nickel Plate Creek and Sunset Creek (Comparison A), Tailings Storage Facility (TSF) seepage into Cahill Creek (Comparison B), and site influence (Comparison C).

In general, Nickel Plate Mine Creek (NPM Creek), which is considered the nearest mining-influenced environment in the *2018 Benthic Invertebrate Monitoring Program* at Cahill Watershed, presented the lowest mean values for species richness, Simpson's Evenness Index, Simpson's Diversity Index, and Hilsenhoff's Biotic Index (i.e. organic pollution unlikely). On the other hand, NPM Creek presented the highest invertebrate density mean, the second highest Bray Curtis Index mean (less similar when compared with reference station Cahill-1), and the highest % EPT mean.

The exposure site NPM was significantly different from the reference site Cahill-1 for Bray Curtis Index, Simpson's Evenness, Simpson's Diversity, HBI, and EPT abundance; at this site the predominant taxa were the stoneflies Yoraperla (32%), Peltoperlidae (28%), and Zapada Columbiana (11%) (Barrick, 2019).

- ❖ *Cahill Creek Watershed - Comparison A*

Comparison A assessed effects of the reclaimed North Waste Rock Dump and Canty Waste Rock Dump seepage on exposure sites in NPM Creek, Sunset Creek, and Cahill Creek (Cahill-4) by comparing results for these exposure sites to results for the reference site Cahill-1 (Appendix C).

The lack of significant differences or lack of significant differences above the critical effect size between the reference site Cahill-1 and the exposure sites NPM Creek, Sunset, and Cahill-4, plus the predominance of sensitive EPT taxa at these sites indicates potential discharge from the reclaimed dumps has an effect on the invertebrate community, but it may not indicate a high risk to the aquatic community according to Barrick (2019).

- *Cahill Creek Watershed - Comparison B*

Comparison B assessed potential effects of groundwater recharge from the TSF on Cahill Creek, using Cahill-2 as the reference site, Cahill-2A as the nearfield exposure site and Cahill-3 as the mid-field exposure site. There are no additional mine inputs below Cahill-2 (Appendix C).

The change in benthic invertebrate community composition noted between Cahill-2 to Cahill-3, with either no significant differences or with significant differences below the critical effect size, plus the predominance of sensitive EPT taxa at these sites, suggests that the groundwater recharge to Cahill Creek is not a high risk to the aquatic community. Some of the differences in benthic invertebrate community composition may be due to its location in the watershed, as Cahill-3 is at a lower elevation, with warmer water temperatures than the upstream sites at Cahill-2 and Cahill-2A (Barrick, 2019).

- *Cahill Creek Watershed Comparison C*

Comparison C assessed potential differences in benthic communities between Cahill-2A and Cahill-3 since there were no additional mine inputs below Cahill-2 and Cahill-3 is at a lower elevation than Cahill-2 (Appendix C).

There was a change in community composition between Cahill-2A and Cahill-3 as reported by the difference in Bray Curtis index, HBI, and percent EPT. Cahill-3 had a significantly higher Bray Curtis index (0.61) than Cahill-2A (0.33) indicating that the community at Cahill-3 is more dissimilar from the reference community than Cahill-2A, and the difference was more than 2 SD, i.e., above the critical effect size, and indicates a difference of potential ecological relevance (Barrick, 2019). In addition, according to Barrick (2019), the difference in community composition between Cahill-3 and Cahill-2A may be related to changes in aquatic habitat between the sites. Cahill-3 is at a lower elevation in the Similkameen Valley, with surrounding sagebrush-steppe habitats and warmer water temperatures. As a result, this site would be expected to have a more tolerant invertebrate community.

3.2.3 Benthic Invertebrates Tissue Metal

Metal concentrations in benthic invertebrate tissue were analyzed to evaluate whether changes in water quality related to mine discharges are being carried up the food chain.

In general, arsenic tissue concentrations were higher at exposure than reference sites for both Hedley Creek and Cahill Creek. However, there was no clear pattern and the results may not be related to the mine. (Barrick, 2019).

Cobalt was higher in tissue from exposure sites in the Hedley Creek watershed (exposure sites: H2 = 6.66 mg/kg, HDL Creek D-S Difser = 2.75 mg/kg, and reference station H1 = 1.17 mg/kg), and in surface water samples total cobalt also was over the WQO's for Hedley Creek (H2 = 0.0111 mg/L; HDL Creek D-S Diffuser = 0.0104 mg/L. WQO's = 0.0009 mg/L), but did not show any pattern in the Cahill watershed, consistent with the water quality results (Barrick, 2019).

