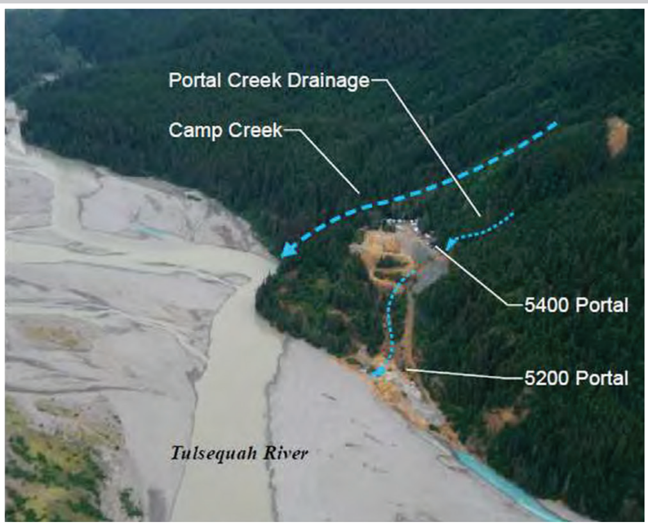
A REVIEW OF THE

TULSEQUAH CHIEF ECOLOGICAL RISK ASSESSMENT



Sarah O'Neal

sarahlouiseoneal@gmail.com
Agua Dulce Freshwater Consulting
Seattle, WA

June 2016

INTRODUCTION

Tulsequah Chief is a small abandoned mixed metals underground mine in northwest British Columbia very close to the Alaska border. The site is in a remote, mountainous environment about 100 air km (60 mi) south of the town of Atlin, B.C., and about 65 air km (40 m) northeast of the town of Juneau, Alaska on the Tulsequah River, a tributary to the transboundary Taku River. The Taku River is southeast Alaska's largest coho (*Oncorhynchus kisutch*) and Chinook (*O. tshawytscha*) salmon producing river (ADFG 2010), and supports robust populations of other Pacific salmon species. The river provides important customary and traditional, commercial and sport fisheries.

The Tulsequah Chief deposit was historically mined from 1937 to 1957, at which time low metal prices made mine operations unprofitable. The mine was abandoned in 1957 without any reclamation. Acid mine drainage (AMD)—created by unearthing sulfide minerals as part of the mining process and exposing them to air and water—has been leaching from the site at least since 1957. AMD exhibits both high acidity (low pH), and high concentrations of metals dissolved in acidic waters. Because of the toxicity of AMD to salmon and other aquatic life upon which salmon depend, the legacy of AMD and high metals concentrations is of great concern to subsistence, commercial, and recreational fishermen in B.C. and Alaska.

The mine has continually violated permit requirements for water quality and Canadian federal law because of chronic AMD and associated metals contamination. Recent estimates indicate that 12.8 liters/second (over 1 million liters per day, and 400 million liters per year) of AMD are leaching exhibiting a pH of <3.5 and copper concentrations up to 52,000 parts per billion (Core6 Environmental et al. 2003).

Copper, zinc and other contaminants are draining into the Tulsequah River from the Tulsequah Chief mine. Reports indicate copper levels as high as 1000 times the water quality criteria used for screening. At increases of just 2-20 parts per billion (equivalent to 2-20 drops in an Olympic-sized swimming pool), copper impacts a salmon's ability to smell (Baldwin et al. 2011, McIntyre et al. 2012). That ability facilitates locating spawning grounds, finding food and mates, and detecting predators. In other words, sense of smell is essential to salmon survival. Zinc exceeds legal standards by over 2000 times at the mine site. Zinc is toxic to fish—inhibiting growth, breathing, heart function, and spawning, and ultimately decreasing survival (Di Giulio and Hinton 2008).

In 2009, after an Environment Canada official collected water from the site that caused 100% fish mortality in subsequent lab studies, the agency ordered an immediate cleanup of Tulsequah Chief (Comin 2009). In response, mine owner Chieftain Metals constructed an Interim Water Treatment Plant (IWTP). The IWTP operated for less than four months and was shut down in June 2012 because operations costs were purportedly too high for Chieftain Metals to afford. When metals concentrations in receiving waters again increased after IWTP closure, the B.C. Ministry of Environment required Chieftain Metals to commission an Ecological Risk Assessment (ERA) for the mine waste produced at Tulsequah Chief. The objectives of the ERA are to characterize the general risk of AMD and associated metals to aquatic life and to compare this risk to aquatic life under IWTP operation versus this risk after IWTP operation ceased. This document is a review of the ERA. The ERA can be downloaded at: http://www.chieftainmetals.com/wp-content/uploads/reports/Tulsequah-Chief-Aquatic-ERA-report.pdf.

In short, this review concludes that the ERA relied on an unclear and insufficient sample design, used inappropriate receptor (bioindicator) species, incorporated previously collected data of unknown quality, failed to address some study objectives altogether, and reported information haphazardly. Consequently, the conclusion of low risk to aquatic life from Tulsequah Chief Mine AMD is unreliable.