Cadmium, chromium, iron and selenium tissue concentrations did not show any pattern in relation to location or mine inputs (Barrick, 2019).

Selenium tissue concentrations were also compared to the BC guideline for dietary exposure of 4 mg/kg (Table 1 below, table 3-12 Barrick, 2019). In Hedley Creek, tissue concentrations exceeded the guideline at reference site H1, but not at the two exposure sites (H2 and HDL Creek D-S Diffuser). In Cahill Creek watershed, all samples except at *Cahill-2 were above the guideline (range of 2.5 to 9.2 mg/kg) (Barrick, 2019).

Table 1: Selenium Concentrations in Benthic Invertebrate Tissue, 2018 (table 3-12 Barrick, 2019).

			Cahill Watershed							Hedley Watershed		
Parameter	Units	RDL	Cahill-1	NPM Creek	Sunset	Cahill-4	Cahill-2	Cahill-2A	Cahill-3	H1	H2	HDL CREEK D-S DIFFR
Total Selenium	mg/kg	0.1 to 0.3	**4.37**	**5.09**	**4.43**	**4.15**	2.50	**6.25**	**9.20**	**5.74**	2.65	2.65

***Bold:** indicates the values exceeding the Ambient Water Quality Guideline for Selenium (ENV, 2014).

4. Other Issues

4.1 Impact Assessment for the Flow out of the Spillway / Rock Quarry into Cahill Creek

On April 14, 2018, a power line failure resulted in a water level increase in the untreated TSF, as the seepage collection system at the TSF was not operable during the power failure. The elevated water levels resulted in an overflow from the TSF over the engineered spillway into the rock quarry, where overflow water mixed with water in the rock quarry and flowed into Cahill Creek between April 26 and May 26, 2018. The release into Cahill Creek was monitored daily during the event (Barrick, 2019).

*Cahill-2: exposure site, downstream of Cahill-4 and NPM Creek; groundwater recharge from the TSF; historical discharge of NPM Creek treated water from the denitrification treatment plant (turned off in 2003).

As a requirement by the BC Ministry of Environment and Climate Change Strategy (ENV), Barrick Gold Inc. (Nickel Plate Mine) conducted a study to assess the potential impacts associated with the discharge of untreated tailings storage facility (TFS) seepage water from Nickel Plate Mine to the local environment by way of an engineered spillway into the Cahill Creek, via the rock quarry (Chandran, 2018).

According to Chandran (2018), the potential environmental effects of untreated effluent from the TSF into Cahill Creek were:

1. A short-term sub-lethal effect on benthic invertebrate in Cahill creek (Cahill-2) that could potentially be related to the overflow,

2. Cyanide, total cobalt, total chromium and total iron exceedances (WQG's) in Cahill creek (Cahill-2) could be related to the discharge as the concentrations were below the water quality guideline at Cahill-4 (located approximately 550 m upstream of the discharge),

3. Cyanide, total cobalt, total chromium and total iron exceedance in Cahill 3 (downstream of Cahill-2) could be attributed to the discharge since the concentrations were below the water quality guideline at Cahill-4 (located approximately 550 m upstream of the discharge),

4. In Similkameen River, the exceedance of total chromium, total iron, and total cobalt also could be related to discharge as their concentrations were below the water quality guideline at Cahill-4 (upstream location).

Overall by comparing the upstream location (Cahill -4) with the environment affected by the discharge, it is evident and has been demonstrated that mine overflow discharge has affected cyanide, total cobalt, total chromium and total iron concentration in the downstream receiving water in Cahill creek (Cahill-2 and Cahill-3) and Similkameen River as these constituents did not show exceedance at Cahill-4 (upstream) while exceedance was noticed in Cahill -2, Cahill-3 and in Similkameen River (Chandran, 2018).

To address this issue, ENV's staff recommended that: *"Further monitoring is required to assess the long-term effect in response to the observed water quality guidelines exceedances, and the sub-lethal effect on benthic invertebrates and its residual uncertainty* (Chandran, 2018)".

RECOMMENDATIONS

The following section describes L. Ronqui's review of the *NPM Annual Water Quality Report 2018*. Comments have been organized under subsections which identify a specific issue and provide pertinent recommendations including rationale to address the associated issue.