GENERAL COMMENTS

ERA Study Design and Methods

In general, the Ecological Risk Assessment (ERA) is poorly organized and includes dozens of errors, suggesting little concern for quality and scientific defensibility. It includes typos, pages out of order, mislabeled sections, mixed units of reporting, and flawed data. As written it appears the ERA is considered a formality by Chieftain Metals rather than an important assessment that will be used to determine significant risk to fish and water quality. The ERA fails to provide an adequate review of the cumulative impacts that decades of AMD has had and continues to have on the culturally and commercially important salmon resource.

The ERA failed to use scientifically defensible site selection methodology, and overlooked habitat types important to salmon and other aquatic biota. The ERA reported water quality samples from just four sites: two sites above the location of AMD discharge, one site immediately below, and another site 2.7 km (1.7 mi) downstream of the AMD discharge. Although the ERA bases its conclusions on the assumption that water quality is unaffected by AMD in off-channel habitat, samples from that habitat were not taken to verify the assumption. There is no explanation of how sites were chosen to characterize the full extent of impacts and risks and results indicate that site selection was insufficient to identify the "zone of impact" (Sharpe 2013), much less provide adequate information with which to accurately estimate risk. This raises serious questions regarding the validity of the conclusions of the ERA and precludes accurate estimation of risk.

Failing to use a scientifically defendable site selection methodology as well as failing to take samples from specific habitats and species raises serious concerns regarding the validity of the conclusions in the ERA and provides little to no information upon which to accurately estimate risk. Moreover, some of the data that is collected directly contradicts the conclusion of "low risk" found in the ERA.

The study relied heavily on data collected in eight limited and largely outdated studies. Nearly all studies cited were conducted by mine proponents and may be biased toward conclusions favorable to the mining company. The rigor and reliability of most of these studies is unknown because they are not easily accessible for review (Core6 Environmental et al. 2003).

The study describing fish distribution was conducted in 2001, and quantitative assessments have not occurred since at least 1997, making data from which conclusions were drawn out of date and unreliable. Two assessments of fish habitat (but not fish populations) were conducted in 2007 (Cambria and Gordon Ltd. 2007a and Cambria and Gordon Ltd. 2007b), but they evaluated only small stream crossings along proposed temporary access roads as opposed to the Tulsequah River itself where AMD is leaching. No empirical fish density or abundance data are reported in the most recent studies considered.

Furthermore, the ERA used salmon and char—sockeye (*O. nerka*), coho (*O. kisutch*), Chinook (*O. tshawytscha*), and Dolly Varden (*Salvelinus malma*)—as the "primary receptors." Best available science defines primary receptors (aka bioindicators) as those which are 1) highly abundant, 2) relatively immobile, and 3) sensitive to contaminants of concern (Suter 2006). Salmon and Dolly Varden fail to meet the first two criteria because, in general, they occur at lower abundances than lower-trophic level biota (e.g., sculpin and aquatic insects), and they are highly mobile (Bramblett et. al. 2002). Consequently, if salmon and Dolly Varden sense contamination, they can simply move to a new environment. For those and other reasons, aquatic insects are typically used as primary receptors or bioindicators of aquatic contamination (Karr and Chu 1998). Aquatic insects tend to be highly abundant, move over limited distances, and many taxa exhibit high sensitivity to pollutants. Although consultants for Chieftain Metals argued that invertebrate data were inadequate for analysis and that invertebrate communities were "likely" unstable due to active river channel migration, they provide no empirical support for those arguments. At least three previous studies of the Tulsequah River considered in the ERA characterize aquatic insect communities in the Tulsequah River and surrounding watersheds (Rescan Environmental services Ltd. 1997, Gartner Lee 2000, Gartner Lee 2008a).

Because of the widespread scientific acceptance of their utility as bioindicators, Chieftain Metals' consultants should provide empirical evidence (i.e., some analysis of previously collected data) to support their decision to exclude aquatic insect data. Previous research quite clearly indicates that aquatic insects in fact persist in glacially influenced, highly active floodplains, and thus could serve as useful bioindicators in environments like the Tulsequah River (Milner et al. 2001). In addition to failing to evaluate aquatic insects as indicators themselves, the ERA also excludes consideration of dietary uptake of contaminated insect prey by fish as a pathway of exposure to contamination. Given that insects comprise the primary diet items for juvenile salmon and Dolly Varden in streams, this oversight leads to vast underestimation of risk of contaminants to fish.

The ERA also considered metals in Dolly Varden muscle tissue a further indictor of the lack of effects of AMD in the Tulsequah River (Hitselberger 2012). Again, because Dolly Varden are highly mobile, moving more than 150 km (nearly 100 mi) within a year (Bramblett et al. 2002), they are less likely to accumulate metals in tissue and are thus poor indicators of metals contamination in AMD receiving waters. Moreover, in the tissue analysis study, it is unclear if the Dolly Varden captured were representative of typical fishes occurring around the area of the mine, how much time they spent in/around the mine site and whether or not they were affected by mine waste in ways that may not have been evident by analyzing muscle tissue alone (i.e., detrimental impacts to physiology, behavior, etc.).