1. Monitoring Program Changes for Barrick Gold Inc. – Nickel Plate Mine

- (i) Regarding subsection 3.2.2.1 Hedley Creek Comparisons (into section: 3.2 *2018 Benthic Invertebrate Monitoring Program*):

Based on the *2018 Benthic Invertebrate Monitoring Program* data, a potential effect of mine effluent discharge on benthic invertebrate communities and periphyton biomass in the receiving environment was observed. The benthic invertebrate composition data added to the reported increment of periphyton biomass as chlorophyll *a* detected in H2 and HDL Creek D-S Diffuser and its association with the presence of Didymo (*Didymosphenia geminate*) (Barrick, 2019), which is an invasive species in western rivers in Canada and possesses a broad range of ecological tolerances (Campbell, 2005), supported assessment of the low quality of the water in Hedley Creek downstream of the discharge.

> ***Recommendation:*** Additional monitoring should be conducted including periphyton tissue analyses, acute toxicity test using the invertebrate *Daphnia magma* and chronic toxicity test using the invertebrate *Ceriodaphnia dubia* in the receiving environment (H2 and HDL Creek D-S Diffuser) and compared with background characteristics of the region. The toxicological tests should be accompanied by surface water quality analysis. Particular attention must be given to the "parameters of potential concern" (ENV, 2019): sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc and selenium, given that the elevated levels of these elements, detected in the receiving environment of Nickel Plate Mine, have the potential to cause toxic effects and bioaccumulate leading to changes in populations of aquatic biota.

- (ii) Regarding subsection 3.2.2.2 Cahill Creek Watershed Comparisons (into section: 3.2 *2018 Benthic Invertebrate Monitoring Program*):

> ***Recommendation:*** *Cahill Creek Watershed Comparison C:* Based on the data from Cahill Creek watershed comparisons, L. Ronqui is in agreement with the Barrick (2019) statement, that the difference in benthic invertebrate community composition between Cahill-3 and Cahill-2A may not be directly related with NPM activities in the area.

However, the *Benthic Invertebrate Monitoring Program* in Cahill Creek Watershed must be kept to ensure the quality of the water in the area. In addition, during the sampling monitoring conducted to address the issues related to the TSF untreated effluent discharge in 2018 in Cahill Creek (Technical Report dated February 15, 2019), toxicological tests were performed using water from the TSF and adverse effects in both species, Rainbow trout and *Ceriodaphnia dubia*, were observed, with 60% and 100% of mortality, respectively.

- (iii) Regarding subsection 3.2.3 Benthic Invertebrates Tissue Metal (into section: 3.2 *2018 Benthic Invertebrate Monitoring Program*):

According Barrick (2019) statement: *"Cobalt was higher in tissue (benthic invertebrates) from exposure sites in the Hedley watershed (Co mg/kg: H2 = 6.66, HDL Creek = 2.75) when compared with reference site (Co mg/kg: H1 = 1.17) (Barrick, 2019)".* The surface water data confirmed this statement; the concentration of cobalt in surface water, in the *2018 Benthic Invertebrate Monitoring Program* was above the WQO's (H2: = 0.0111 mg/L; HDL Creek D-S Diffuser: 0.0104 mg/L. WQO's = 0.0009 mg/L). In addition, cobalt concentrations in surface water (from Jan/18 to Dec/18 sampling monitoring) at the downstream location on Hedley Creek (Co mg/L: HC DS: max. 0.0149; average 0.0029; min. 0.00005) consistently exceeded the Working Water Quality Objective (WQO's) of 0.0009 mg/L for the protection of freshwater aquatic life (MoE, 2014). Thus, a pattern can be observed when compared the high levels of cobalt tissue concentration in benthic invertebrates and the water quality in Hedley Creek downstream of the treated effluent discharged.

Recommendation: Additional monitoring should be conducted including periphyton tissue analyses, acute toxicity test using the invertebrate *Daphnia magma*, and chronic toxicity test using the invertebrate *Ceriodaphnia dubia* in the receiving environment (H2 and HDL Creek D-S Diffuser) and compared with background characteristics of the region. The toxicological tests should be accompanied by surface water quality analysis. Particular attention must be given to the "parameters of potential concern" (ENV, 2019): sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc and selenium, given that the elevated levels of these elements, detected in the receiving environment of Nickel Plate Mine, have the potential to cause toxic effects and bioaccumulate; leading to changes in populations of aquatic biota.