Results of the ERA

In general, results are reported inconsistently and in a confusing manner. Metals are reported as both micrograms per liter (µg/L or parts per billion) and milligrams per liter (mg/L or parts per million). Because these units are three orders of magnitude different, metals levels reported are frequently misleading. Several graphs in the ERA display hazard quotients and metals concentrations on a logarithmic scale, making risk appear lower than it actually is.

The ERA used hazard quotients (HQs) to estimate risk of contamination to ill-suited receptor species (sockeye, chum, and Chinook salmon, and Dolly Varden). As the ERA explains, "When HQs are less than or equal to one (1), no unacceptable risks will occur in the exposed aquatic population. When HQs are greater than one, unacceptable risks may occur." In the ERA results, HQs consistently exceeded 1 (meaning conditions pose unacceptable risks to aquatic life) for cadmium, copper, and zinc at a site about 0.3 km (0.2 mi) downstream of the mine. Hazard quotients for copper, one of the most toxic elements to aquatic life, exceeded 1 at least 2.7 km (1.7 mi) downstream of the mine. Results indicating hazard quotients exceeding thresholds of acceptable risk simply do not support the conclusions of low risk drawn in the ERA.

For many water quality results, concentrations of dissolved metals are reported to exceed those of total metals, which is not possible. The dissolved concentration of metals in water is always a fraction of the total concentration. This raises doubt about the entire water chemistry dataset, and the ERA's conclusions, because they rely upon this data.

Conclusions of the ERA

Many of the conclusions of the ERA, which claim low to no risk to fishes from AMD, also depend on the tenuous assumption that fish do not use turbid mainstem environments. It is unclear from the ERA if such environments were adequately sampled to justify that assumption. Furthermore, salmon have been extensively documented using turbid waters in the Taku River and other glacially turbid systems (e.g., Murphy et al. 1989, Young and Woody 2007). Lorenz and Eiler (1989) concluded, "[s]pawning by sockeye salmon in the lower Taku River ***seems*** particularly unlikely because of high sediment loads, unstable channel conditions, and little access to typical lacustrine rearing habitat associated with this species; however, our study showed that this glacial river does provide suitable spawning habitats for sockeye salmon" (emphasis added).

Consequently, the erroneous assumption that juvenile salmon do not utilize glacially turbid habitat in the Tulsequah River raises considerable concern regarding the overall conclusions of the ERA. Because fish and other aquatic life are easier to detect in clear water habitats than glacially turbid habitats, data regarding fish distribution may be erroneous. Also, since clear water habitats were not sampled for AMD impacts, the assumption made in the ERA that off-channel habitat allow salmon to avoid risk is unfounded.

In the Ministry of Environment's initial request for the ERA (Sharpe 2013), Chieftain Metals was directed to "identify the zone of influence from the discharge of untreated mine effluent"—in other words, to delineate the areal extent of water quality impacts from AMD. At the furthest downstream site 2.7 km (1.7 mi) downstream of the mine site, copper and zinc concentrations still exceeded water quality limits by two and three times, respectively. Consequently, the ERA includes no sites where the effects of AMD are entirely diluted—it thereby fails to identify the zone of impact. Additional zone of impact calculations rely on estimates rather than verification from rather easily collected empirical data. Estimates inherently include more error than direct sampling.

The report concludes that "Until such time that the historic waste rock is capped to reduce infiltration, it does not appear possible to prevent occurrences of HQs exceeding the threshold of 1," contradicting the additional conclusion that the AMD poses low to no risk to aquatic life.

SPECIFIC COMMENTS

EXECUTIVE SUMMARY

Summary of Mine Effluent Quality

"Current water quality of the effluent in SE-2 (water discharging into Tulsequah River) is comparable to historic portal discharge water quality which indicates the water quality has not undergone noticeable change since the mid-1990s." (pg. 3 of Executive Summary)

Comment: *This clearly indicates that exceptionally degraded water quality that initially prompted the ERA and other mitigation measures has not improved in decades. Based on previously documented lethal impacts of mine effluent to fish (Comin 2009), risks to aquatic life persist despite conclusions drawn by the ERA.*

Primary Receptor Selection

"Of the aquatic resources in the Tulsequah River, fish are likely the primary receptors with the highest risk of exposure to mine discharge." (pg. 3 of Executive Summary)

Comment: *Fish were chosen as primary receptors, ignoring the importance of the base of the aquatic foodweb including algae and aquatic insects which are not mobile and consequently more susceptible to impacts of mine waste. Reasons for excluding insects were briefly discussed, but diatoms were not discussed, despite being both better suited for biomonitoring and essential to the growth and survival of culturally and commercially important fish species. Furthermore, the three fish assessed (coho, sockeye, and Dolly Varden) are some of the most mobile of fish species documented in the study area, also underscoring their inadequacy as a "primary receptor" for estimating risks from mine waste.*

1 REGULATORY SETTING

1.2 Interim Water Treatment Plant History

"Prescribed discharge water quality criteria were achieved but design parameters were not being met, operating costs were significantly higher than anticipated and it was apparent that water discharge quality criteria could not be assumed." (p. 4)