- (iv) *"Selenium tissue concentrations in all samples, except at Cahill-2*, were above the Ambient Water Quality Guideline for Selenium (ENV, 2014) equal to 4 mg/kg for benthic invertebrates tissue in the Cahill Creek watershed* (Table 1, table 3-12, Barrick, 2019)". Based on the statement above:

Recommendation: Additional monitoring should be conducted including periphyton tissue analyses, acute and chronic toxicity tests in the receiving environment in Cahill Creek Watershed (NPM Creek, Sunset Creek and Cahill Creek) and compared with background characteristics of the region. The toxicological tests should be accompanied by surface water quality analysis, given that selenium has the potential to cause toxic effects and bioaccumulate; leading to changes in the aquatic biota.

- (v) Regarding sampling design statement: "*One benthic invertebrate sample was collected at each site for tissue metal analysis*" (Barrick, 2019).

Recommendation: The lack of a composite sample can elevate the uncertainty levels and the reliability of the results. In order to assess if the elevated levels of selenium and other chemicals elements in benthic invertebrate tissue in the receiving environment of Hedley Creek Watershed and Cahill Creek Watershed is related to mining activities, the benthic tissue sampling collection and analyses should follow the CABIN Manual (Canada, 2012) and be a composite sample.

- (vi) Surface Water Results - Comparison among Sampling Stations and Variables

Recommendation: Surface water quality results must be compared to short-term maximum (acute) and long-term average (chronic) water quality guidelines, and with the WQO's for both, Hedley Creek Watershed and Cahill Creek Watershed included in the next annual water quality report submission to ENV.

2. Recommendation for MAS receiving environment monitoring

- (i) Regarding subsection 3.1.1 Discharge limits and exceedances downstream of the mining-influenced environment:

Since 2016 Nickel Plate Mine has been presenting cobalt exceedances, which was kept in 2018 (Barrick, 2016; pers. Commu. Chris White – Compliance, ENV). I recommend the following regarding the WQO's update for Cahill Creek Watershed:

Recommendation: Cobalt concentrations should be consistently monitored and included in the section "*Guidelines and Objectives Table B: AWQOCCT Objectives – Cahill Creek (page 3) in Barrick Gold Inc. – Nickel Plate Mine Annual Water Quality Report"* in the next annual water quality reports submissions to ENV. Cobalt limits for Cahill

Creek Watershed can be found in the *Okanagan Area Cahill Creek and its Tributaries Water Quality Assessment and Objectives* (MoE, 1987). In addition, cobalt levels monitoring is a permit requirement in sub-section 4.3.3 (PE-7613): *"The permittee must ensure that cobalt analyses use the most sensitive analytical methods available, enabling trend assessment at the part per billion level"* (ENV, 2014).

- The table below (Table 2) presents a summary of all sampling stations encompassed into the *NPM Annual Water Quality Report 2018* and in the *2018 Benthic Invertebrate Monitoring Program* (Barrick, 2019), and lists all parameters of potential concern (POPC), water quality objectives (WQO's) exceedances, biological analyses performed and CABIN monitoring.

Table 2: Nickel Plate Mine surface water sampling stations and additional information:

Watershed	Creek Name	Site Name/ EMS	Purpose	Rationale	*POPC*	*WQO's1 exceedances*	Biological Analyses/CABIN
				NPM Annual Water Quality Report 2018*			
CAHILL CREEK WATERSHED	SUNSET	Sunset Cr. u/s Cahill Cr. (Sunset #3) E206634	Exposure	Downstream of seepage from the reclaimed waste rock dumps and also downstream of Canty Pit.	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	No exceedances reported.	-
	UPPER-SS	Sunset Cr. u/s Canty Pit (Sunset #1) E215954	Reference	Upstream of Canty Pit.	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	No exceedances reported.	-
	CAHILL-1	Cahill Cr. u/s confluence w/ Sunset Cr. (Cahill #1) E206635	Reference	Upstream of the confluence with Sunset Creek	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	No exceedances reported.	-
	NICKEL PLATE MINE CREEK	NPM Cr. u/s confluence w/ Sunset Cr. E206633	Exposure	Downstream of seepage from the reclaimed waste rock dump.	sulphate, cyanide (SAD), thiocyanate, arsenic,	TDS, Sulphate	-