Comment: *Although water quality did not always meet permit criteria during IWTP operation, it was significantly improved with operation. Ceasing operation **increased** risk to aquatic life. Characterizing the IWTP as ineffective is spurious.*

2 RISK ASSESSMENT INTRODUCTION

2.2 Scope of Work

"Of the aquatic resources in the Tulsequah River, fish are likely the primary receptors with the highest risk of exposure to mine discharge." (p. 8)

Comment: *Again, insects and diatoms are much more likely to suffer impacts of impaired water quality because of their lack of mobility or ability to escape sub-optimal conditions. Although aquatic insects in particular were sampled for some previous studies of the Tulsequah Chief mine, the ERA fails to incorporate or summarize that data. Consequently, the assertion that aquatic insects are inhibited by glacial conditions in unsubstantiated both in the ERA and the general scientific literature (Milner et al. 2001).*

"Available data on sediment and benthic invertebrates are limited and the hydrologic regime of the Tulsequah River (i.e., seasonal major glacial outbursts) ***would likely*** preclude the presence of stable benthic invertebrate communities or sediment quality over the years." (emphasis added) (p. 8)

Comment: *Data explicitly describing previously collected insect (benthic invertebrate) data should be presented in order to substantiate this argument. Scientific literature confirms that aquatic insects in fact colonize glacial streams globally, including in Southeast Alaska (Milner et al. 2001, Milner et al. 2011). They are much more commonly used as receptors than fishes (Karr and Chu 1998), and are important components of sockeye, coho, Chinook, and Dolly Varden diets.*

3 PROBLEM FORMULATION

3.1 Site Description

3.1.2 Aquatic Ecological Setting

3.1.2.5 Tulsequah Fisheries

"Within the Tulsequah watershed, juvenile Coho Salmon (O. kisutch) and Dolly Varden were the most common and ubiquitous species captured during previous studies (Gartner Lee 2007)." (p. 18)

Comment: *Coho salmon, although a poor "receptor" species, are highly sensitive to heavy metals contamination from metals like zinc and copper which are leaching from the Tulsequah Chief Mine site. At increases of just 2-20 parts per billion, copper impacts a salmon's ability to smell, which it uses to identify predators, prey, mates and kin, and to identify natal spawning grounds (Baldwin et al. 2011, McIntyre et al. 2012). Consequently, their occurrence in the zone of AMD discharge is of considerable concern.*

"Although the Tulsequah River is used primarily as a migration corridor, which allows fish access to several minor tributaries, and to Shazah Creek, as well as other wetland and clear water side channel habitat, Chum are known to spawn in the lower mainstem and juvenile Coho and Sockeye salmon and Dolly Varden/Bull Trout were captured in mainstem habitats upstream and downstream from the mine site (Rescan 1997)." (p. 18)

Comment: *The ERA frequently downplays the importance of main channel habitat to salmonids by describing it as simply a "migration corridor." Because olfaction plays a critical role in the ability to home to natal sites to spawn (Quinn 2011), copper can interfere even during the migration process. That ultimately could degrade the genetic structure that is maintained by salmon returning to the site of their birth, which is critical to maintaining overall sustainability of salmon populations (Schindler et al. 2010). Furthermore, chum clearly use mainstem habitat for more than migration as the ERA points out itself in this statement. It is also unclear if efforts to capture fish in mainstem, turbid (and thus challenging to work in) habitat were adequate. Chinook salmon, arguably the most prized salmon species, tend to spend their initial 1-2 years rearing in freshwater in larger, mainstem habitats as Murphy et al. (1989) documented in the Taku River. The tenuous nature of the assumption that mainstem habitat is unimportant to salmon undermines conclusions drawn in the ERA.*

"Within the Tulsequah River floodplain, the highest quality salmonid rearing and overwintering habitat is known to occur in clear water side channels along the river margins (both banks) and to a lesser degree in mid-channel areas." (p. 19)

Comment: *It is unclear if the limited fisheries data collected to date on the Tulsequah can sufficiently support this conclusion. A cursory attempt was made to locate reports cited in the ERA that include fisheries data and they were not readily available through internet or university library sources.*

"To a lesser extent, some deeper pools in the mainstem, primarily at channel convergences and outside meanders, provide limited overwintering habitat (Rescan 1997)." (p. 20)

Comment: *In general, glacial streams are clearer in winter when glacial melt is not occurring and consequently could provide ample habitat based on the questionable assumptions of the ERA. It is unclear if any winter sampling was ever conducted in the study area, which would be essential to support the assumption that areas impacted by AMD are not important overwintering habitat. Overwintering habitat is often the most limiting to Alaska fishes because of the cold climate (Reynolds 1997).*

In addition to failing to sample habitat in winter, mainstem habitat may have been insufficiently sampled during other times of year. In general, because it is more difficult to observe or capture fishes in turbid waters, their true abundance may be underestimated relative to abundance in clearer waters where fishes may be easier to see.

3.2 Receptor Description

"Further, salmonid species tend to be more sensitive to environmental or chemical disturbances, compared to non-salmonid species, and are therefore more representative of receptor species that best measure potential risks." (p. 21)

Comment: *Many fish species are more sensitive to disturbance than the receptor species chosen for the ERA. For example Arctic grayling (Thymallus arcticus) occur in the river, but were not assessed as a receptor species. They tend to be more sensitive to metals than species chosen as receptors such as coho or rainbow trout (Buhl and Hamilton 1991)."*

"The relative tolerances (96h LC50) of juvenile Chinook Salmon and Steelhead Trout (alevins, swim-up, parr and smolts life stages) to Cadmium (Cd), copper (Cu) and zinc (Zn) were evaluated by Chapman (1978). The research determined that newly hatched alevins were much more tolerant to Cd and to a lesser extent Zn than were later juvenile forms (e.g., parr and smolts). However, with respect to Cu concentration, steelhead smolts, the oldest juvenile form was the more tolerant (96h LC50: 29 µg/L) than the younger forms while Chinook parr (96h LC50: 38 µg/L) were the most tolerant form for that species. Chapman (1978) recommends that when a sensitive life stage for acute toxicity with metals is required, that the use of the more resistant newly hatched alevins be avoided, and that the more sensitive later juvenile forms be considered." (p. 21)

Comment: *Although the relevance of this paragraph to the rest of the ERA is unclear, it highlights the fact that sensitivity to metals varies widely across life stages and time. The ERA failed to clearly identify the most sensitive species present in the river and their most sensitive life stages. In order to avoid risk, water quality criteria should be the most conservative (i.e., below sensitivity levels of most sensitive species and life stages).*

3.2.1 Chinook Salmon

Comment: *In general, the description of Chinook salmon fails to indicate that they prefer large, main channel habitat (Murphy et al. 1989). Because water quality impacts are assumed most pronounced in the mainstem, conclusions that overall risk is low, particularly to Chinook salmon, are suspect.*

3.2.3 Sockeye Salmon

"In November, population densities of Sockeye peaked in side channels, suggesting that juveniles overwinter in these areas (Thedinga et al. 1988)." (p. 23)

Comment: *This suggests that sockeye are migrating into side channels in November from other habitats. The ERA fails to describe sockeye habitat utilization prior to November.*

3.3 Source Description

3.3.3 Mine Effluent Quality (SE-2)

"Limited mitigation options exist on site since the shutdown of the IWTP." (p. 26)

Comment: *At least one other mitigation strategy (capping waste rock) is discussed in the ERA. Furthermore, although expensive, the IWTP did decrease overall risk. No mitigation option should be dismissed.*

"In addition, now the Site Exfiltration pond is currently the only point of collection of the various water sources before discharging into the Tulsequah River, it does have filter fabric incorporated to reduce particulate matter and when the discharge goes into the River, it is diffused over approximately 10 meters instead of a single point." (p. 26)

Comment: *Given that over 1 million liters per day of contaminated AMD are entering the Tulsequah River daily (Core6 Environmental et al. 2013), a tenfold increase in surface area at the point of discharge is unlikely to have a noticeable effect. Reduction of particulate matter also has no impact on most metals contamination.*

3.3.4 Receiving Environment

FIGURES 12 AND 13 (PP. 33-34)

Comment: *The figures illustrate copper levels as high as 1000 times the water quality criteria used for screening—which was not the most conservative standard possible. It is also worth noting that pages are posted out of order starting at this point in the report, which is confusing for the reader.*

3.3.6 Constituents of Potential Concern

"The screening level selection approach was as follows: the previously accepted SSWQOs took precedence over the BCWQO and CCME values, otherwise the lowest of the provincial and federal values were selected as the screening levels, except where the background level exceeded regulatory criteria. In such cases, the 90th percentile for the background data was carried forward as the screening level – this was the case for only four parameters: nitrite, total aluminum, total chromium, and total vanadium." (p. 35)

Comment: *Generally, the selection process for determining screening levels was justified. However, it highlights that mine effluent contains at least thirteen elements with adverse impacts to aquatic life, including copper, zinc, and cadmium, which are some of the most toxic.*

TABLES 6-12 (PP. 41-47)

Comment: *For many water quality results, concentrations of dissolved metals are reported to exceed those of total metals, which is not possible. The dissolved concentration of metals in water is always a fraction of the total concentration. This brings the entire water chemistry dataset into question, in addition to the conclusions which rely upon that data.*

3.4 Exposure Pathway(s) Description

"Given that benthic invertebrates and sediment was evaluated as not being a source for uptake (see Section 2.2), this risk assessment focused on water quality and hence was the only direct contact pathway evaluated quantitatively through the estimation of hazard quotients (HQs)." (p. 48)

Comment: *This overlooks dietary intake of macroinvertabrates which authors previously acknowledge as an important exposure pathway. Because the fishes considered in the ERA rely largely on aquatic insects during their freshwater rearing phase, dietary intake should be factored into risk calculations, and direct risks to insects should also be considered.*