					cobalt, cadmium, zinc, selenium		
	CAHILL-4	Cahill Cr. u/s tailings impoundment (Cahill #4) E206823	Exposure	Upstream of TSF, downstream of the confluence with Sunset Creek and NPM Creek.	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	No exceedances reported.	-
	CAHILL-2	Cahill Cr. d/s tailings impoundment @ Hedley Road (Cahill #2) E206824	Exposure	Downstream of TSF and groundwater wells area.	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	Sulphate, Selenium	-
	CAHILL-3	Cahill Cr. @ Hwy 3 (Cahill #3) E206637	Exposure	Far-site, downstream of Cahill-2, upstream of the confluence with Similkameen River.	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	Sulphate, Selenium	-
	REDTOP	Red Top Gulch Cr. @ Hwy 3 E206638	Exposure	Downstream of TSF and the confluence between Red Top West and East	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	TSS, Turbidity, TDS, Sulphate, Cyanide (SAD), total arsenic, total ammonia, total aluminum, total selenium	-
Dry	RT-EAST	Red Top Gulch Cr. East Fork E215957	Exposure	-	-	-	-
	RT-WEST	Red Top Gulch Cr. West Fork E215956	Exposure	Downstream of TSF.	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	TSS, Turbidity, Cyanide (SAD), total arsenic, total ammonia, total aluminum, total selenium.	-
HEDLEY	HDL	Hedley (20	Reference	Downstream of Hedley	sulphate,	Cu and Fe	-

CREEK WATERSHED	CREEK U-S DIFSER	Mile) Cr. u/s Discharge E223873		Town	cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	slighted exceeded the WQO's.	
	LT #1	Biological Treatment Plant Discharge to HC E223876	End-of-pipe	Discharge of treated effluent from the Biological Treatment Plant to Hedley Creek	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	All permit limits were met (Barrick, 2019).	-
	HDL CREEK D-S DIFSER	Hedley (20 Mile) Cr. d/s Discharge E223874	Exposure	Upstream of the confluence with Similkameen River.	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	All Water Quality Discharge Limits met (Table 3, Barrick, 2019). Cobalt was exceedances regarding the WQO's.	-

2018 Benthic Invertebrate Monitoring Program**

CAHILL CREEK WATERSHED	Cahill-1	x	Reference	Hedley Creek, approximately 10 m upstream of the Nickel Plate Mine Biological treatment plant outfall diffuser.	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium		yes
	NPM Creek	x	Exposure	Nickel Plate Mine Creek, a headwater tributary of Sunset Creek, in the Cahill Creek watershed; fed by groundwater and located downslope of the North Waste Rock Dump (reclaimed in 1995)	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	Arsenic, Cadmium, Chromium, Cobalt, Selenium Sulphate Uranium	yes
	Sunset	x	Exposure	Sunset Creek, a headwater tributary of Cahill Creek, which receives	sulphate, cyanide (SAD), thiocyanate,	Arsenic, Cadmium, Chromium, Cobalt,	yes

				drainage from the Canty Waste Rock Dump (reclaimed in 1993)	arsenic, cobalt, cadmium, zinc, selenium	Selenium	
	Cahill-4	x	Exposure	Cahill Creek downstream of the confluence with Sunset Creek and upstream of the confluence with NPM Creek	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	Arsenic, Cadmium, Chromium, Cobalt, Selenium	yes
	+Cahill-2	x	Exposure	Cahill Creek downstream of Cahill-4 and NPM Creek; groundwater recharge from the TSF; historical discharge of NPM Creek treated water from the denitrification treatment plant (turned off in 2003). There are no additional mine influences on Cahill Creek below Cahill-2	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	Arsenic, Cadmium, Chromium, Cobalt, Selenium	yes
	+Cahill-2A	x	Exposure	Cahill Creek, 1.6 km downstream from Cahill 2	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	Arsenic, Cadmium, Chromium, Cobalt, Selenium	yes
	+Cahill-3	x	Far-field Exposure	Cahill Creek, 1.6 km downstream from Cahill 2A and approximately 250 m from the confluence with the Similkameen River.	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	Arsenic, Cadmium, Chromium, Cobalt, Selenium	yes
HEDLEY CREEK	H1	x	Reference	Hedley Creek, approximately 10 m upstream of the Nickel Plate Mine Biological treatment plant outfall diffuser.	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc,		yes

					selenium		
	H2	x	Nearfield Exposure	Hedley Creek, approximately 20 m downstream of the Nickel Plate Mine biological treatment plant outfall diffuser	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	Cobalt	yes
	HDL CREEK D-S DIFSER	x	Mid-field Exposure	Hedley Creek, approximately 400 m downstream of the Nickel Plate Mine biological treatment plant outfall diffuser and less than 125 m from the confluence with the Similkameen River.	sulphate, cyanide (SAD), thiocyanate, arsenic, cobalt, cadmium, zinc, selenium	Cobalt	yes

-Not applicable.