4 EXPOSURE ASSESSMENT

4.1 Direct Contact with Surface Water

4.1.3 Main Stem versus Side Channel Surface Water Concentrations

"In most cases, clear water side channels are isolated from mainstem surface flows and remain wetted through tributary or upwelling (sub-surface flow) sources. As such, clear water side channels are also removed to a large extent, from the influences of effluent released at the mine site as shown in Table 13." (p. 50)

Comment: *The ERA fails to provide any empirical support for this assumption. Based on data presented in the ERA, water quality data was never collected in clear water side channels where the ERA assumes fish use exclusively. Consequently, the assumption of lower or no risk in these habitats is not validated.*

4.1.4 COPC Zone of Influence

"If the HQ for receptors for any chemical was greater than 1 at station W32 then the zone of influence of the mine site was assumed to extend further downstream beyond W32." (p. 51)

Comment: *Because HQs do exceed 1 at site W32, the most downstream water quality sampling site from the mine site, the full extent of impact (i.e., the zone of influence) was not delineated by the ERA.*

"If we assume that half of the increase in the flow of the Taku at the Canada-US border is related to the Tulsequah River drainage, then the flow from the Tulsequah River can be estimated by dividing the difference in flow at the WSC gauge (Station 08BB001) and WSC gauge (Station 08BB005) by 2." (p. 51)

Comment: *Site-specific flow measurements are straightforward and inexpensive, and thus should have been taken along with water quality sampling so that estimates were not used to understand dilution factors. Furthermore, water quality sampling should have continued downstream past the influence of mine effluent in order to accurately delineate the zone of influence.*

5 EFFECTS ASSESSMENT

5.1 Toxicity Profiles

5.1.2 Aluminum

"The sensitive life stage varies amongst fish species; however, the fry stage is generally very sensitive." (p. 55)

Comment: *Water quality results and summaries indicate that aluminum reached highest levels during spring melt, which tends to coincide with fry emergence. Consequently, sensitivity of fry to contaminants poses risk and should be of great concern.*

5.1.6 Copper

"Salmonid fry appear to be highly sensitive to copper toxicity." (p. 57)

Comment: *Water quality results and summaries indicate that copper reached highest levels during spring melt, which tends to coincide with fry emergence. Consequently, sensitivity of fry to contaminants poses risk and should be of great concern. At that time, fry are also beginning the process of imprinting required to accurately return to their natal habitats to spawn. Because copper can inhibit that process, its impacts are of particular concern.*

5.1.8 Lead

"The larval and juvenile life stages appear to be more susceptible to lead toxicity than eggs and adult life stages." (p. 58)

Comment: *Water quality results and summaries indicate that lead levels are particularly high in mine effluent, and peak during spring melt, which tends to coincide with fry emergence. Consequently, sensitivity of fry to contaminants poses risk and should be of great concern. Juvenile salmon spend up to two years rearing in freshwater receiving environments, so their sensitivity should also be of concern.*

5.2 Toxicity Reference Values

"Chronic EC20 concentrations were preferred. If not reported, other endpoints were considered and adjusted to an estimated EC20 value. For adjustment from chronic LC50 to chronic EC20, a factor was used based on an assumed linear chronic dose-response with zero response at EC0 and 50% response at the EC50 concentration." (p. 61)

Comment: *It is unclear that this is a standard method. At the very least, a citation should be provided indicating this methodology is widely accepted.*

6 RISK CHARACTERIZATION

6.1 Hazard Quotient Estimates

"For comparative purposes, each graph also contains an HQ boxplot for the background station W32."

Comment: *It is worth noting that the designated background station is W10—an important typo because water quality impacts are still evident at W32—the most downstream site sampled for the ERA. Furthermore, boxplots for cadmium and copper at the actual background site (W10) indicate occasional HQs well above 1, suggesting W10 may not be an appropriate background site.*

Hazard quotient boxplots (pp. 65-68)

Comment: *Plotting hazard quotients and metals concentrations on a logarithmic scale is misleading, making hazard appear lower than it actually is.*

6.3 Uncertainty Analysis

"Risks to fish from COPCs in the Tulsequah River were evaluated for direct contact exposure pathways (surface water), but not for dietary uptake (see Section 2.2). This may lead to an underestimation of risk. While the magnitude of this underestimation is not known, it is not considered to be substantial as it is likely that the direct contact pathway (see Section 2.2) is more important than the ingestion pathway and that the magnitude of the error is relatively small." (p. 69)

Comment: *It may be more accurate to state that failure to consider dietary uptake of contaminants would certainly lead to an underestimation of risk. To suggest the underestimation is not substantial requires literature support at the least, and ideally empirical evidence (data) from the study area.*

"Conversely, some water samples were collected from sites suspected of increased (maximum) contamination (e.g. station W51, which becomes isolated from the Tulsequah River except for mostly hyporheic flow, leaving it inaccessible to fish for part of the year." (p. 69)

Comment: *The assumption that the most contaminated sites are inaccessible to fish is unsubstantiated. Empirical fish distribution data should be provided from the study site in order to draw any conclusions about risk based on this assumption.*

7 DISCUSSION AND CONCLUSION

7.1 Receptor Exposure when the IWTP was Operational and was Not Operational

"Based on the above, the operation of the IWTP clearly showed a positive influence on water quality at the stations monitored." (p. 71)