[1]**Metals Exceeding** One or More Water Quality Guidelines or Objectives in the Cahill Creek Watershed and Hedley Creek.

X = not informed.

***Parameters analysed:** Water Quality Samples: Flow, pH, hardness, conductivity, temperature, turbidity, total dissolved solids, nitrate, ammonia, sulphate, cyanide (SAD), cyanide (WAD), thiocyanate, dissolved arsenic, dissolved cobalt, dissolved zinc, total iron (LT#1, HDL Creek upstream and downstream).

****Parameters analyzed: Water Quality Samples:** Conductivity, dissolved oxygen, hardness, pH, TDS, TSS, turbidity. Anions and Nutrients: alkalinity, ammonia, bromide, chloride, fluoride, nitrate, nitrite, orthophosphate-dissolved, total phosphorus, sulphate, total nitrogen, total cyanide, cyanide (WAD), thiocyanate. Organic/Inorganic Carbon: TOC. Total metals: aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, calcium, cesium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, mercury, molybdenum, nickel, phosphorus, potassium, rubidium, selenium, silicon, silver, sodium, strontium, sulfur, tellurium, thallium, thorium, tin, titanium, tungsten, uranium, vanadium, zinc, zirconium. Dissolved Metals: aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, calcium, cesium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, mercury, molybdenum, nickel, phosphorus, potassium, rubidium, selenium, silicon, silver, sodium, strontium, sulfur, tellurium, thallium, thorium, tin, titanium, tungsten, uranium, vanadium, zinc, zirconium. **Biological analyses:** CABIN, periphyton biomass as chlorophyll *a*, benthic invertebrate communities, environmental effects monitoring endpoints, and benthic invertebrate tissue metal.

[+]**The periphyton samples** for Cahill-2, Cahill-2A and Cahill-3 were combined in the laboratory into one sample for each site; as a result, reference-exposure site comparisons could not be made for the 2018 Benthic Invertebrate Monitoring Program.

- **(ii) Regarding POPC:**

  Recommendation: The Parameters of Potential Concern (POPC) listed in Table 2 must be analyzed in the 2019 Monitoring Program to be performed by the Monitoring Assessment Stewardship (MAS) team.

  Rationale: These parameters were selected based on a screening of historic mining activities, WQG's and WQO's exceedances, upward trending's and high variability.

- **(iii) Regarding WQO's comparisons and exceedances:**

Recommendation: The parameters which presented WQO's exceedances (Table 2) should be closely monitored in the receiving environment (Hedley Creek, Nickel Plate Mine Creek, Sunset Creek, Cahill Creek, Red Top Gulch Creek, Red Top Gulch West) and in the Similkameen River.

Rationale: These parameters were selected based on WQO's and WQG's exceedances. Detailed monitoring can make it viable to predict future changes and a decrease in water quality characteristics.

- **(iv) Regarding an audit sampling:**

Recommendation: NPM Creek, Cahill-2, Red Top and Red Top West sampling stations should be sampled by ENV Compliance Team to confirm the elevated level of sulphate and the WQO's exceedances regarding the parameters listed in Table 2.

Rationale: These sampling stations are likely being affected by mining effluent discharges, what is decreasing the quality of the water in the area.

- (v) Regarding CABIN monitoring:

Recommendation: To perform CABIN analyses in Cahill Creek (Upper-SS, NPM Creek, Cahill-4, Cahill-2, Cahill-3, RedTop, and RedTop West) and Hedley Creek (HDL Creek U-S Difser and HDL Creek D-S Difser).

Rationale: Based on the reports assessed, Barrick Gold Inc. has not been performing CABIN analyses in the above stations. A detailed assessment of benthic macroinvertebrates associated with stream information could make feasible the detection of environmental effects caused by mining activities in the area.

- (vi) Regarding the lack of data:

Recommendation: To perform periphyton biomass and chlorophyll-*a* analyses in Cahill-2, Cahill-2A, and Cahill-3.

Rationale: According to Barrick (2019): "The periphyton samples for Cahill-2, Cahill-2A and Cahill-3 were combined in the laboratory into one sample for each site; as a result, reference-exposure site comparisons could not be made for the 2018 Benthic Invertebrate Monitoring Program". The lack of results for each of these sampling stations made unfeasible my assessment whether mining activities in Cahill Creek downstream of the Tailings Storage Facility (TSF) is affecting the periphyton biota. In addition, the same area was affected by the incident in 14 April 2018, where a discharge of untreated TSF seepage water from Nickel Plate Mine reached Cahill Creek by way of an engineered spillway, via Rock Quarry.

Thank you for the opportunity to provide technical review comments on the *Nickel Plate Mine Annual Water Quality Report 2018*. If you have any questions regarding the content of this memo, please do not hesitate to contact me at Leilane.Ronqui@gov.bc.ca or 604-582-5344.

Sincerely,

Leilane Ronqui, Ph.D.
Auxiliary Environmental Impact Assessment Technician - Biologist, Mining Operations
Ministry of Environment and Climate Change Strategy

Cc: Deb Epps, Water Quality Section Head - Monitoring and Assessment Stewardship
Gabriele Matscha, Environmental Impact Assessment Section Head – Mining Operations

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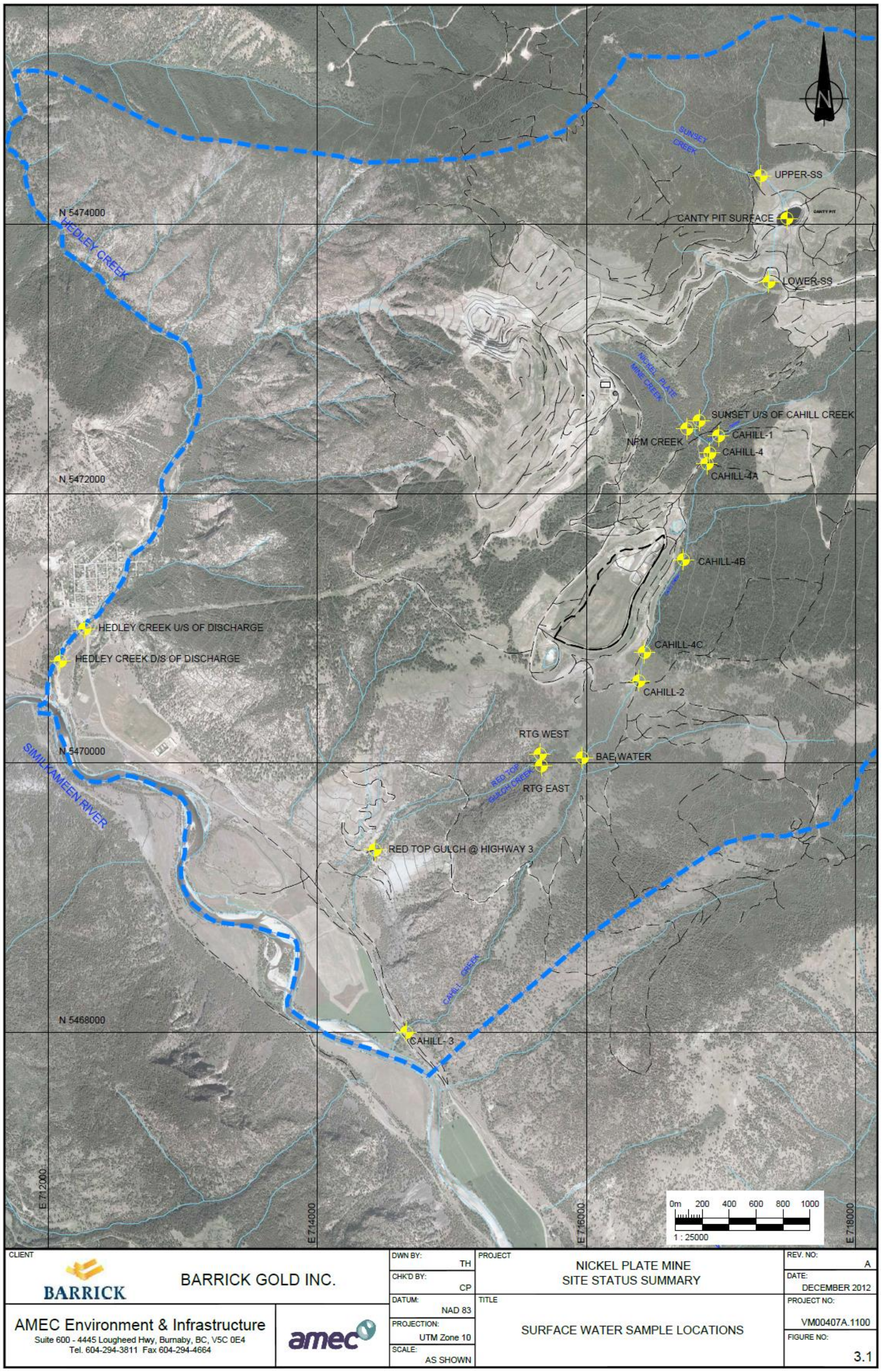
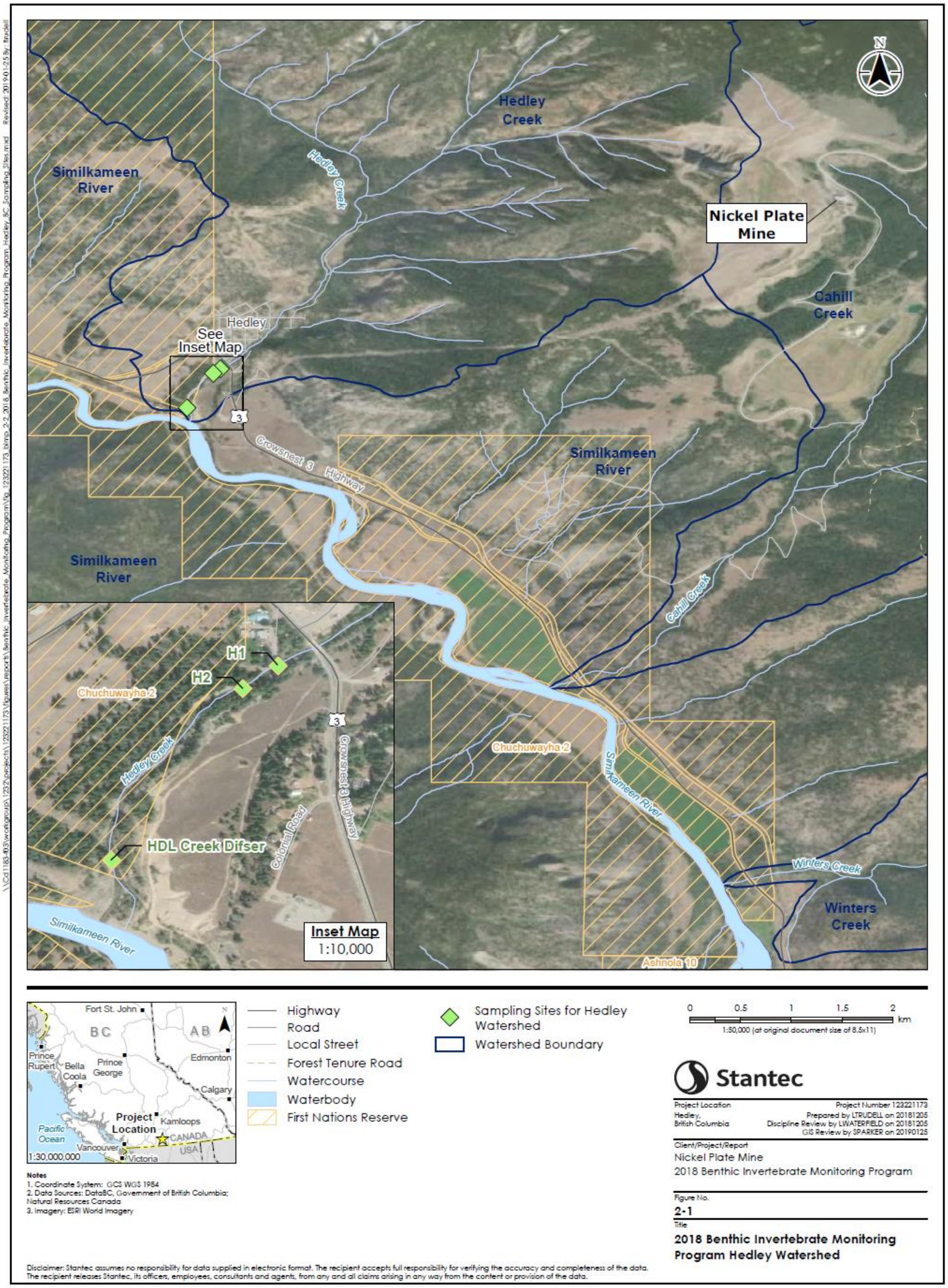
APPENDIX A: Surface Water Sample Locations (Figure 3.1 from Barrick, 2019).



APPENDIX B: 2018 Benthic Invertebrate Monitoring Program Hedley Watershed (Figure 2-1 from Barrick, 2019).



APPENDIX C: 2018 Benthic Invertebrate Monitoring Program Cahill Watershed (Figure 2-2 from Barrick, 2019).