Comment: *This contradicts statements made earlier in the ERA and suggests the IWTP is an appropriate consideration for mitigation of risk.*

7.2 Seasonal Trend in Surface Water COPC Concentrations

"Until such time that the historical waste rock is capped to reduce infiltration, it does not appear possible to prevent occurrences of HQs exceeding the threshold of 1. However, and perhaps most importantly, is that whether or not the IWTP was operating, the HQ was less than 1 for the majority of the year including the critical time periods when

Chinook Salmon, Sockeye Salmon and Coho Salmon are migrating to spawn and the eggs are incubating and hatching. " (p. 72)

Comment: *This conclusion is simply not supported by the information preceding it in the ERA.*

7.3 Risk Mitigation as a Result of Timing of Receptor Presence by life-stage in the Tulsequah River

"Moreover, when they do enter the Tulsequah River, they are more likely to be found in the clear water side channels, accessible wetlands and lower tributary reaches than in the mainstem. These high quality habitats are known to support rearing, overwintering and spawning for salmonids." (p. 73)

Comment: *Again, this could be the result of ease of observation and capture in clear water environments (observer bias), lack of winter sampling, and other factors. It is unclear if the statement that salmon are confined to clear water habitats is supportable.*

"Juvenile salmonids in the Tulsequah River watershed are less likely to rear extensively in the fast-flowing, turbid water of the mainstem as they typically rear and overwinter in beaver ponds, side channels, sloughs, channel edges, and tributaries. As such, juvenile forms of the receptors of concern are less likely to be exposed to the episodic loadings of COPCs from mine discharge. It is therefore reasonable to assume that the sensitive life stage of the juvenile form is unlikely to be exposed to high exposure of mine effluent discharge in the Tulsequah River. " (p. 73)

Comment: *Murphy et al. (1989) showed that juvenile salmonids, and particularly Chinook salmon, indeed do rear in mainstem environments of the Taku River. Furthermore, the ERA fails to characterize water quality in the off-channel habitats it claims are more important to salmon. It is unclear that clear water habitats are unimpacted by mine waste.*

"However, the metals tissue residue study completed by Hitselberger (2012) of juvenile Dolly Varden char from the Tulsequah River found that the discharges from the mine site were not causing elevated metals in juvenile Dolly Varden char suggesting that either the exposures were not significant or that the exposure levels were within a range that the fish could readily bioregulate." (p. 76)

Comment: *Hitselberger (2012) is of little utility for estimating risk and exposure to aquatic life in general. It is unclear if the Dolly Varden captured in the Hitselberger study were representative of typical fishes occurring around the area of the mine, how much time they spent in/around the mine site and whether or not they were affected by mine waste in ways that may not have been evident by analyzing muscle tissue alone (i.e., olfaction impacts, etc.).*

7.4 Zone of Influence

"The zone of influence extends downstream within the braided mainstem beyond station W32." (p. 76)

Comment: *Although this statement is substantiated in the ERA, the document overall fails to delineate the full zone of impact as requested by Environment Canada. In order to do so, Chieftain's consultants would have needed to assess water quality as far downstream from the mine as metals are elevated. The farthest downstream site tested was still showing elevated levels of copper and zinc.*

7.5 Tissue Residue Assessment

Comment: *Hitselberger (2012) is of little utility for estimating risk and exposure to aquatic life in general. It is unclear if the Dolly Varden captured in the Hitselberger study were representative of typical fishes occurring around the area of the mine, how much time they spent in/around the mine site and whether or not they were affected by mine waste in ways that may not have been evident by analyzing muscle tissue alone (i.e., olfaction impacts, etc.).*

7.6 Summary

"Overall, the potential risk to aquatic receptors as a result of mine discharge is considered low." (p. 77)

Comment: *Given the multitude of shortcomings, errors, and unsupported assumptions in the ERA, this conclusion is unwarranted.*

STATEMENT OF QUALIFICATIONS

Sarah O'Neal has over 15 years of international experience in freshwater ecology in salmon ecosystems, including a combined nine years of experience between British Columbia and Alaska. Her expertise includes water quality, aquatic plants, diatoms, zooplankton, macroinvertebrates, resident and anadromous fishes, and interactions between them in both lakes and streams. She has worked in private, public, and non-governmental sectors. She has a Bachelor's Degree in Ecology, Evolution, and Conservation Biology from the University of Washington, a Master's Degree in freshwater ecology from the University of Montana's Flathead Lake Biological Station, and is currently pursuing a Ph.D. with the School of Aquatic and Fisheries Sciences at the University of Washington.

REFERENCES

ADFG 2015. Website http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyareasoutheast.salmon_harvestbyarea. Accessed 7 November 2015.

Baldwin, D. H., C. P. Tatara, and N. L. Scholz. 2011. Copper-induced olfactory toxicity in salmon and steelhead: Extrapolation across species and rearing environments. Aquatic Toxicology **101**:295-297.

Bramblett, R. G., M. D. Bryant, B. E. Wright, and R. G. White. 2002. Seasonal use of small tributary and main-stem habitats by juvenile steelhead, coho salmon, and Dolly Varden in a southeastern Alaska drainage basin. Transactions of the American Fisheries Society **131**:498-506.

Buhl, K. J., and S. J. Hamilton. 1991. Relative sensitivity of early life stages of arctic grayling, coho salmon, and rainbow trout to nine inorganics. Ecotoxicology and Environmental Safety **22**:184-197.

Cambria and Gordon Ltd. 2007a. Fish stream Identification Results in Support of Phase II Notice of works for Mineral Exploration Access -- Temporary Access Road from Tulsequah Chief Exploration Camp to Proposed Airstrip. Prepared for Redfern Resources, Project 237.01.

Cambria and Gordon Ltd. 2007b. Fish Stream Identification Results in Support of Phase II Notice of works for Mineral Exploration Access -- Big Bull/Tulsequah Chief Temporary Access Road. Prepared for Redfern Resources, Project 237.01.

Comin, W. 2009. Affidavit no. S091670 of Wade Comin, Senior Enforcement Officer for Environment Canada, in the Supreme Court of British Columbia, in the Matter of the Comapnies' Creditors Arrangement Act, R.S.C. 1985 c. C-36 and in the matter of the Canada Business Corporations Act, R.S. 1985 c C-44, and in the matter of the Britisch Columbia Business Corporations Act, S.B.C. 2002, c 57 and in the matter of Redcorp Ventures Ltd. and Redfern Resources Ltd. May 25. Whitewhorse, YT.

Core6 Environmental, Palmer Environmental Consulting Group Inc., Triton Environmental Consultants Ltd. 2013. Aquatic Ecological Risk Assessment Tulseqah Chief Mine. Prepared for Chieftain Metals Inc. Port Coquitlam, B.C.

Gartner Lee Limited. 2000. Tulsequah Chief Mine EEM Program - 1998/1999 Results. Prepared for Redfern Resources Limited. January, 2000. Burnaby, B.C.

Gartner Lee Limited. 2008. Tulsequah Chief Mine: Environmental Effects Monitoring Program for the Tulsequah River - 2007 Baselie Data Collection. Report prepared for Redfern Resources. May 2008. Burnaby, B.C.

Hitselberger, J. P. 2012. Tulsequah Chief Mine Acid Rock Drainage: Whole Body Metals Concentrations in Dolly Varden Char. Alaska Department of Fish and Game, Division of Habitat, Southeast Region.

Jones, E. L., S. A. McPherson, D. J. Reed, and I. M. Boyce. 2010. Spawning abundance of Chinook salmon in the Taku River from 1999 to 2007. Alaska Department of Fish and Game, Fishery Data Series No. 10-70. Anchorage, AK.

Karr, J.R. and E.W. Chu. 1998. Restoring life in running waters. Island Press.

Lorenz, J. M., and J. H. Filer. 1989. Spawning habitat and redd characteristics of sockeye salmon in the glacial Taku River, British Columbia and Alaska. Transactions of the American Fisheries Society **118**:495-502.

McIntyre, J. K., D. H. Baldwin, D. A. Beauchamp, and N. L. Scholz. 2012. Low-level copper exposures increase visibility and vulnerability of juvenile coho salmon to cutthroat trout predators. Ecological Applications **22**:1460-1471.

Milner, A. M., J. E. Brittain, E. Castella, and G. E. Petts. 2001. Trends of macroinvertebrate community structure in glacier-fed rivers in relation to environmental conditions: a synthesis. Freshwater Biology **46**:1833-1847.

Milner, A. M., A. L. Robertson, L. E. Brown, S. H. Sonderland, M. McDermott, and A. J. Veal. 2011. Evolution of a stream ecosystem in recently deglaciated terrain. Ecology **92**:1924-1935.

Murphy, M. L., J. Heifetz, J. F. Thedinga, S. W. Johnson, and K. V. Koski. 1989. Habitat Utilization by Juvenile Pacific Salmon (Onchorynchus) in the Glacial Taku River, Southeast Alaska. Canadian Journal of Fisheries and Aquatic Sciences **46**:1677-1685.

Quinn, T. P. 2011. The behavior and ecology of Pacific salmon and trout. UBC Press.

Rescan Environmental Services Ltd., R. E. S. 1997. Environmental Assessment for the Tulsequah Chief Mining Project.

Reynolds, J. B. 1997. Ecology of overwintering fishes in Alaskan freshwaters. Pages 281-302 Freshwaters of Alaska. Springer.

Schindler, D. E., R. Hilborn, B. Chasco, C. P. Boatright, T. P. Quinn, L. A. Rogers, and M. S. Webster. 2010. Population diversity and the portfolio effect in an exploited species. Nature **465**:609-612.

Sharpe, I., B.C. Ministry of the Environment. 2014. Memorandum re: Tulsequah Chief Mine, Authorization #105719, Risk Assessment of Current Mine Effluent Discharge into the Tulsequah River.

Suter II, G. W. 2006. Ecological risk assessment. CRC press.